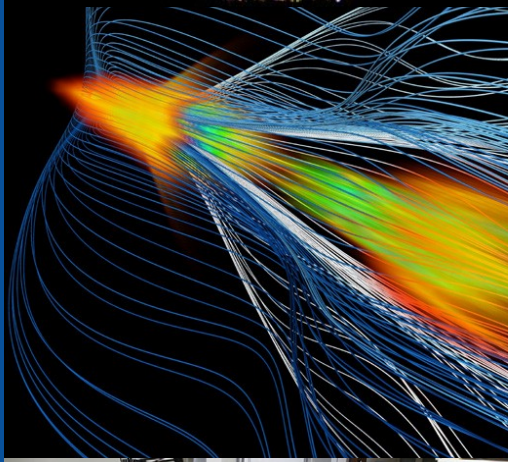
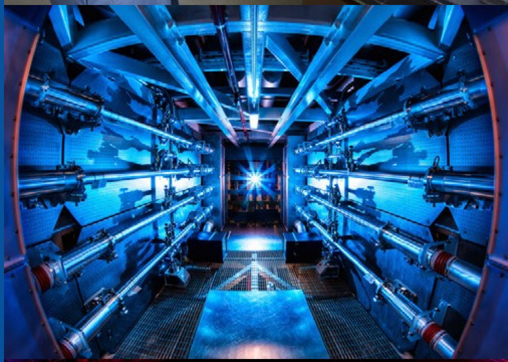
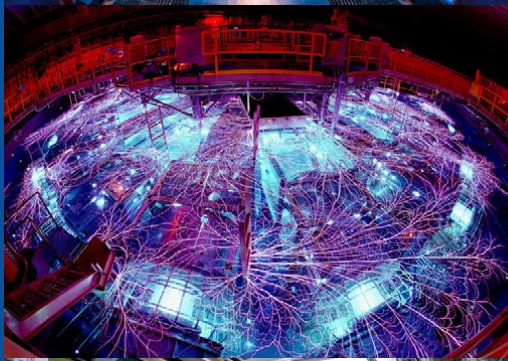
U.S. DEPARTMENT OF
ENERGY

THE STATE OF THE DOE NATIONAL LABORATORIES

2020 EDITION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MESSAGE FROM THE SECRETARY OF ENERGY

Dan R. Brouillette
Secretary of Energy

The U.S. Department of Energy (DOE), sometimes referred to as the "Department of Everything" or the "Department of Exploration," is one of the most unique and critical U.S. government agencies due to its broad and diverse portfolio of research and development (R&D) activities. DOE has a rich and impactful history, populated by brilliant pioneers who then, and now, strive to overcome the Nation's greatest challenges.

Over the past four years, DOE made energy production, reliability, and security a top priority. By pursuing a true "all-of-the-above" American energy strategy that leverages all sources and all technologies, DOE has made innovation the cornerstone of our success. The accomplishments achieved in pursuit of this policy pushed our economy to new heights and will help drive our post-pandemic economic comeback.

Between the years 2017 and 2020, America realized an energy renaissance unprecedented in our history. The implementation of a pro-growth tax and regulatory agenda, combined with Executive actions promoting energy exploration and infrastructure development, led to the United States securing the enviable position of being the world's largest producer of oil and natural gas. Our robust production brought with it economic and consumer benefits here at home, but it also allowed us to export energy to trading partners around the globe. Liquified Natural Gas (LNG) exports from the United States reached an all-time high at the end of 2020, enough to meet nearly one-fifth of current global LNG demand. To date, the United States has exported LNG to over 38 countries spanning five continents.

Meanwhile, in 2019, U.S. civil nuclear power plants generated the most electricity ever produced by a fleet in the world, and our solar and wind energy production each ranked second globally.

The foundation of these and so many other accomplishments can be found in innovation stemming from DOE programs and research conducted by our 17 award winning National Laboratories. Our Laboratories are working on some of the most difficult challenges we face as a Nation. The following pages tell of both the achievements and the on-going work at DOE, which have cemented America's place as the global leader in science and energy innovation.

Maintaining this leadership is paramount for the future of our Nation. In particular, our laboratories support DOE's critical role in national security, especially in the stewardship of the Nation's nuclear deterrent and the protection of the U.S. grid from physical and cyber threats.

From supporting NASA's exploration of distant planets and developing novel ways to benefit from resources beneath our feet, to advancing plastics recycling techniques and harnessing the power of the sun and wind, DOE's National Laboratories are leading America into a safe, prosperous future.

Chief among the benefits of serving as Secretary is the opportunity to work alongside the incredible DOE men and women driving the discovery and innovation.

I hope readers will benefit from learning about the role that the National Laboratories play in advancing the Department's mission to address our energy innovation, environmental, and nuclear challenges through transformative science and technology solutions. And, I hope that readers will be inspired to partner with us to innovate toward an even brighter future. Finally, I hope this report serves as a guide for future administrations in charting a course for our country's energy policies.

ACKNOWLEDGEMENTS

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The report was developed by Allison Bury, Julie Wulf-Knoerzer, and Benjamin Reinke, with significant contributions from Mark Gilbertson, Clara Asmail, Mary Monson, the National Laboratory Chief Communications Officers (NLCCOs), the National Laboratory Chief Research Officers (NLCROs), the Laboratory Operations Board "SOL Working Group", the DOE Office of Strategic Policy and Planning, the DOE Office of Management, and the DOE Office of Public Affairs.

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EXECUTIVE SUMMARY

The Backbone of the Nation's Scientific Research Enterprise

The most complex challenges facing the world today comprise the work of DOE's 17 National Laboratories: unlocking the solutions to a clean energy future, enabling humans to live and work in space, advancing quantum information science for an era of secure communication, accelerating innovations to reduce plastic waste, creating a more resilient energy grid with the aid of artificial intelligence (AI), and preparing the world to respond to pandemics today and protect against them tomorrow. Indeed, these are the very solutions that the men and women of the National Laboratories are helping to advance every day through scientific R&D.

DOE's laboratory system is the backbone of the United States' scientific research enterprise. Formed from strategic national investments in science during and following World War II, the National Laboratories form the most comprehensive research network of its kind in the world. For 75 years, they have delivered solutions to some of the most pressing national challenges, garnering 118 Nobel Prizes and discovering 22 elements on the periodic table along the way.

While most of the National Laboratories' work is led by the Department's missions—energy innovation, science discovery, nuclear security, and environmental cleanup—they also represent a national resource and serve the national interest by addressing challenges extending beyond energy, and catalyzing research that spans across sectors. From furthering U.S. energy independence and leadership in clean technologies; to promoting innovation that advances U.S. economic competitiveness; to conducting research of the highest caliber in the physical, chemical, biological, materials, computational, and information sciences to advance understanding of the world around us—the Laboratories' purview is expansive and their contributions are indispensable.

Building a Pipeline of Talent for Tomorrow

At the core of the National Laboratories is a first-rate workforce of research scientists, engineers, and support personnel who are entrusted to serve the American people. Working separately and in tandem, the National Laboratories invest in growing the Nation's science and technology workforce. Building a talent pipeline has proven to be an invaluable investment that sets the National Laboratories apart from other Federally Funded Research and Development Centers (FFRDCs) and is part of how the Laboratories are able to maintain their innovative edge.

A Structure to Enable Complex Problem-Solving

The unique structure of the laboratory network—including 17 individual laboratories with distinct but complementary capabilities—facilitates the "big picture" multidisciplinary investments and partnerships essential for large-scale, complex problem-solving. Scientists, engineers, technicians, and analysts collaborate throughout the system, as well as with academia and industry, helping to ensure the best solutions are pursued without regard to organizational boundaries.

With their focus on mission-driven science and engineering, and the ultimate translation of basic science to technology development, the Laboratories fill an innovation ecosystem gap that bridges the work of universities and the private sector. Universities emphasize teaching and discovery science and typically focus on research by a single faculty member or small groups of faculty members. Industries, on the other hand, respond to market needs and focus their R&D on near-term solutions or the integration of multiple technologies. The Laboratories typically operate in the space in between, by concentrating on complex problems requiring sustained, long-term focus. Moreover, the Laboratories conduct R&D in some areas that are not pursued by either academia or industry, such as classified nuclear security work.

A Critical Hub for Collaboration

The types of partnerships that the Laboratories form are diverse—spanning engagements with other federal agencies, academia, and the private sector. Partnerships allow the National Laboratories to serve as a key node in the R&D ecosystem and to integrate fundamental advancements and applied precompetitive research outcomes with broad networks of expertise to address new challenges and critical national needs.

Research partnerships vary in size and scope, ranging from small groups of investigators who conduct discovery science to address specific technical questions to large research centers that bring together dozens of experts from various disciplines and institutions to cooperatively address major research challenges. The act of bringing together top talent across the full spectrum of R&D performers, including universities, businesses, nonprofits, and National Laboratories, is a key function of the Department intended to enable collaboration and teamwork in its topical areas—from artificial photosynthesis to energy storage through future battery technologies.

For universities in particular, collaborating with National Laboratories enables them to conduct science that requires large, complex, and specialized facilities that are often far too resource-intensive for a university to maintain. For the private sector, these partnerships not only provide critical access to resources, but also expand the commercial impact of DOE research and accelerate taxpayer return on investment.

Responding to the Urgent Needs of the Nation

While long-term contributions are the predominant focus, the National Laboratories are also capable of responding with agility to emerging crises. As the national needs for innovation shift, DOE calls on the National Laboratories' unique scientific expertise, tools, facilities, and intellectual environments to respond quickly and with authority—as was the case during the COVID-19 pandemic. Through the National Virtual Biotechnology Laboratory (NVBL) established by DOE, the National Laboratories have collectively contributed to AI-informed epidemiological and molecular modeling, personal protective equipment supply chain challenges, the search for genomic clues, and other areas to support the Nation's (and world's) pandemic response. Specifically, the National Laboratories established the COVID-19 High-Performance Computing (HPC) Consortium to harness the world's most advanced computing capabilities in support of COVID-19 research. The advanced computing capabilities and systems made available through the Consortium processed massive numbers of calculations in support of studies related to bioinformatics and modeling, allowing scientists to significantly speed up their ability to answer complex scientific questions.

Additionally, a Manufacturing Task Force consisting of 15 of the 17 National Laboratories was established to accelerate the development and deployment of new technologies into the U.S. manufacturing industrial base. Several National Laboratories also adopted a rapid licensing approach that transfers promising technologies to industry partners more quickly. The rapid licensing process allows for improved response to national emergencies and corresponding health and economic crises.

Establishing the Nation's Scientific Leadership on the Frontiers of Discovery

For 60 years, the National Laboratories have been key players in U.S. space activities, and that focus continues today. The multi-disciplinary expertise within the National Laboratories' community of researchers, coupled with decades of experience conducting "science at scale," makes DOE and the National Laboratories uniquely suited to tackle the biggest challenges in space-related science, including establishing an expanded human presence in space and ensuring the unfettered ability to operate there by deterring, countering, and defeating space-oriented threats to U.S. security. Specifically, the National Laboratories' diverse expertise in fields like AI, advanced computing, materials science, systems biology, plasma science, space weather, radiation-tolerant microelectronics, and quantum information science enables the achievement of both increased scientific knowledge and an increased manned presence in space. Key to all of this is advancing space-capable energy technologies (nuclear and non-nuclear) and exploring innovative technologies for space—which the Laboratories are doing today.

Another frontier that the National Laboratories are exploring is that of quantum information science (QIS)—a form of computing, sensing, and information processing that relies on quantum effects in order to sidestep traditional physical limitations of computing. In 2017, DOE began a series of investments to harness the unique expertise and capabilities of the National Laboratory complex to advance QIS for the benefit of the Nation. A notable milestone in this work was the quantum supremacy announcement of October 2019, which resulted from the collaboration of researchers from Oak Ridge National Laboratory (ORNL), Google, the National Aeronautics and Space Administration (NASA), and a number of academic institutions.

Consensus is growing that using quantum mechanics to build a system to securely communicate and transmit information will be one of the most important technological breakthroughs of the 21st century—ushering in enormous benefits to national security, industry, and science. In July 2020, DOE released a Quantum Internet Blueprint that portrays a plan to develop a secure, reliable system initially connecting the National QIS Research Centers and ultimately the National Laboratory complex. In effect, DOE and the National Laboratories are bringing the United States to the forefront of the global quantum race.

In tandem, ensuring the resilience of the Nation's energy infrastructure and enabling the widespread use of clean energy are critical focus areas for the National Laboratories. The Laboratories are advancing R&D on a number of fronts to make these goals possible. Those fronts include:

• Developing a wide array of energy storage resources to manage over 4 trillion kilowatt-hours of electricity for the coming era of greater electrification;

• Reducing the cost of electrolyzers for hydrogen fuel cell technology in automobiles and other devices;

• Using AI to protect the energy system against cyber-attacks and blackouts;

• Designing clean power plants for the future that are fueled by coal, natural gas, biomass, and waste plastics and that incorporate technologies to capture, use and store carbon; and

• Accelerating the development of carbon-free energy from nuclear fusion for the private sector.

A Vital Role—Today and Tomorrow

In summary, the National Laboratories are invaluable assets to the Department and our Nation. For 75 years, the National Laboratories have delivered tremendous scientific and technological impact against the United States' greatest national needs. Today, as America faces ever more pressing challenges of enormous complexity and scope, the National Laboratories' role is only more vital.

1. THE DEPARTMENT OF ENERGY AT A GLANCE AND AN OVERVIEW OF THE NATIONAL LABORATORY SYSTEM

1.1 DOE at a Glance

DOE is the lead Federal agency supporting fundamental R&D for major mission areas of energy innovation, science discovery, nuclear security, and environmental cleanup of legacy nuclear materials, and the Nation's largest supporter of basic research in the physical and computing sciences. At its core, DOE is a science and technology (S&T) powerhouse with an unparalleled network of 17 National Laboratories. The DOE laboratory system is the backbone of the Nation's scientific research enterprise and is the most comprehensive research network of its kind in the world.

Through transformative S&T solutions, DOE and the laboratory complex tackle America's energy innovation, environmental, and nuclear challenges to help ensure peace and economic well-being for generations to come. DOE leadership in innovation and scientific discovery is instrumental to overcoming national security threats, promoting energy independence, creating jobs, increasing prosperity, and boosting U.S. manufacturing competitiveness. The Department leverages its long history and unique scientific resources in meeting these challenges.

The organizational and management structure of DOE is designed for success in executing its mission. DOE is led by the Secretary of Energy, who, among other things, maintains a safe, secure, and effective nuclear weapons stockpile and works to reduce nuclear threats, oversees the U.S. energy supply, manages the 17 National Laboratories, and executes the environmental clean-up of the Cold War nuclear mission.

The Secretary provides leadership and strategic direction to achieve the Department's mission, directly supported by the Deputy Secretary. The Deputy Secretary serves as the Department's Chief Operating Officer and oversees the Under Secretaries, and a variety of corporate organizations that are instrumental to ensuring an enterprise-wide approach, resulting in greater consistency across the DOE complex. The Secretary is also supported by the Office of the Secretary, and the Office of Strategic Planning and Policy (OSPP).

The energy innovation, science discovery, nuclear security, and environmental cleanup missions are carried out under the leadership of the three Under Secretaries: the Under Secretary of Energy, the Under Secretary for Science, and the Under Secretary for Nuclear Security. They manage the core functions that carry out the Department's missions, with significant cross-cutting work spanning the National Laboratory complex. The Under Secretary organizations are integral to ensuring that DOE line management has the resources and support needed to achieve mission objectives. The Under Secretaries oversee and manage Program Offices, which have diverse subject areas to support the DOE mission.

The Under Secretary of Energy serves as the principal Under Secretary and the Department's principal advisor on energy policy, energy security, and applied technology R&D. The Under Secretary of Energy is focused on applied technologies that pertain to the operation and reliability of our Nation's energy infrastructure, thus positioning the Nation to become more energy independent and develop energy policies and programs that lower costs and maximize the use of resources. This Under Secretary manages DOE's three applied research laboratories and four Power Marketing Administrations. In addition, the Under Secretary of Energy is responsible for policy and oversight of safety, security, and project management across the DOE complex.

The Under Secretary for Science serves as the Department's principal advisor on fundamental energy research, energy technologies, and science. This Under

Secretary drives the DOE mission through programs including nuclear and particle physics, basic energy sciences, advanced computing, fusion, and biological and environmental research. The Under Secretary for Science manages the 10 DOE science National Laboratories and their world-leading User Facilities. In addition, this Under Secretary manages the world's largest environmental and legacy management as well as national security missions, addressing the U.S. legacy of nuclear weapons production and government-sponsored nuclear energy research, including management of an additional National Laboratory that focuses on R&D in support of the environmental and legacy management missions. The Under Secretary for Science also leads the expanding DOE role in technology commercialization, especially for the National Laboratories.

The Under Secretary for Nuclear Security also serves as the National Nuclear Security Administration (NNSA) Administrator, who leads the NNSA and its three core missions: maintaining the safety, security, and effectiveness of the nuclear stockpile; preventing, countering, and responding to proliferation and terrorism threats; and providing operational support for naval nuclear propulsion. As NNSA's mission continues to evolve to meet national security requirements, its workforce has adopted an enterprise-wide approach, instilling a culture of safety, efficiency, and effectiveness across all core mission areas. NNSA has a large civilian and contractor workforce, with locations at Headquarters in Washington DC as well as three National Laboratories, two Naval Reactors Laboratories (Knolls Atomic Power Laboratory and the Bettis Atomic Power Laboratory), several production sites (Pantex Plant, Kansas City National Security Campus, Y-12 National Security Complex, and the Savannah River Site), and the Nevada Nuclear Security Site. The NNSA laboratories, plants, and sites, which are supported by

FIGURE 1-1: THE ALIGNMENT OF THE DOE AND NATIONAL LABORATORY LEADERSHIP

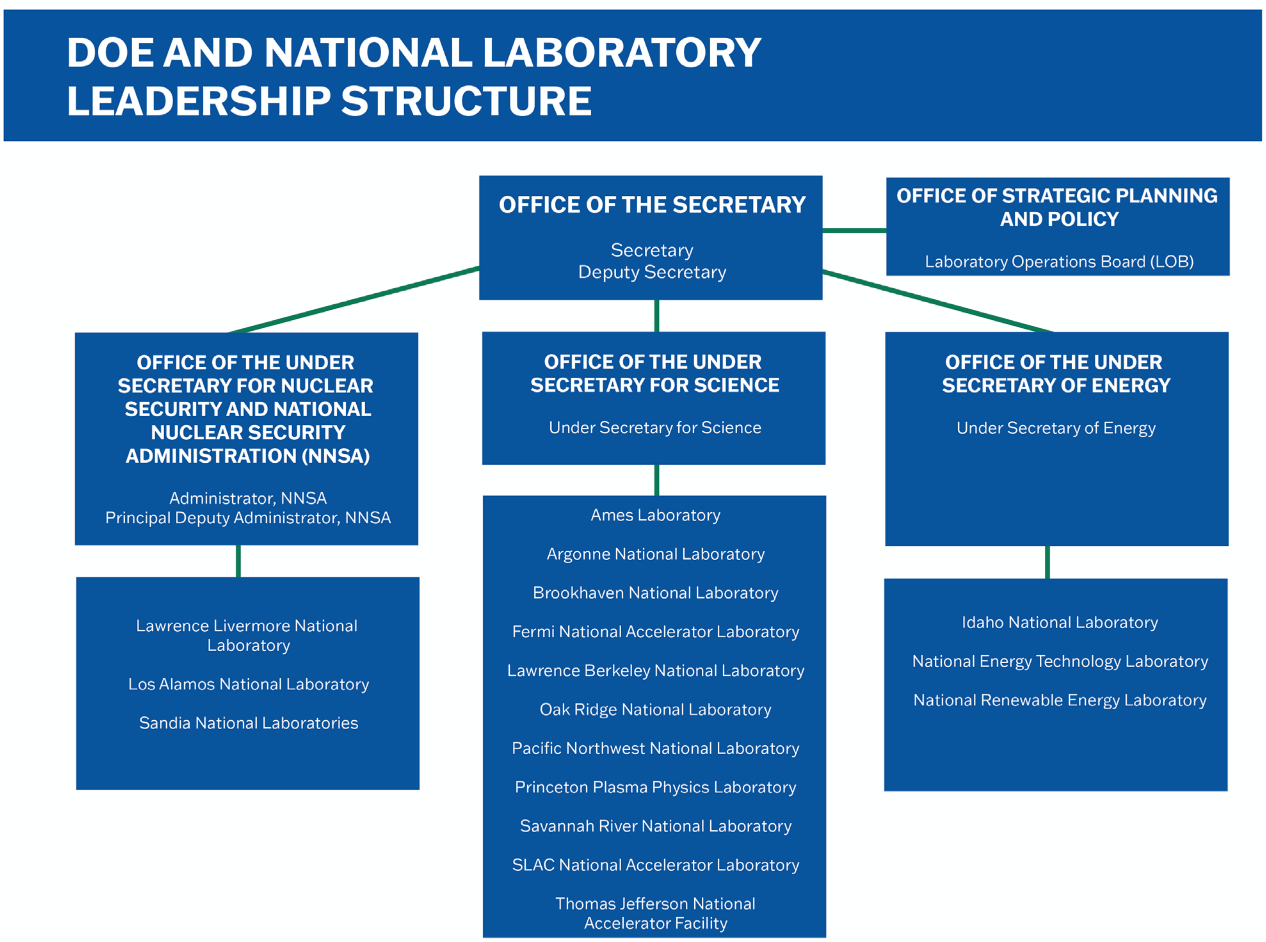


Figure 1-1 Footnote: This figure represents where each Laboratory falls within the broad DOE senior leadership structure. Please see Figure 4-1 for a full organization chart that includes other key positions involved in Laboratory oversight and direction.

the technical expertise resident throughout the DOE/NNSA nuclear security enterprise, serve a mission-essential function, strengthening our nation through the nuclear security mission. DOE/NNSA keeps its technical expertise at the cutting edge in mission-essential functions such as manufacturing, diagnostics, and evaluation among many other such areas.

DOE's Program Offices are an integral part of the Department and the strategic planning of the National Laboratories; their relationship to the Under Secretaries is shown in Figure 4-1 in Section 4.

DOE's senior leaders are also responsible for the overall success and stewardship of the National Laboratory complex. As depicted in Figure 1-1, the 17 National Laboratories are managed by the three Under Secretaries to support coordination and strategic planning. However, the overall funding and operations of the laboratory complex are overseen by the Secretary and Deputy Secretary, with input from the Laboratory Operations Board (LOB) within the OSPP.

The Department has approximately 13,000 Federal employees and more than 95,000 National Laboratory staff and contractor employees at 17 National Laboratories, five nuclear security plants and sites, and 16 environmental clean-up sites at 85 field locations in 30 States. DOE is proud to have a diverse workforce in various disciplines and fields, on which it relies to meet its broad mission. The Department continues to focus on the maintenance of a strong STEM workforce pipeline to support the future needs of our country.

DOE's rich and diverse history is inextricably linked with the history of the National Laboratories and the evolution of science-based public policy. An in-depth history and description is available in a January 2017 document entitled Annual Report on the State of the DOE National Laboratories, available at https://www.energy.gov/sites/prod/files/2017/02/f34/DOE%20State%20of%20the%20National%20Labs%20Report%2002132017.pdf. This 2020 report provides an update focused on the National Laboratories, their accomplishments, and events since 2017.

1.2 Overview of the National Laboratory System

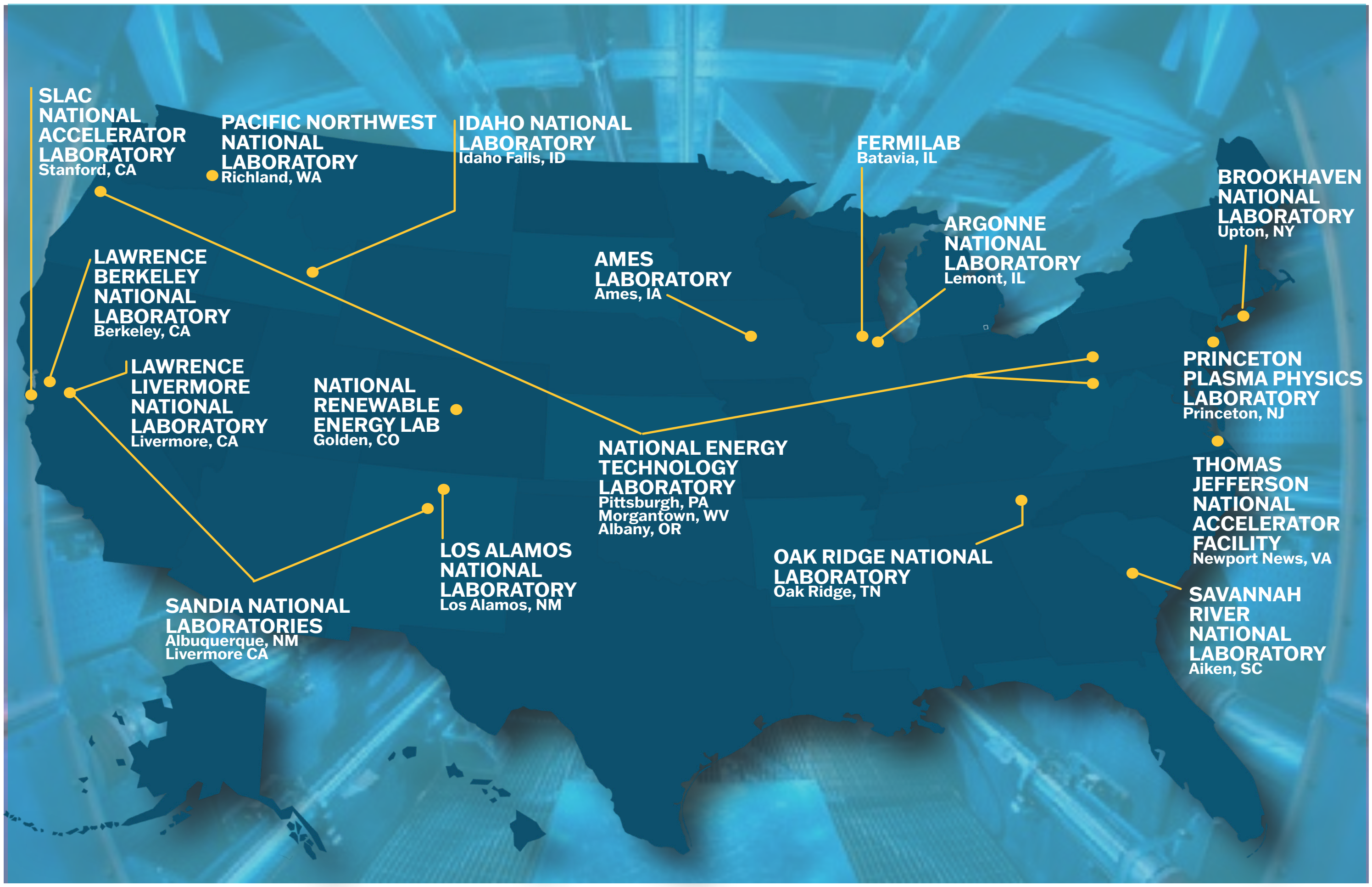
The 17 National Laboratories, which span the Nation geographically, provide a breadth and depth of scientific and technology leadership that is essential to America's scientific discovery and innovation (see Figure 1-2).

The forerunners of the National Laboratories were created during the Manhattan Project of World War II to counter the existential threat facing the United States and its allies. After the war, the U.S. Government continued to invest significantly in S&T research, which grew the technical capabilities and facilities of the Atomic Energy Commission (AEC), created in 1946, and ultimately established the first Laboratories at AEC research sites. The Energy Reorganization Act of 1974 split the AEC into the Nuclear Regulatory Commission and the Energy Research and Development Administration (ERDA); the National Laboratories were then managed by ERDA. In 1977, the Department of Energy Organization Act created DOE to replace ERDA and take on functions from several other agencies; this Act provided authorities that still broadly govern DOE's work today. Since 1946, the missions of DOE and the National Laboratories have evolved significantly to meet national needs.

While most of the National Laboratories' work is guided by DOE's diverse missions, they are also a resource for the entire Federal government and for others. As such, the Laboratories engage in diverse partnerships and research collaborations with other Federal agencies, academia, and the private sector.

Powering the National Laboratories is a world-class workforce of research scientists, engineers, and support personnel who serve the American people. Separately and together, the National Laboratories invest in growing the Nation's S&T workforce. Building a resilient talent pipeline has been imperative for the National Laboratories and has aided them in creating and maintaining an innovative edge.

FIGURE 1-2: OVERVIEW OF THE NATIONAL LABORATORY SYSTEM



1.2.1 Types of DOE National Laboratories

Each of the 17 National Laboratories varies in mission, capabilities, and structure. Figure 1-3 depicts the types of Laboratories and the range of research conducted at each. Additional detail and Laboratory-specific information is provided in Appendix A.

Energy Technology Laboratories enhance DOE's energy mission and develop technologies that focus on different aspects of an "all-of-the-above" energy mission.

Multipurpose Science Laboratories are home to unique research programs, core capabilities, and facilities that are key to multidisciplinary, crosscutting science.

Single-Program Science Laboratories focus on discoveries in fundamental science and the forces in the universe.

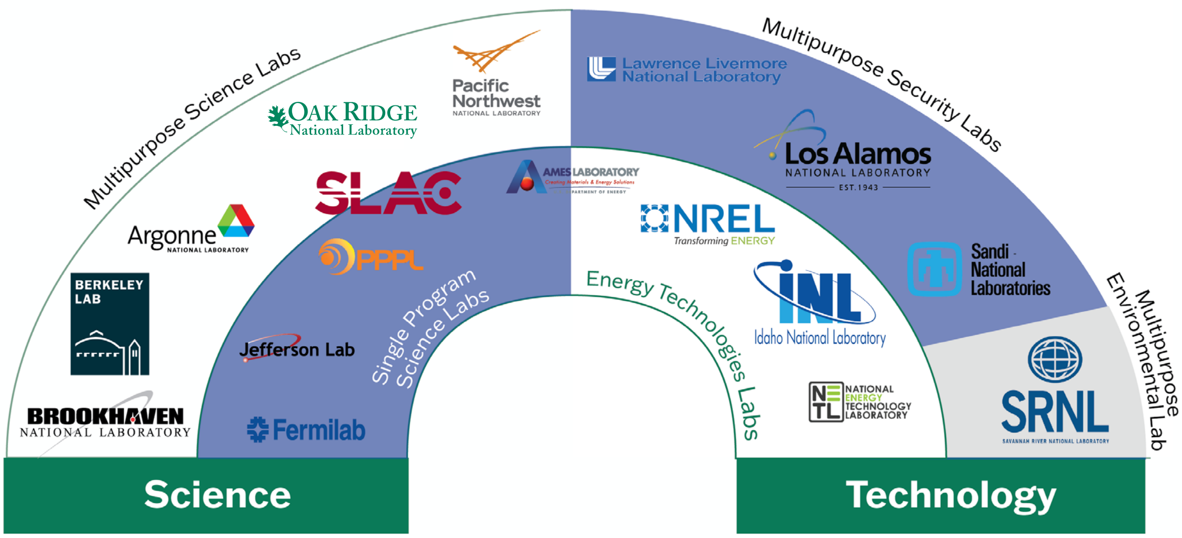
Multipurpose Security Laboratories are key to the nuclear security mission and principally work in classified space supporting the protection of the country through cutting-edge science and engineering.

The Multipurpose Environmental Laboratory focuses on the environmental management and long-term stewardship missions of the Department.

All but one of the National Laboratories are managed through a government-owned, contractor-operated (GOCO) model, which allows for competitively selected contractors to effectively operate the Laboratories and the investment of Laboratory R&D funding, while carrying out DOE's missions. The GOCO model also allows for a recompete process that enables DOE leadership to change the management and key personnel to improve contractor performance in support of strategic direction while maintaining the talented workforce. The National Energy Technology Laboratory (NETL) is the only government-owned, government-operated (GOGO) National Laboratory.

FIGURE 1-3: TYPES AND RANGE OF DOE NATIONAL LABORATORIES

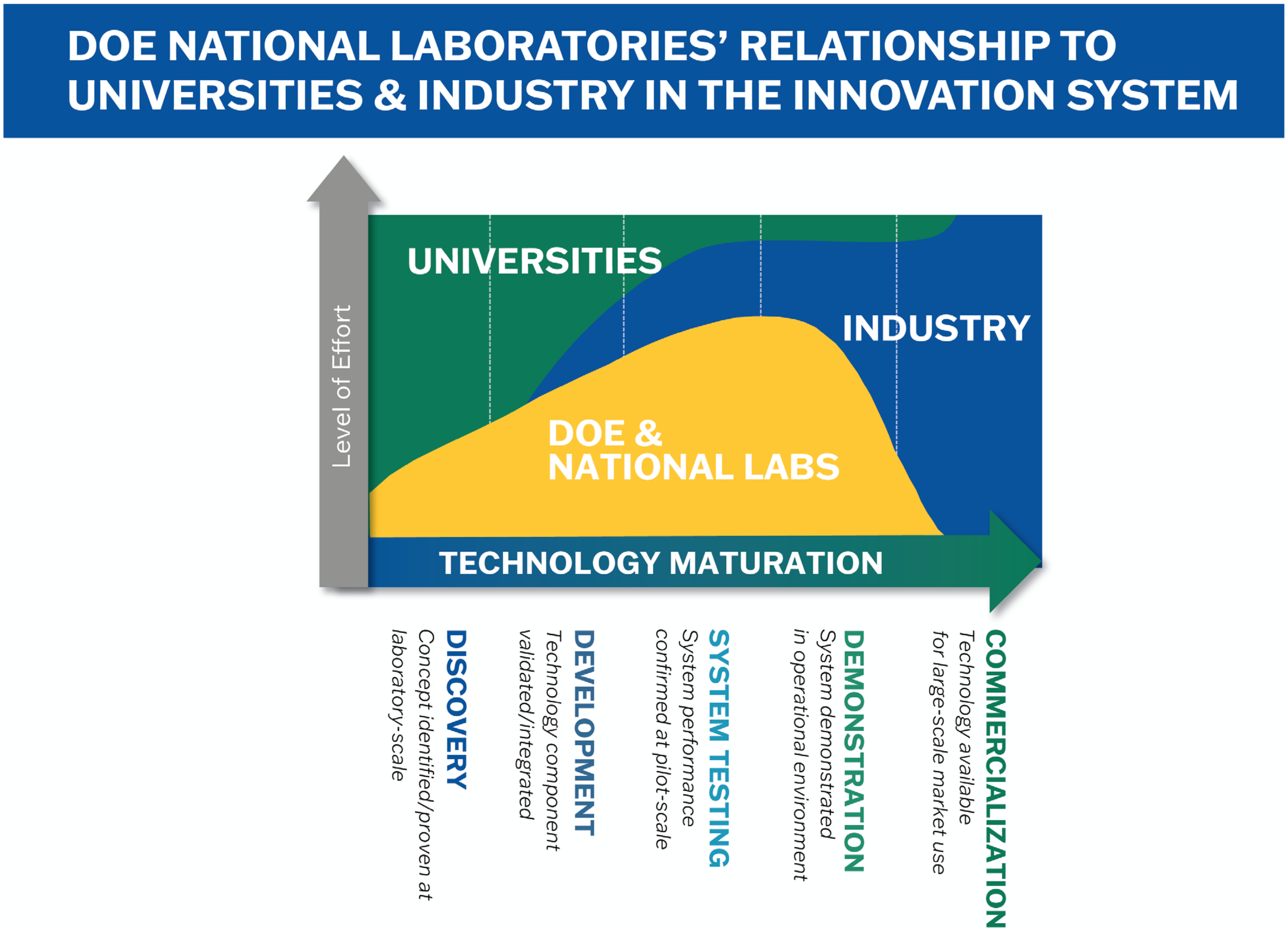
DOE EXECUTES ITS MISSIONS THROUGH DIVERSE NATIONAL LABS



1.2.2 The National Laboratory Ecosystem and Adaptability

The Laboratory system is constantly adapting to the evolving mission needs of the Department and ultimately, the Nation. DOE's National Laboratories are the crown jewels of the Nation's R&D ecosystem and serve as critical collaboration hubs for the scientific community. The Laboratories collaborate extensively with researchers and innovators from academia, industry, and other Federal agencies in discovery science and development of scientific and technological solutions that meet national needs. As the national needs for innovation shift, the National Laboratories adapt and fill in critical gaps, as shown in Figure 1-4. By concentrating on complex problems requiring sustained, long-term focus, the Laboratories typically operate in the space between universities' early discovery efforts and industry's focus on near-term solutions to meet market needs.

FIGURE 1-4: DOE NATIONAL LABORATORIES' INNOVATION ECOSYSTEM



1.2.3 The National Laboratories' Core Capabilities

The National Laboratory complex functions as an interdependent system with an extensive set of core capabilities, world-class staff, and state-of-the art facilities and instrumentation. Together, the complex has produced a wealth of scientific discoveries and technology innovations in support of DOE's overarching mission of advancing the national, energy, and economic security of the United States, garnering 118 Nobel Prizes and discovering 22 elements on the periodic table along the way.

While the National Laboratories are uniquely suited to provide long-term sustained R&D, the breadth of their core capabilities enable them to respond with agility to emerging crises. Together, the capabilities of the National Laboratories allow them to make impactful contributions by:

- Conducting research of the highest caliber in physical, chemical, biological, materials, and computational and information sciences that advances our understanding of the world around us;
- Furthering U.S. energy independence and leadership in clean energy technologies to ensure the availability of clean, reliable, and affordable energy;
- Enhancing global, national, and homeland security by maintaining a safe, secure, and effective nuclear weapons stockpile, reducing global nuclear threats, and by supplying the U.S. Navy with safe, militarily effective naval propulsion plants;
- Stewarding vital scientific and engineering capabilities that are essential to our Nation's continued S&T primacy in a rapidly changing world;
- Designing, building, and operating unique and distinctive scientific facilities and instrumentation, and making these resources available to tens of thousands

of scientists and engineers from academia and industry as they collaborate on solutions to pressing and complex problems; and

• Promoting innovation that advances U.S. economic competitiveness and contributes to our future prosperity.

In summary, the National Laboratories are invaluable assets to the Department and our Nation. They have repeatedly demonstrated the ability to anticipate national needs and have delivered tremendous scientific and technological impact over more than seven decades.

National Laboratory Core Capability Categories:

- Accelerator S&T
- Advanced Computer Science, Visualization, and Data
- Applied Materials Science and Engineering
- Applied Mathematics
- Biological and Bioprocess Engineering
- Biological Systems Science
- Chemical and Molecular Science
- Chemical Engineering
- Climate Change Science and Atmospheric Science
- Computational Science
- Condensed Matter Physics and Materials Science
- Cyber and Information Sciences
- Decision Science and Analysis
- Earth Systems Science and Engineering
- Electrical & Mechanical Design & Engineering
- Environmental Subsurface Science
- Large-Scale User Facilities/Advanced Instrumentation
- Materials Science, Engineering & Advanced Manufacturing
- Materials & Component Prototyping, Manufacturing, Production & Integration
- Mechanical Design and Engineering
- Nuclear and Radiochemistry
- Nuclear Physics, Nuclear Chemistry & Nuclear Engineering
- Particle Physics
- Plasma and Fusion Energy Science
- Power Systems and Electrical Engineering
- Systems Engineering and Integration
- Weapons Systems Design, Engineering, Integration & Testing

1.3 Special Sections

Below are select noteworthy achievements of DOE and its National Laboratories since 2017. While this section highlights three major areas that were critical to the Department's success since that time, a more in-depth and detailed sampling of S&T accomplishments by the National Laboratories is highlighted in Section 2 and DOE Accomplishments can be found in Appendix B.

1.3.1 The National Laboratory Response to Bio-threats such as COVID-19

When faced with an exigent need, DOE calls on the National Laboratories' unique scientific expertise, tools, facilities, and intellectual environments to respond quickly and with authority. This type of role for the Laboratories has been displayed recently as DOE has helped lead the response to the COVID-19 pandemic in the United States. Partnerships between the National Laboratories and external partners advanced collaborative science for near-term solutions. The National Laboratories have collectively contributed to epidemiological research, molecular modeling, securing PPE supply chains, searching for genomic clues, and otherwise supporting the Nation's (and world's) pandemic response.

The National Laboratories' collective rapid response efforts included the highly successful establishment of the COVID-19 HPC Consortium to harness the world's most advanced computing capabilities in support of COVID-19 research. The Consortium partners provided an unprecedented amount of computing power (330+ petaflops) to scientists and medical researchers as they responded to the global emergency. The Consortium includes Argonne National Laboratory (ANL), Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), Oak Ridge National Laboratory (ORNL), and Sandia National Laboratories (SNL); Federal partners; industry; and academia. The

NVBL's R&D Efforts that Helped Fight COVID-19:

Epidemiological Modeling: improved U.S. policymakers' understanding of pandemic impacts and aided in the response efforts. A team of researchers developed an integrated COVID-19 pandemic monitoring, modeling, and analysis capability. This project takes advantage of National Laboratory supercomputers—including the world's second most powerful—along with other capabilities in scalable data and computing, spatial demography, and human dynamics research, along with economic and risk modeling.

Manufacturing: minimized significant supply chain issues regarding critical medical supplies and equipment, especially PPE. Shortages in supplies such as N95 surgical masks and respirators, face shields, swabs, and ventilators put medical professionals at risk and delayed an effective response to the ongoing crisis. This project leveraged advanced manufacturing capabilities at the National Laboratories, including additive manufacturing processes for metals, composites, and polymers, to facilitate accelerated production of these items.

Molecular Design for Medical Therapeutics: applied a combined computational and experimental approach to accelerate scientific discovery for therapeutics targeting the SARS-CoV-2 virus that caused COVID-19. This effort took advantage of the National Laboratory capabilities, including supercomputing and artificial intelligence, materials characterization at x-ray light and neutron sources, and nanoscience research.

COVID-19 Testing R&D: discovered an effective vaccine for SARS-CoV-2 and laboratory-based diagnostic tests that were critical for protecting vulnerable populations, managing risk to all populations, supporting work strategies, and tracking the evolution of the virus and disease. The R&D addressed the challenges of virus susceptibility, infection, and immunity. This project leveraged deep expertise at the National Laboratories in chemical analysis and biology to develop new approaches for improved diagnostic testing, including antigen and antibody testing.

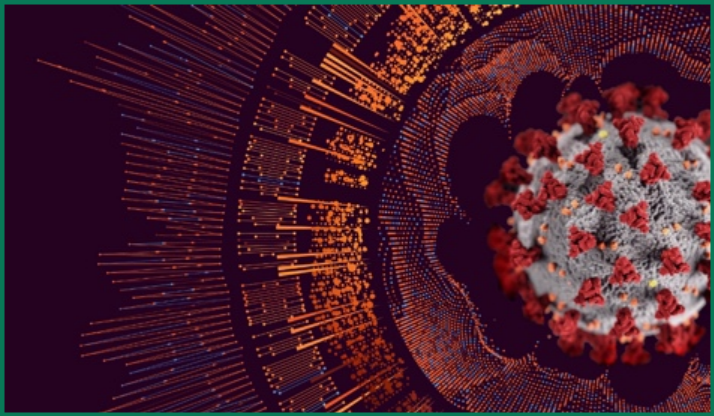
Viral Fate and Transport Research: supported experimentation combined with physics-based and data-driven modeling and simulation to address the challenge of SARS-CoV-2 transport, transmission, and fate. This research provided critical data and modeling results to influence the response to the crisis and helped understand factors involved in the emergence, circulation, and resurgence of pathogenic microbes.

advanced computing capabilities and systems made available through the Consortium processed enormous quantities of calculations for studies related to bioinformatics, epidemiology, and molecular modeling. These HPC resources allowed scientists to significantly speed up their ability to answer complex scientific questions related to COVID-19.

As the United States began to see a dramatic increase in COVID-19 cases, the country experienced a material, manufacturing, and supply chain crisis associated with items needed to combat the pandemic. A Manufacturing Task Force, consisting of 15 of the 17 National Laboratories, was created to accelerate the development and deployment of new technologies into the U.S. manufacturing industrial base. The task force established a DOE strategy for mobilizing the manufacturing capabilities across the National Laboratories to develop, demonstrate, and make operational key technologies needed to address pandemic supply chain issues. The task force identified challenges and implemented rapid and effective solutions in days rather than weeks and months. Several National Laboratories also adopted a rapid licensing approach that transfers promising technologies to industry partners more quickly, which will benefit the Nation in the future during responses to national emergencies and corresponding health and economic crises.

To respond to the current pandemic, and possible future pandemics, the Department's Office of Science (SC) instituted the NVBL to capitalize on the National Laboratories' world-leading expertise, capabilities, and facilities. Funded by the Coronavirus Aid, Relief, and Economic Security (CARES) Act in March 2020, the NVBL takes advantage of DOE User Facilities, including light and neutron sources, nanoscale science centers, sequencing and bio-characterization facilities, and high-performance computers, to address key challenges in responding to pandemics. The NVBL allows for collaboration across the extraordinary breadth of bioscience and biotechnology expertise in the 17 DOE National Laboratories, in addition to collaboration with academia and industry.

The NVBL framework provides the Department with a standing mechanism to quickly assess R&D needs associated with a rapidly evolving situation and identify critical capabilities existing within the National Laboratory system and DOE's broader research enterprise. This new framework will allow for the development of a multi-program and multi-institutional plan to deploy DOE's unique capabilities, and to coordinate efforts with other Federal agencies, state and local representatives, and partners in industry.



Under a special project launched in May, a team of computing and bioinformatics experts at Lawrence Berkeley National Laboratory are working together to develop a platform that consolidates disparate COVID-19 data sources and uses the unified library to make predictions - about potential drug targets, for example.

1.3.2 DOE and the National Laboratories' Role in Advancing U.S. Leadership in Space

For decades, the United States has been the world's leading space power, with no equal in technical capability or operational presence. Over time, as with most of the world, the United States became crucially reliant on space systems. From economic prosperity and national security to science and diplomacy, space activities provide practical as well as symbolic benefits to the nation. But today, and for the foreseeable future, the United States will be facing a space environment that is increasingly more diverse and competitive, with an increasing number of space-faring nations and commercial entities, as well as countries such as China and Russia that are growing space threats pursuing their own commercial and military advantage in the space domain. In response, the 2020 U.S. National Space Policy calls for a reinvigorated, whole-of-nation approach to maintain and enhance America's leadership in space-based science, technology, commerce, and security. This includes the priorities of returning American astronauts to the Moon for the long term, followed by human exploration missions to Mars and beyond, to ensure an unfettered ability to operate in space by deterring, countering, and defeating space-oriented threats to U.S. security and fostering the growth of space commerce.

For 60 years, DOE and the National Laboratories have been key players in U.S. space activities. Through a multidisciplinary S&T workforce, combined with unique instruments and facilities, DOE and its Laboratories can address the types of large-scale, complex R&D challenges inherent in the future of U.S. space exploration, science, and commerce. The National Laboratories leverage their collaborative relationships with other U.S. government research centers, universities, and private sector entities to expand the foundations of space science knowledge and grow the U.S. space industry. While DOE is not unique in having this expertise, it is unique in the breadth of knowledge concentrated within a single organization and in the experience of applying that knowledge to a highly diverse mission set.

DOE and the Laboratories are applying their core mission competencies and emerging capabilities to meet the needs of the U.S. space community in order to:

- **Power the Exploration of Space:** developing space-capable energy technologies (both nuclear and non-nuclear) for U.S. space customers, exploring energy management systems for their potential application to space missions, and considering innovative energy generation, collection, storage, distribution, employment, dissipation, and thermal management technologies for space systems.
- **Solve the Mysteries of Space:** harnessing the capabilities and expertise within the National Laboratory complex and across its broad community of researchers to make scientific discoveries for space and in space, advancing not only our fundamental understanding of the universe, but how we can live and work in it safely, securely, profitably, and productively.
- **Support the Secure and Peaceful Use of Space:** providing technical capabilities, systems, multi-purpose sensors, and satellite development/deployment support with application to national security as well as civil space programs.
- **Enable the Development of Space:** harnessing innovation to transform space science research and achieve breakthroughs in space-applicable technology to enable future U.S. space missions and grow U.S. space commerce.

The Department's mission—to address America's energy, environmental, and nuclear challenges through transformative S&T solutions—simultaneously creates opportunities for DOE to advance American space innovation and drive American space exploration. DOE supports the world's most advanced and unique scientific facilities, which enable discoveries made possible by these facilities that push the boundaries of human knowledge across many scientific disciplines.

For example, DOE provides expert knowledge and world-leading capabilities in nuclear and non-nuclear energy technologies, AI and robotics, high-speed information technology, advanced manufacturing, microelectronics, materials for extreme environments, radiation science, isotope production, and a host of other areas. This engine of discovery can power crewed missions to the Moon and beyond, as well as pave the way for human habitats and sustained presence on the surface of other planetary bodies. DOE is one of the largest supporters of technology transfer in the Federal government. Thus, DOE's R&D investments can aid in accelerating the commercialization and industrialization of space, forge new capabilities for sustainable expansion into the solar system, and provide benefits for life on Earth.

For decades, the DOE innovation enterprise has worked with U.S. space programs in the design, development, and deployment of space nuclear power systems, having provided such power systems for nearly 30 missions over the past 60 years. This includes numerous Mars rovers, the Galileo mission to Jupiter, the Cassini mission to Saturn, and the Voyager and New Horizon missions to the outer edges of our solar system and beyond. DOE also supplied the power source, in addition to other essential equipment and technology, for the Mars 2020 Perseverance Rover.

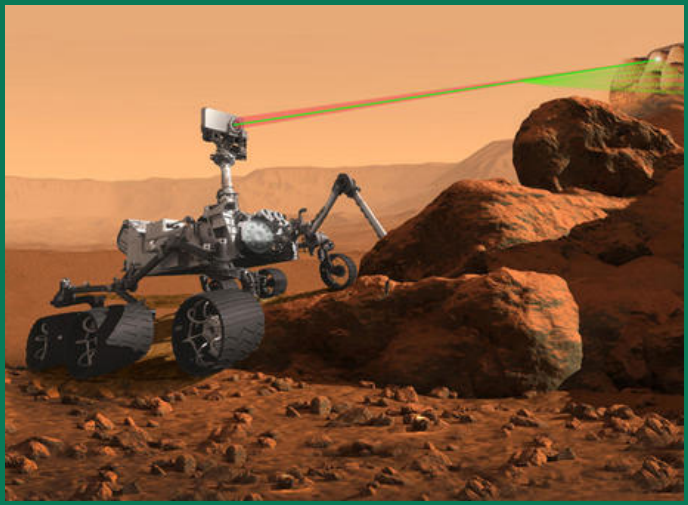
But DOE and the National Laboratories have also partnered with the U.S. space community to develop many other enabling technologies and instruments, and has provided S&T resources for high-profile scientific missions such as the Fermi Gamma-ray Space Telescope, the Planck Cosmic Microwave Background mission, and the Alpha Magnetic Spectrometer, experiments that have each made important contributions to our understanding of the nature of the universe, including dark matter and dark energy.

DOE's cutting-edge work on next-generation computing technologies, such as QIS and AI, will help our Federal and private sector partners protect against space weather events and debris. The DOE enterprise is also solving the mysteries of space and fostering technology development by expanding our understanding of the effects of harsh space environments on humans and materials, searching for dark energy, and exploring for past signs of life on Mars. And DOE is working closely with other United States government departments and agencies on S&T solutions to address asteroid deflection techniques for planetary defense, as well as strengthen U.S. satellite system resiliency and space situational awareness against space-based threats.

The core expertise within DOE's community of researchers, coupled with decades of experience conducting "science at scale," uniquely enables DOE to take on the biggest challenges in space-related science and an expanded human presence in space. Several National Laboratories already play major roles in space science research, including the SLAC National Accelerator Laboratory (SLAC), Lawrence Berkeley National Laboratory (LBNL), Fermi National Accelerator Laboratory (FNAL), Brookhaven National Laboratory (BNL), and Los Alamos National Laboratory (LANL). SLAC plays a development and operations role in the Fermi-Gamma Ray Telescope and the Vera C. Rubin Observatory, LBNL has the lead role for DOE in the Cosmic Microwave Background Experiment, and LANL developed the SuperCam, a remote-sensing spectroscopy instrument attached to the mast of the Perseverance rover due to land on Mars in February 2021, as well as the earlier ChemCam instrument on the Mars Curiosity rover.

The goal of an expanded human presence in space is an extraordinary opportunity to pursue completely new opportunities for science and technological research across many domains. DOE's diverse expertise in fields like AI, advanced computing, materials science, systems biology, plasma science, space weather, radiation-tolerant microelectronics, and QIS enable the achievement of both increased scientific knowledge and an increased human presence in space.

In addition, DOE's NNSA has unique capabilities to assist with national defense through its treaty monitoring, indications, and warning programs; national defense of its space assets, such as satellites; and global defense, including planetary defense from near-Earth objects. SNL and LANL have been key technical partners in the nearly 60-year partnership between the U.S. Air Force and NNSA on the U.S. Nuclear Detection System to develop, test, produce, and integrate nuclear detonation detection instrument payloads onto global positioning system satellites and other satellite hosts to monitor compliance with international bans on atmospheric, space, and underwater nuclear testing. Both LANL and SNL have advanced technologies for nuclear detonation detection instruments that improve system performance to meet changing national needs. Researchers at LLNL are using computer simulations to validate their ability to accurately simulate how an Earth-bound asteroid may be deflected, an essential component of the design of a modeling plan for the National Aeronautics and Space Administration's Double Asteroid Redirection Test (DART) mission in 2021, which will be the first-ever kinetic impact deflection demonstration on a near-Earth asteroid.



Los Alamos National Laboratory's SuperCam on the Mars Perseverance rover - a remote-sensing instrument for the Mars 2020 mission.

1.3.3 DOE's Role in the Future of Quantum Information Science

QIS, which is a form of computing and information processing that relies on quantum effects in order to sidestep traditional physical limitations of computing, has emerged as a critical technology of the future. QIS builds on uniquely quantum phenomena such as superposition, entanglement, and squeezing to obtain and process information in ways that cannot be achieved according to classical physics. With broad-ranging applications in sensing and metrology, networking, simulation, and computing, QIS has the potential to enable significant advances in critical areas such as physics, chemistry, biology, and materials science. At the same time, research in the theoretical foundations of QIS is opening new areas of science discovery and technology innovation.

QIS is on the threshold of providing transformative technology that will impact discovery science and technological innovation in the coming decades. Advances in QIS are critical to data protection and our national competitiveness in information technology. America continues to lead in QIS and emerging technologies, but competitor nations, like China, have made QIS a top investment priority with a goal of surpassing the United States. The race for leadership in quantum technologies will be a determinative factor in the competitiveness of future advanced economics. This is a race we cannot afford to lose.

To support this effort, President Trump signed the bipartisan, bicameral National Quantum Initiative Act in December 2018, which established a coordinated multiagency program to support research and training in QIS, encompassing activities at the DOE, the National Institute of Standards and Technology (NIST), and the National Science Foundation (NSF). Consistent with this initiative, the President launched the National Quantum Strategy, which positions the U.S. to achieve success by leveraging the combined strengths of academia, industry, and the DOE Laboratories to drive QIS breakthroughs. The National Laboratories are well aligned with the National Quantum Strategy, which provides the framework and direction to pursue DOE's strategic objectives:

• **Science:** DOE programs and laboratory-directed research and development (LDRD) funds support an expansive research portfolio across the complex. A notable highlight is the quantum supremacy announcement of October 2019, which resulted from the collaboration of researchers from ORNL, Google, NASA, and a number of academic institutions. ORNL's Summit, the Nation's fastest supercomputer, was used in this demonstration to compete with Google's quantum computer.

• **Workforce:** The DOE National Laboratories support QIS careers via training programs and summer schools such as LANL's Quantum Computing Summer School Fellowship. Additionally, DOE programs like the Office of Science Graduate Student Research Program (SCGSR) and Computational Science Graduate Fellowship (CSGF) allow students to leverage Laboratory resources during their graduate training.

• **Industry:** The Laboratories collaborate with the industry to advance QIS and technology via research partnerships and User Facilities that make Laboratory capabilities available to industry. The Laboratories also connect the broader scientific community with industry. For instance, ORNL's quantum computing user program provides the scientific community with access to quantum computing resources from IBM, D-Wave, Rigetti, and Atos.

• **Infrastructure:** The User Facilities at the Laboratories, including x-ray light sources and supercomputers, are already being used for QIS-related research. Development of specific technologies such as superconducting radio frequency (SRF) cavities for qubits at FNAL and investments at the Nanoscale Science Research Centers add advanced capabilities for QIS.

DOE and the National Laboratories' Pivotal Role in Quantum Internet:

Around the world, consensus is building that a system to communicate using quantum mechanics represents one of the most important technological frontiers of the 21st century. DOE released a Quantum Internet Blueprint in July 2020 that presents a plan to develop a secure and reliable system initially connecting the National QIS Research Centers and ultimately the National Laboratory complex. The plan is based on the experience and expertise of testbed networks established by the ANL-FNAL-University of Chicago collaboration and the BNL-Stony Brook University collaboration. DOE is proud to play an instrumental role in the development of the national quantum internet and by constructing this new and emerging technology, the United States continues with its commitment to maintain and expand our quantum capabilities. DOE's Laboratories will serve as the backbone of the coming quantum internet, which will rely on the laws of quantum mechanics to control and transmit information more securely than ever before. Currently in its initial stages of development, the quantum internet could become a secure communications network with a profound impact on areas critical to science, industry, and national security. DOE and the National Laboratories are bringing the United States to the forefront of the global quantum race and ushering in a new era of secure communications.

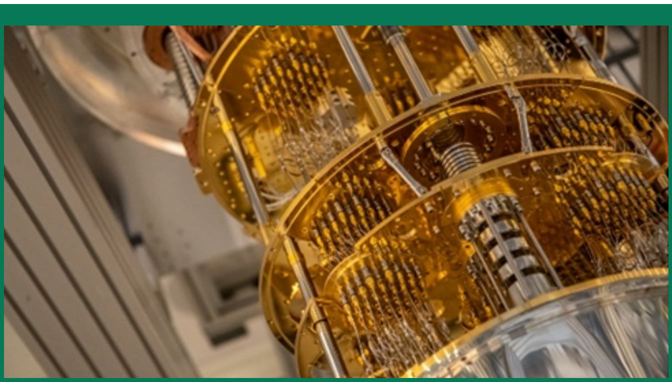
• **Economic and Security:** Foundational research at the Laboratories provides a base for future technologies. Exploration of technology at the precompetitive level, such as quantum testbeds at LBNL and SNL funded by DOE-SC, mitigates risk for industry.

• **International:** The Laboratories play an active role in the international QIS community. In addition to forging research partnerships, many Laboratory researchers serve on international scientific advisory boards.

As DOE continues to establish its leadership in QIS, the National Laboratories remain strongly vested in future QIS advances via awarded and planned efforts. The Laboratories bring their extensive resources and expertise to the field and, in some cases, supplement DOE's investments with their internal initiatives.

The National Quantum Initiative Act called for the creation of competitively awarded QIS research centers. Five of the Laboratories lead the National QIS Research Centers that were established in August 2020; those Laboratories are ANL, BNL, FNAL, LBNL, and ORNL. These Centers constitute DOE's largest investment to date in QIS and across the technical breadth of DOE-SC. They span a wide scope within QIS that includes communication, computing/emulation, devices/sensors, materials/chemistry, and foundries, and they address all levels of the QIS S&T innovation chain from fundamental science to devices, systems, prototypes, and applications. While led by the DOE National Laboratories, the Centers engage academia and industry as participating partners and have innovative workforce advancement programs.

In summary, the DOE National Laboratories host the scientific User Facilities and multi-laboratory initiatives that are strongly embedded in the nationwide QIS ventures. This robust ecosystem, combined with DOE's strategic investments in core QIS research, as well as in the National QIS Research Centers and the proposed quantum internet, is expected to bring additional benefits to the American people.



DOE's Lawrence Berkeley National Laboratory is using a sophisticated cooling system to keep qubits - the heart of quantum computers - cold enough for scientists to study them for future use in quantum computers.

2. HIGHLIGHTING THE NATIONAL LABORATORIES' S&T ACCOMPLISHMENTS

The contributions of the National Laboratories span the spectrum from discovery science to development of advanced technology. Summarized here are examples that illustrate the impact of the Laboratories' work.

Architecture Lights the Path to Grid Modernization: The Grid Modernization Laboratory Consortium, a strategic partnership between DOE and 14 National Laboratories, recently completed five reference architecture specification sets to provide a practical pathway for utilities to manage advanced power grids and deal with the complexity of grid modernization. This groundbreaking architecture work is being used in at least 26 states and in multiple countries around the world. The architectural concepts have also been adopted by U.S. electric utilities, including the Hawaiian Electric Company, which is pursuing an ambitious grid modernization initiative to enable the transition to 100% clean energy by 2045.

The Grid Modernization Laboratory Consortium's smart energy plaza test bed at ANL is part of a strategic partnership between DOE and 14 National Laboratories working to provide a practical pathway to deal with the complexity of grid modernization.

CRISP combines state-of-the art threat analysis with U.S.intelligence insights to identify sophisticated attacks targeting U.S. energy systems.

The North American Energy Resilience Model (NAERM): Designed to increase resilience of the Nation's energy infrastructure, NAERM is a coordinated effort by DOE, the National Laboratories, and industry to enable breakthrough advances in resilience analysis for critical energy infrastructure on a national scale. The NAERM team has developed and demonstrated a resilience modeling platform to analyze the behavior of complex electric power systems, as well as dependencies with other critical energy infrastructure, such as natural gas. By improving our ability to predict and understand the impacts of natural and man-made threats to our energy infrastructure, NAERM supports the Nation's prosperity, security, and safety.

Cybersecurity Risk Information Sharing Program (CRISP)—Heads Up on Cyber Threats: A good way to prevent cyberattacks is to share timely information about potential threats with organizations that can put the information to use. The DOE Office of

Cybersecurity, Energy Security, and Emergency Response (CESER) developed CRISP to combine state-of-the-art threat analysis with U.S. intelligence insights to identify sophisticated attacks targeting U.S. energy systems. CRISP has identified intrusions that would have otherwise gone undetected, notified targeted organizations, and coordinated federal onsite assistance teams to mitigate threats. The CRISP network has also recently expanded to include smaller electric and gas utilities and oil infrastructure.

Researchers at Lawrence Berkeley National Laboratory and Carnegie Mellon University have designed new solid electrolytes that light the path to wider electrification of transportation.

Energy Storage Grand Challenge: Moving to the next stage of a sustainable and resilient U.S. electricity infrastructure will impact nearly every aspect of society. Beyond advancing fundamental and applied research into new sources of power, the National Laboratories are combining forces to develop a wide array of energy storage resources needed to manage over 4 trillion kilowatt-hours of electricity.

Breakthroughs in Battery Technology: National Laboratory scientists worked with the U.S. auto industry to reduce the price of batteries by more than 80% in the last 10 years. Breakthroughs in new materials, advanced manufacturing methods, and advanced system modeling and cost analysis have enabled the development of high-energy-density battery technologies at greatly reduced prices.

Reducing the Cost of Electrolyzers: Electrolyzers use electricity to split water into hydrogen and oxygen. The hydrogen, in turn, can be used in fuel cells to power automobiles and other devices. In the past decade, the groundbreaking work of the National Laboratories has cut electrolyzer costs by 80% and reduced automotive fuel cell costs by 60%, while quadrupling fuel cell durability. These advances will help the Nation realize clean hydrogen energy sources.

Securing our Energy Future: With the aging of the existing U.S. fleet of commercial nuclear power reactors, the National Laboratories have partnered with industry to test, improve, and validate advanced reactor designs and prototypes to accelerate the entry of these technological breakthroughs into the U.S. market. This ambitious program seeks to demonstrate a functioning advanced reactor in seven years and will work in partnership with the National Reactor Innovation Center, an advanced platform for private sector technology developers to assess the performance of their nuclear reactor concepts, and secure safe, reliable, carbon-free energy production for current and future generations.

Energy Plants with a Net-Zero Carbon Emissions: The Coal Flexible, Innovative, Resilient, Small & Transformative (FIRST) initiative supports the development of 21st century electricity and hydrogen energy plants that have net-zero carbon emissions. The National Laboratories are working together to design these plants, which will be fueled by coal, natural gas, biomass, and waste plastics and incorporate carbon capture, utilization and storage technologies.

Accelerating the Development of Fusion Energy in the Private Sector: The International Thermonuclear Experimental Reactor (ITER) is a collaborative international facility being developed in France. With initial operations estimated to begin in 2035, the sustained large-scale production of carbon-free energy from nuclear fusion will take a big step toward becoming a reality. ITER will be the first fusion device to test the integrated technologies, materials, and physics regimes necessary for the commercial production of fusion-based electricity. As a result, many commercial opportunities will arise as fusion transitions from public to private investment. To attract and facilitate capital and innovation, the Innovation Network for Fusion Energy will accelerate fusion energy development in the private sector by reducing collaboration impediments to leveraging the expertise and unique resources available at DOE Laboratories.

International Thermonuclear Experimental Reactor (ITER) site, May 2020

Scientific User Facilities at the International Forefront: The National Laboratories' scientific User Facilities provide exceptional tools for scientific discovery and advances in technology. Particle accelerators, x-ray and neutron sources, nanoscience centers, lasers, nuclear reactors, genomics centers, and supercomputers are essential to the mission of the Department, as well as to the more than 30,000 researchers at universities and in industry who make use of their capabilities each year. Upgrades of existing facilities and the construction of new unique facilities, such as the Electron-Ion Collider, are underway to keep our Nation's network of scientific facilities at the international forefront.

ORNL's Summit, a supercomputer of unprecedented capability, is providing scientists with incredible computing power to solve challenges in energy, artificial intelligence, human health, and other research areas. These discoveries will help shape our understanding of the universe, bolster US economic competitiveness, and contribute to a better future.

Transforming S&T at One Quintillion Calculations per Second: Supercomputers, with their thousands of processors working in parallel, can process unimaginable amounts of data, offering unique advantages in S&T. At a staggering quintillion operations per second, exascale computing will provide the capability to tackle grand challenges in scientific discovery and national security. The DOE-led Exascale Computing Initiative, a partnership between SC and the NNSA, is delivering exascale computing capability to the National Laboratories. The Laboratories' supercomputers are among the fastest in the world, with Summit being the first in the world to break the exascale barrier in 2018. These exascale computers will more realistically simulate the processes involved in precision medicine, regional climate, magnetically confined fusion plasmas, conversion of plants to biofuels, the relationship between energy and water use, and myriad other fields of science and technology.

Leading the World in AI: The DOE and its Laboratories are leading hundreds of different AI and machine learning projects to accelerate scientific discovery and strengthen our Nation's energy and national security missions. AI leverages advances in mathematical and statistical science and is transforming the frontiers of high performance computing. AI methods are being applied to design new drugs, accelerate scientific simulations, and enhance the power of DOE scientific facilities. Further, AI will help ensure reliable and resilient electric grids, guard against cyberattacks, predict earthquakes, and optimize therapies for disease.

NVBL meets the challenge of COVID-19: NVBL, a novel partnership of DOE's 17 Laboratories, was rapidly established to respond to the R&D challenges presented by COVID-19. NVBL efforts included research generating more than 1,000 jobs in production of PPE, sampling kits and ventilators; helping decision makers predict the transmission of the virus at the regional, state, and Federal levels; assuring the efficacy of testing procedures, and modeling the distribution of the virus in rooms. The National Laboratories also co-led the COVID-19 HPC Consortium, a unique public-private effort bringing together federal government, industry, and academic leaders volunteering free computer time and resources to address the national COVID-19 emergency.

Meeting Health Needs with Cutting-Edge Radioisotope Treatment and Diagnostics: The National Laboratories, in collaboration with industry, are providing a safe and reliable domestic supply of medical isotopes that are critically important in medical treatment and diagnostics. Actinium-225, produced by DOE, has recently been commercialized for prostate cancer treatment. Strontium and germanium isotopes developed by DOE have been transitioned to industrial production. Approaches for domestic supply of molybdenum-99, used for more than 80% of medical imaging procedures, are also being developed. In addition to providing the best care possible for Americans, these efforts will reduce dependence on foreign imports and create new opportunities for U.S. industry and the economy.

The Plastics Innovations Challenge: This initiative brings together the expertise of the National Laboratories with universities and industry to accelerate innovations that will dramatically reduce plastic waste in oceans and landfills. The advanced plastics recycling technologies and the manufacture of new, recyclable-by-design plastics will position the United States as a global leader in addressing the environmental challenges and market opportunities presented by plastics pollution.

Critical Materials for Critical Times: DOE and the National Laboratories address challenges associated with critical minerals for U.S. economic and national security through research to diversify sources, develop substitutes, and drive recycling and reuse. The Critical Materials Institute (CMI), an Energy Innovation Hub supported by the Office of Energy Efficiency and Renewable Energy – Advanced Manufacturing Office (EERE-AMO), with dozens of public-private partners, has developed award-winning technologies focused on clean energy. The Critical Minerals Sustainability Program, supported by the Office of Fossil Energy (FE), focuses on domestic coal-based resources and demonstrating the technical feasibility of producing small quantities of rare earths in small pilot-scale facilities. DOE Laboratories advance the fundamental science of separation with support from the Office of Science – Basic Energy Services (SC-BES), conduct demonstration projects for new sources of lithium and rare earth elements for EERE-AMO, and explore bioleaching for separations of critical materials for the Advanced Research Projects Agency – Energy (ARPA-E).

3D Printing and Magnetic Materials: National Laboratories have used 3D printing to reduce waste and energy typically generated in conventional “subtractive” manufacturing where an object is made by machining away materials. “Additive” manufacturing has been used to print 3D magnets containing rare earth materials, such as niobium, in complex geometries not possible with conventional machining approaches. Further, a modified 3D printer was recently used to create the first demonstration of liquid droplets that are permanently magnetized.

A Nobel Effort: The 2020 Nobel Prize in chemistry, shared by a researcher at a DOE National Laboratory, recognized the discovery of genetic “scissors” (i.e., CRISPR/Cas9) that allow researchers to precisely change the DNA of animals, plants, and other organisms. This revolutionary technology has already had an enormous impact on the life and medical sciences, contributing to new cancer therapies, and may make the dream of curing inherited diseases come true.

Scientists at Savannah River National Laboratory are among a group of National Laboratory scientists that have developed chemical processes to recover plutonium, americium/curium, and other isotopes from Mark-18A targets.

Quenching the Nation’s Thirst: Through the Energy-Water Desalination Hub, National Laboratory scientists have embarked on a bold, five-year mission to dramatically lower the cost and energy of desalination through technological innovations with university and industry partners. A key focus is enabling small-scale, modular desalination systems to allow for localized, distributed water reuse.

Recovering Rare Nuclear Materials: National Laboratory scientists have developed chemical processes to recover plutonium, americium/curium, and other isotopes from Mark-18A targets. The harvesting of plutonium 244, a highly valuable isotope beneficial in nuclear forensics and medical research applications, will create a supply of material not found anywhere else within the United States (and possibly the entire world).

Processing Waste More Efficiently: National Laboratory scientists have developed critical real-time characterization of supernate waste samples to allow streamlined salt processing activities to proceed in the tank closure cesium removal demonstration project and Salt Waste Processing Facility (SWPF) at the Savannah River Site. Full operation of the SWPF begins a new era in processing radioactive material and is expected to allow DOE to process tank waste more efficiently. In addition, an alternative defense waste processing facility flowsheet, utilizing glycolic acid with nitric acid, was developed to complete the necessary chemical reactions in the melter feed, while greatly reducing the hydrogen produced from catalytic reactions. Extensive bench and pilot-scale testing of the flowsheet and downstream processes were completed to provide improved processing parameters and a better understanding of the impact of changes throughout the system.

Artificial Photosynthesis: Researchers at the Joint Center for Artificial Photosynthesis (JCAP), a DOE Energy Innovation Hub, have come up with a new recipe for renewable fuels: an artificial photosynthesis device that turns sunlight and water into not just one type of energy but two—hydrogen fuel and electricity, a promising technological breakthrough for new energy sources.

Restart of the Historic TREAT Reactor: The restart of the Transient Reactor Test Facility (TREAT) restored a capability critical to the U.S. role in the development of nuclear fuels, for both the existing fleet and a new generation of advanced reactors. This facility, at Idaho National Laboratory, will once again enable systems that serve the U.S. economy, environment, and national security.

Mapping the Connectome and Understanding the Brain: By unleashing the full power of DOE's supercomputers, National Laboratory researchers have constructed a huge brain functional connectivity graph and map of the functional areas in the brain, providing data for neuroscience discoveries.

Labs Go Virtual to Support the Workforce of the Future: The National Laboratories went virtual in 2020, providing internship and research opportunities for undergraduate and graduate students from across the country through the internet. Students were paired with mentors to do exploratory research across a wide array of scientific and engineering disciplines. Beyond responding to the pandemic through virtualization, the National Laboratories regularly host and provide research opportunities for tens of thousands of students and postdocs providing STEM educational opportunities and fueling DOE's workforce pipeline.

Earth Systems Modeling and Climate Impacts: The National Laboratories have long been leaders in large-scale modeling of earth and climate systems, coupled with associated measurement and observation campaigns. Advances in these capabilities are now facilitating regional impact analyses and shorter-time predictions. These efforts help inform DOE's program in clean energy, carbon capture and grid security, contributing to a resilient and prosperous future. AI methods are increasingly being applied in this area also.

Idaho National Laboratory's TREAT provides transient testing of nuclear fuels and materials.

3. HOW THE NATIONAL LABORATORIES WORK WITH THE INNOVATION COMMUNITY

3.1 Partnership Models

Partnerships allow the National Laboratories to serve as key nodes in the R&D ecosystem and integrate their fundamental advancements and applied precompetitive research outcomes with broad networks of expertise to address new challenges and critical national needs. As shown in Figure 1-4, the ecosystem spans the full R&D spectrum and ultimately contributes to U.S. economic prosperity as the National Laboratories work with industry partners to mature and move technologies into the marketplace.

DOE uses a suite of flexible tools to facilitate R&D partnerships that allow the National Laboratories to address a wide array of challenges. These tools include research centers, Innovation Hubs, research subcontracts, Cooperative Research Development Agreements (CRADAs), Strategic Partnership Projects (SPPs), and Agreements for Commercializing Technology (ACT). Research partnerships vary in size, scope, and duration. They range from a small group of investigators conducting discovery science to address specific technical questions to large research centers that bring together dozens of experts from various disciplines and institutions to cooperatively address major research challenges. Annual Laboratory solicitations provide additional flexibility and allow DOE's applied energy technology offices to directly fund core and enabling S&T capabilities. These solicitations are often used to encourage inter-Laboratory collaboration and bigger consortia-like projects where Laboratories combine enabling capabilities to accomplish challenging multiyear goals.

The DOE National Laboratories participate in cross-disciplinary work in strategic partnerships projects, commercialization, or transferring appropriate technologies to industry, academia, and other partners.

3.1.1 Partnering of National Laboratories and Other Entities through Research Centers, Hubs, and Institutes

To effectively partner with external entities, the National Laboratories use Research Centers, Hubs, and Institutes such as:

Bioenergy Research Centers (BRCs): BRCs are accelerating the transformational scientific breakthroughs necessary for cost-effective production of biofuels and bioenergy, including cellulosic ethanol. These centers bring together researchers from National Laboratories, industry, and academia to conduct comprehensive, multidisciplinary research into microbes and plants in an effort to develop innovative biotechnology solutions for energy production.

DOE Innovation Hubs: First established in 2010 and modeled on the proactive approach to science management exemplified by the Manhattan Project and AT&T's legendary Bell Laboratories, the DOE Energy Innovation Hubs are integrated, multidisciplinary research centers that combine basic and applied research with engineering to accelerate scientific discovery and address critical energy issues. The act of bringing together top talent across the full spectrum of R&D performers, including universities, private industry, nonprofits, and National Laboratories, is intended to enable each Hub to function as a world-leading R&D center in its topical area. The mission of these Hubs is to advance promising areas of energy science and engineering from the earliest stages of research to the point of commercialization.

DOE's Four Innovation Hubs:

• Critical Materials Institute: Developing solutions for rare earth elements and other materials critical to a growing number of energy technologies.

• Joint Center for Artificial Photosynthesis: Conducting advanced research to produce fuels directly from sunlight.

• Joint Center for Energy Storage Research (JCESR): Establishing a science-based underpinning for future battery technologies for transportation and the grid.

• National Alliance for Water Innovation (NAWI): Conducting research on desalination and associated water-treatment technologies to secure affordable and energy-efficient water supplies from nontraditional water sources.

Energy Frontier Research Centers (EFRCs): The EFRC program brings together researchers from multiple disciplines and institutions, including universities, National Laboratories, industry, and nonprofit organizations. The program combines them into synergistic, highly productive teams to address fundamental science questions that must be solved in order to remove roadblocks to transformational energy technologies. Their "use-inspired" discovery science is motivated by the need to solve a specific problem, such as energy storage, photoconversion, or cost-effective techniques for carbon dioxide sequestration.

Manufacturing Innovation Institutes (MIIs): The MIIs include 14 public-private partnerships established between DOE and other federal agencies as part of the National Network for Manufacturing Innovation (NNMI). NNMI brings together industry, academia, National Laboratories, and state and local economic and workforce development stakeholders to revitalize America's manufacturing industry. This network of regional "ecosystems" combines public and private resources to: develop advanced technologies that help U.S. manufacturers achieve a competitive advantage in global markets, attract private industry to site future manufacturing facilities in the U.S. and create a talent pipeline needed to support the growth of U.S. manufacturing. DOE and the National Laboratories have collaborated with the MIIs by partnering as members of the R&D network within MIIs as well as establishing four MIIs to support advanced manufacturing and other initiatives.

3.1.2 Partnering with Academia

The National Laboratories engage in important partnerships with universities through avenues such as personnel exchanges, research collaborations at the individual investigator level, joint research programs established to develop and take advantage of DOE User Facilities, and strategic institutes that focus on new areas of scientific endeavor. Collaborating with National Laboratories provides universities with the ability to conduct science that requires:

• Large, complex facilities and teams trained in their safe and effective operation, such as the Advanced Photon Source at ANL, the Relativistic Heavy-Ion Collider at BNL, the Spallation Neutron Source at ORNL, and a dozen other facilities;

• Substantial engineering and instrument development, such as the Environmental Molecular Sciences Laboratory at Pacific Northwest National Laboratory (PNNL); or

• Specialized facilities that are challenging to maintain, such as the Combustion Research Facility at SNL.

These collaborations provide opportunities for interdisciplinary research, professional development, and training to achieve goals that benefit the Nation. Indeed, every year over 2,000 graduate students make use of Laboratory facilities in order to carry out their research, enabling a pipeline of scientific talent with broad benefit to the Nation's S&T capacity.

The National Laboratories also subcontract with educational institutions. This provides the Laboratories with an additional avenue for education and training, and also represents a substantial flow of DOE resources to the academic research community. The National Laboratories collectively subcontract more than $500 million annually to universities and employ more than 8,500 students, post-doctoral fellows and faculty in a typical year. This subcontracted research is in addition to the more than $900 million that DOE directly provides each year to universities through academic research grants. This demonstrates how tightly interwoven the Laboratories and universities are within the national research ecosystem and how they are building the next generation of a STEM workforce with DOE support.

3.1.3 Partnering among National Laboratories

The National Laboratories maintain a critical role in the energy innovation ecosystem by addressing complex, multidisciplinary problems with long time horizons, using their combination of unique facilities and expertise. Since 2017, DOE has worked to more strategically engage the Laboratory system and its unique resources in focusing on large-scale, impactful initiatives.

In addition to participation in the broader U.S. innovation ecosystem that includes universities, businesses, and Federal R&D partners, the National Laboratories also collaborate with one another, leveraging their various strengths as a cohesive system that flexibly responds to major challenges. Indeed, the National Laboratories increasingly rely on one another's capabilities for the design and construction of state-of-the-art facilities. Three examples of collaboration among the Laboratories are inter-entity work orders (IEWOs), the NLDC, and the Oppenheimer Science and Energy Leadership Program (OSELP).

IEWOs are used for a wide array of collaborations between the Laboratories, including R&D, partnership on scientific construction projects, software development, materials testing and characterization, engineering analysis and design, and project management reviews. They enable the transfer of funds and work scope between Laboratory partners without the need for separate agreements between DOE and each partner Laboratory. In FY 2019, more than $600 million was transferred between the National Laboratories and production facilities through IEWOs.[1]

The NLDC is a self-organized, self-governing body composed of the directors of all 17 Laboratories. The NLDC advances the effectiveness of the Laboratory complex in addressing national needs and provides an interface to DOE on issues and concerns of common interest. The NLDC provides a forum for presenting the Secretary of Energy and DOE senior management with consensus views on matters that affect the Laboratories and their ability to contribute to the DOE mission. In addition, the NLDC has established standing working groups, made up of the most senior operational and scientific leaders at the Laboratories that are a key mechanism for coordinating across the National Laboratory complex on matters ranging from scientific directions to operational issues and requirements. The NLDC and its working groups are a critical resource available to DOE that can help inform strategy and policy.

OSELP is an annual Fellowship program created by DOE and the NLDC to develop and retain emerging laboratory leaders. OSELP Fellows are recommended by a distinguished panel of current and former Laboratory and DOE leaders and ultimately selected by the NLDC. These Fellows are encouraged to explore the complexities, challenges, and opportunities facing the National Laboratory system and DOE. Through site visits and development of strategic think-pieces that are presented annually to the NLDC, the Fellows are immersed in the breadth, diversity, and complexity of the Laboratories, DOE, and their partners. OSELP represents a collective commitment from the Laboratories to cultivate the leaders needed to sustain long-term impacts throughout the complex. In 2020, the NLDC expanded the Oppenheimer program by creating the Oppenheimer Leadership Network, a formal network of OSELP alumni to serve as an intellectual resource to support the current leadership teams in stewarding the Laboratory complex into the future.

3.2 Transferring Technologies to Innovation Partners

DOE and the National Laboratories are focused on the transition of technology, specifically recognizing the multiple, interlinked connections among different stages of research and demonstration that are needed to reach commercial impact. DOE's Office of Technology Transitions (OTT) facilitates these connections by fostering programs and initiatives that guide interactions between DOE, the National Laboratories, and the private sector in collaborative research, strategic partnerships, facilities access, and technology transfer. OTT's mission is to expand the commercial impact of DOE's R&D portfolio to advance U.S. economic, energy, and security interests. It carries out its mission by examining current programs and practices, analyzing areas of need and additional focus, and proposing new programs and mechanisms to enhance the impact of DOE investments. Complementary to OTT, NNSA features the Office of Strategic Partnership Programs, which has a mission to develop and maintain partnerships with both Federal and non-Federal entites to help sustain the Nation's nuclear deterrent and broader national security

[1]The $600 million does not include transactions with NETL or Thomas Jefferson National Accelator Facility (JLab) due to differing accounting

mission. While the office maintains its focus on NNSA National Laboratories, Plants, and Sites, it partners with OTT for agency-wide programs.

3.2.1 Innovation/Entrepreneurial and Laboratory-to-Market Activities

DOE fosters programs and initiatives that guide interactions between the National Laboratories and its technology partners. In recent years, DOE has explored several new avenues to increase the National Laboratories' ability to move technologies from a laboratory setting to the marketplace by equipping each Laboratory and their researchers with the appropriate tools and resources.

For example, many Laboratories have entrepreneurial leave programs for Laboratory staff and researchers who want to pursue joining or starting businesses that will move National Laboratory-developed technologies into the marketplace. These leave programs allow enterprising researchers to test the waters and enable more commercialization pathways through technology transfer, with the potential outcome of leaving the Laboratory for a successful venture or returning to the Laboratory with the rich experience of having participated in a start-up or tech venture.

Another example is the Lab-Embedded Entrepreneurship Program (LEEP), which takes top entrepreneurial scientists and engineers and embeds them within U.S. National Laboratories to perform early-stage R&D that may lead to the launch of energy or manufacturing businesses in the future. This dual focus on early-stage R&D and entrepreneurial development provides innovators with the platform they need to take their ideas from the Laboratory and onto the commercialization pathway. Examples of successful LEEP programs include:

Cyclotron Road: Based out of LBNL, this program supports leading entrepreneurial scientists as they advance technology projects with the potential for global impact. For two years, a cohort of entrepreneurial scientists and engineers from around the world are embedded in the Berkeley research ecosystem, where they are provided with funding, access, training, and mentorship to mature their ideas from concept to first product, positioning them to align with the most suitable commercial path to bring their technology to scale.

Chain Reaction Innovations (CRI): Based out of ANL, this is a two-year program for innovators focusing on energy and science technologies. Program participants receive the financial and technical support needed to perform early-stage R&D that may launch energy or manufacturing businesses in the future. CRI teaches the best and brightest from across the nation the entrepreneurship skills needed to develop transformative cleantech and innovations in advanced manufacturing.

Innovation Crossroads: Based out of ORNL, this two-year program, leverages ORNL's unique scientific resources and capabilities and connects the nation's top innovators with experts, mentors, and networks in technology-related fields to take world-changing ideas from research and development to the marketplace. Participants receive a fellowship that covers living costs and benefits, a travel stipend, a substantial grant to use on collaborative research and development work at ORNL, and comprehensive assistance to build a sustainable business model.

These Laboratory-based programs are crucial in supporting and encouraging innovation throughout the Laboratory system. In addition, there are many other DOE entrepreneurial programs that are worth highlighting, such as:

Energy I-Corps Success:

In the first nine Energy I-Corps cohorts, 101 teams from 11 National Laboratories participated in the program. Initially, $8 million in funds for the program were provided by DOE technology offices, National Laboratories, and industry, and resulted in almost $32 million in follow-on funding for, and six new companies based on, Energy I-Corps technologies. During the cohorts, teams participated in more than 7,000 customer discovery interviews that were conducted with companies such as Hitachi, Lowes, Johns Manville, Lego, Trane, Tesla, GM, Dow Chemical, Yingli, 3M, Whirlpool, GE, Home Depot, ReMax, and Amazon.[2]

Energy I-Corps: This program equips National Laboratory researchers with tools to understand the real-world relevance of their technologies, inform future research initiatives, and identify viable pathways to market for laboratory-developed technologies. The program builds entrepreneurial skills by pairing Laboratory researchers with industry mentors who have substantial expertise in a relevant sector. Each mentorship team participates in an intensive two-month training program that includes lectures,

[2] https://energyicorps.energy.gov/sites/default/files/Nov%202019_BR_Energy%20I-Corps_View%20File.pdf

workshops, and customer discovery interviews to enable the refinement of their unique value proposition. Energy I-Corps has benefited researchers across the entire complex.

Energy I-Corps cohorts met via Teams in 2020, but these enterprising researchers from several labs benefited from industry mentors and business development training.

Energy I-Corps Satellite Programs: These Laboratory-led commercialization training programs equip researchers with the information and skills they need to effectively work with private-sector partners to commercialize DOE-funded technologies. Each participating Laboratory develops a short-course version of the Energy I-Corps program that is customized for their unique needs. This program enables DOE to extend the reach of the Energy I-Corps training platform: While the full Energy I-Corps program serves 20-30 teams per year, more than 200 teams participate in Energy I-Corps Satellite Programs annually, with many continuing to participate in the full Energy I-Corps program or other opportunities offered by OTT.

U.S. Government's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs: In FY 2021, SBIR and STTR partnered with OTT to develop a new commercialization training for DOE SBIR/STTR Phase 1 awardees seeking to maximize the commercial potential of their research. This new training incorporates elements of the Energy I-Corps curriculum with a focus on helping awardees prepare commercialization plans for strong SBIR Phase 2 proposals and beyond. Participants are mentored by veteran program instructors who have broad experience in successfully transitioning SBIR/STTR Phase 1 projects to Phase 2, as well as a practical understanding of the commercialization process such as ecosystem development, go-to-market strategies, market and customer discovery, and resources and partnership opportunities.

FedTech: This private venture program connects entrepreneurs to technologies developed across Federal agencies such as DOE, the Department of Defense (DoD), NASA, the Department of the Interior (DOI), and the Department of Treasury (DOT); universities; corporate R&D arms; and other laboratories. FedTech, with its extensive network of incubators, accelerators, and entrepreneur networks, leads multiple cohorts annually that provide opportunities to pair DOE technologies and inventors with entrepreneur applicants. Through its startup studio and other programs, FedTech employs the "lean" startup business model to position the technology partners to successfully launch a venture around the technology.

Technologist in Residence (TIR) Program: The TIR program is a DOE initiative that strengthens America's competitiveness by streamlining engagement and increasing collaborative early-stage R&D between National Laboratories and industry. The program involves the competitive selection of pairs consisting of a senior technical staff member from a National Laboratory ("lab technologist"), and a senior technical staff member from industry, a consortium of companies, or a state or regional economic development entity ("industry technologist"). These pairs of technologists work together for 18 to 24 months to accomplish several goals:

• Identify the participating company's technical priorities and challenges, and the resources and capabilities across the National Laboratories that may be suitable to address them;

• Propose collaborative R&D efforts to develop science-based solutions to the company's most strategic scientific, technological, and business issues; and

• Establish a general framework agreement and begin developing specific scopes of work for the proposed collaborative R&D efforts. The proposed R&D then takes place outside of the program and does not use TIR Program funds.

TIR Program Success:

To date, DOE has funded 15 TIR pairs involving eight National Laboratories. Industry partners have included Cummins, DuPont, Hewlett-Packard Enterprise, Honeywell UOP, Proctor & Gamble, and others.[3]

Tech-to-Market (T2M): DOE's ARPA-E leads a T2M program that provides resources and guidance to help researchers obtain strategic market insights needed to create innovative and commercially relevant technologies. The program provides support and management to project teams with a goal of better aligning technologies with market needs. It also assists teams in engagements with third-party investors and partners to support technology development toward identified market applications.

3.2.2 Technology Maturation

An enduring challenge for any institution seeking to move technologies from the laboratory to the marketplace is the ability to obtain resources for technology maturation. As the National Laboratories tend to focus on longer-term challenges rather than near-term solutions, many technologies still require investment and development before they can be demonstrated and validated within a particular market application. This dynamic presents risk for industry partners seeking to transfer and commercialize National Laboratory technologies. DOE and the Laboratories have taken significant steps toward addressing this challenge:

Technology Commercialization Fund (TCF): Authorized in the Energy Policy Act of 2005 Sec. 1001(e), the TCF bridges a financial gap to facilitate promising energy technologies developed from DOE investment at the National Laboratories. In FY 2020, the TCF reached $33 million in available funds and supported 82 projects at 11 Laboratories involving dozens of private-sector partners. The TCF supports projects that focus on maturing unlicensed Laboratory-developed technologies identified as having commercial potential and needing additional maturation to attract a private partner. This fund also supports cooperative development projects that focus on a Laboratory-developed technology in collaboration with a private partner for its commercial application.

NNSA Technology Maturation Grants Program: In FY 2020, NNSA initiated the Technology Maturation Grants Program to identify technologies that support the nuclear stockpile and have commercialization value, help mature low Technology Readiness Level (TRL) technologies past the "valley of death," and facilitate technologies' connection to stockpile stewardship. Through a proposal process, the program selects and funds a small number of technologies that clearly demonstrate future benefit to NNSA defense programs and whose commercialization potential has been endorsed by the affiliated National Laboratory's technology transfer office.

Internal Technology Maturation Programs: The majority of National Laboratories operate their own technology maturation programs that use internal resources, typically royalty funds, to advance technologies with commercial potential. Each Laboratory structures its program to fit its particular circumstances, with the ultimate goal of commercializing technology.

3.2.3 Contracting and Liability Reform

The Laboratory Agreement Processing Reform effort streamlines the ability of National Laboratory contractors to enter into certain partnership agreements within a DOE-approved portfolio of routine work through the use of a Master Scope of Work (MSW). The MSW process allows the DOE contracting officer for a National Laboratory or DOE Site to approve an MSW needed for routine work with non-federal parties. The contracting officer places the work and funding onto the contract as required for all work at the facility, using standard contracting procedures, but with a significantly shorter processing time. In addition, the Liability Reform effort provides more flexibility for National Laboratories to address indemnity requirements, a common barrier to private-sector interaction, making it easier for National Laboratories to partner with business and industry by tailoring associated risk to the specific circumstances.

3.2.4 Increased Access to the Laboratory System

In recent years, DOE has launched programs that better enable external partners to access the unique capabilities, expertise, and facilities at the National Laboratories, to help the partners overcome immediate technical challenges within the innovation ecosystem, establish new technology-based offerings, address

[3] *https://www.energy.gov/eere/amo/technologist-residence-program*

national security concerns, and create long-term opportunities.

Innovation X-Lab Summits: Through OTT, DOE sponsors events that facilitate the exchange of information and ideas among industry, universities, manufacturers, investors, end-use customers, and innovators and experts from the National Laboratories and broader DOE R&D complex. The goals of the events are to:

• Catalyze public-private partnerships and commercial handoffs using DOE's extensive assets: technology, intellectual property, facilities, and world-leading scientists and researchers;

• Engage the private sector to ensure DOE understands industry's technical needs, risk appetite, and investment criteria, thereby incorporating "market pull" into DOE's portfolio planning; and

• Inform DOE R&D planning to increase commercialization possibilities.

These events highlight promising technologies from across the Laboratory complex and facilitate connections and commercialization opportunities at the decision-maker level. In preparation for the Summits, OTT creates topic-specific communication materials[4] to better inform potential collaborators and investors of the National Laboratories' capabilities, expertise, and prior accomplishments. This includes success stories and other resources that highlight significant public-private engagements, DOE programs, and funding opportunities designed to keep the United States at the forefront of rapidly developing technology areas.

Focus of Successful X-Lab Summits from 2018-2020:

• CarbonX Summit (October 2020, hosted by NETL): Technologies and capabilities that are transforming the domestic energy economy by enabling value-added products, environmentally conscious storage, and economical carbon dioxide capture.

• Quantum Information Science & Technology Summit (October 2020, hosted by BNL): Accelerating quantum advancements that impact the nation and world.

• Biomanufacturing Summit (January 2020, hosted by LBNL): Synthetic biology, bioenergy, bioplastics, foods, agriculture, bio-based therapeutics, and similar topics.

• Artificial Intelligence Summit (October 2019, hosted by ANL): Using advanced AI tools and techniques to support business transformation and drive economic growth.

• Advanced Manufacturing Summit (May 2019, hosted by ORNL): Exploring new solutions to manufacturing challenges and opportunities.

• Grid Modernization Summit (January 2019, hosted by PNNL): How the latest technologies can address the biggest challenges of grid modernization.

• Energy Storage Summit (September 2018, hosted by SLAC): How energy storage can unlock the potential of next generation transportation and electric grid technologies.

DOE Leadership at Innovation Lab summits, which facilitate a two-way exchange of information and ideas between industry, universities, manufacturers, investors, and end-use customers with innovators and experts from across the National Labs and broader DOE R&D complex.

DOE National Lab Days: These events are hosted by academia to learn about and explore opportunities for partnerships with the National Laboratory system. They bring together students, researchers from regional industry and small businesses, and National Laboratory scientists and leaders. National Lab Days showcase the work of the Laboratories and enable the community to learn about the facilities and expertise available to support research, technology development, and education and discover how to engage with the Laboratories. Past events have been hosted by University of Alaska Fairbanks, University of Toledo, and Montana Technological University. The University of New Hampshire pivoted to a virtual format in the fall of 2020 by hosting a series of webinars on specific topics such as transformative manufacturing and career-building opportunities at the National Laboratories with additional webinars continuing in 2021.

Lab Partnering Service (LPS): This is an online, single-access-point platform that investors, innovators, and institutions can use to obtain information from the

[4]*https://www.energy.gov/technologytransitions/resources/success-stories-technology-spotlights*

National Laboratories about their myriad capabilities. It enables fast discovery of expertise, technologies, and facilities, and it serves as a conduit between investor and innovators by providing multi-faceted search capabilities across numerous disciplines at the Laboratories. Its functions include an expert search, technical summaries, facility locator, visual patent search, and developer application programming interface. The LPS helps companies decide where to partner or invest by helping them identify experts in their fields of interest and providing a searchable database of National Laboratory technologies that are available for licensing.

DOE National Laboratories Partner with ExxonMobil for $100 Million in Joint Research:

In 2019, a major 10-year technology transfer agreement valued at $100 million was executed between DOE's National Renewable Enery Laboratory (NREL), NETL, and ExxonMobil. ExxonMobil's investment in the Laboratories provided the ability to study advancement in lower-emissions energy technologies that could be brought to commercial scale. This agreement is one of the largest public-private partnerships between DOE laboratories and the private sector, and exemplifies DOE's commitment to cross-cutting, result-driven research initiatives.

This successful agreement was a direct result of the TriLab conference, which was organized by the Deputy Secretary in July 2018 to bring together leadership and technical experts from DOE's program offices, and applied energy Laboratories. Speakers and participants also included private sector participants, including ExxonMobil.

The TriLab conference discussed R&D challenges and opportunities for the applied laboratories to work together in order to advance the nation's energy system; to achieve a resilient, reliable, affordable, and technically leading energy system to serve the Nation for the next century.

Solutions Exchange Program: DOE's OTT launched the Solutions Exchange Program pilot to help U.S. businesses solve scientific challenges. Within the pilot program, businesses share specific technical challenges and partnership interests with OTT, which are discreetly communicated across the National Laboratory network to identify potential solutions.

3.2.5 Fostering Multi-Laboratory Technology Transfer Programs

Beyond R&D collaborations among multiple National Laboratories, DOE has created opportunities to streamline the lab-to-market process by promoting cooperation among the Laboratories' technology transfer organizations to leverage their collective strengths. One such opportunity is the Practices to Accelerate the Commercialization of Technologies (PACT) program, which promotes the transition of research developed at the Laboratories toward the marketplace.

The most-recent PACT solicitation sought projects designed to develop new ways to increase technology commercialization by reducing barriers to accessing the National Laboratories' capabilities, lowering transaction costs, and improving the complex's ability to serve the private sector effectively. The selected projects engage all 17 National Laboratories, one NNSA Plant and 23 other partners. A few examples of these efforts include the Accelerating Commercialization by Connecting Laboratory Inventions to Maturation (ACCLAIM) project, Cybersecurity Technology Concentration and Commercialization project, the Diversity and Inclusion in InVentorship and EntrepReneurship Strategies and Engagement – Women (DIVERSE-W), the CMI-developed technologies project, and the Technology Transfer Researcher Liaison Program.

3.3 International Partnerships and Engagements

Scientific output continues to expand internationally, and many of the challenges that DOE researchers are working to overcome are global in scale. In an increasingly interconnected world, technological advancements and shifting policies can have profound impacts on global energy systems and other critical (and sometimes shared) systems. DOE and the National Laboratories are also mindful of the need to protect critical emerging technologies, and are implementing measures to do so. The National Laboratories also recognize the tremendous benefits to the U.S. from active engagement in international collaborations and are working with DOE and other agencies to ensure the proper balance.

DOE has longstanding cooperative agreements, such as CRADA and ACT, with international partners in all mission areas and continues to establish new international collaborations in a strategic manner to achieve R&D goals, while protecting the Nation's competitive position and national security in areas of advanced innovation. Examples of international partnerships include the following:

• In 2016, DOE and FNAL developed an international CRADA, I-CRADA, as a first-of-a-kind agreement between a National Laboratory and a scientific research organization of another nation. The agreement was first implemented for a partnership between FNAL and the Australian Research Council's Centre of Excellence for Particle Physics at the Terascale (CoEPP), which focused on the mutual exchange of expertise in particle physics. The agreement included cooperation in theoretical particle physics, accelerator physics, computing, and experimental areas such as neutrino physics.

• One of LLNL's largest technology transfer projects was completed under an ACT with the Czech Republic, in which LLNL completed the design, development, and construction of an advanced petawatt (quadrillion-watt) laser system for the European Union's Extreme Light Infrastructure Beamlines facility. The laser system, known as L3-HAPLS, went into operation in 2018.

Types of Partnership Agreement Mechanisms:

• CRADAs: A CRADA is a legal agreement that allows collaborative R&D work between the Federal government, its laboratories, and nonfederal partners to optimize resources, share technical expertise in a protected environment, access intellectual property emerging from the effort, and advance the commercialization of federally developed technologies. The participants collaborate by providing personnel, services, facilities, or equipment and pool the results from a particular R&D program.

• SPPs: SPPs permit DOE Laboratories to conduct work for other Federal agencies and nonfederal entities on a 100% cost-reimbursable basis. This work uses Laboratory personnel and/or facilities; pertains to the mission of the Laboratory; does not conflict or interfere with the achievement of DOE program objectives; does not place the Laboratory in direct competition with the domestic private sector; and does not create a potential future burden on DOE resources.

• Agreement for Commercializing Technology (ACT): This is a contract that a DOE M&O contractor negotiates and enters into directly with partners. ACT contracts allow research and technology transfer projects with more-flexible intellectual property arrangements and other terms and conditions used more traditionally in industry agreements, including fixed pricing, advance payments, and performance guarantees.

• SBIR and STTR: These are two U.S. Government programs where DOE programs can set aside a fraction of their funding to be competitively awarded to small businesses to perform R&D projects. The small businesses are encouraged to commercialize the technology, and they retain the rights to technology that they develop.

• Technology Licensing Agreements (TLAs): These agreements provide commercialization rights to patented and/or copyrighted intellectual property (IP) developed at the National Laboratories, which is normally held and licensed by the M&O contractor. Because of the laws and policies governing the licensing of federally funded research and DOE policies regarding IP, TLAs may include provisions such as march-in-rights, government use rights, and indemnification provisions.

• Technical Assistance Agreements (TAAs): These agreements allow Laboratory scientists and engineers to help members of the small business community solve important challenges at no or reduced cost to the small business.

• Material Transfer Agreements (MTAs): MTAs protect biological materials and tangible research products provided to or by the Laboratory from further transmittal. The agreement normally requires return or destruction of materials and products at the end of the agreement.

• User Agreements: These specialized, standard agreements expedite access to DOE scientific user facilities. DOE operates scientific and engineering User Facilities integral to the mission of the DOE and the host laboratory. Each User Facility manages its allocation of facility resources, typically granting access to funds through merit review of submitted research proposals. Prospective nonproprietary users may propose independent or collaborative research. Access to User Facilities is also available on a full-cost-recovery basis for proprietary research that is not intended for publication.

Adapted from Annual Report on the State of the DOE National Laboratories, U.S. Department of Energy, 2017, p. 157-158, January 2017.

- The H2@Scale initiative, led by DOE's EERE, brings together stakeholders to advance affordable hydrogen production, transport, storage, and use while increasing revenue opportunities in multiple energy sectors. It includes DOE-funded projects at National Laboratories and in collaboration with industry to accelerate hydrogen research, development, and demonstration activities. Several CRADAs with international partners have been executed under H2@Scale, including agreements with Air Liquide (France), Chiyoda Corporation (Japan), Honda (Japan), and Tatsuno Corporation (Japan).[5]

- In 2019, Carl Zeiss Industrial Metrology (part of Carl Zeiss AG of Germany) and ORNL executed a CRADA to gain a deeper understanding of additive manufacturing (AM) processes and materials using ZEISS' 3D ManuFACT solution. The partners are developing and implementing a comprehensive powder-to-part characterization methodology for the progression of AM at DOE's Manufacturing Demonstration Facility at ORNL. Fast recipe development combined with improved mass production yield and methodology for quality certification of AM parts will also be defined and demonstrated.[6]

- In January 2020, ORNL executed a $2.7 million CRADA with AddUp (France) to advance laser powder bed fusion technology and develop new materials processes for tooling. The goal is to use additive manufacturing technology to improve fabrication of complex mold and die tooling.[7]

- In December 2018, the DOE established the Federal Oversight Advisory Body (FOAB) and the S&T Risk Matrix outlined under the International Science and Technology Engagement Policy memo. The S&T Risk Matrix highlights critical and emerging research areas and technologies that are expected to contribute to the economic and national security of the United States and mitigate the detrimental exploitation of these research areas and technologies by foreign Countries of Risk, currently defined as China, Iran, North Korea, and Russia. The S&T Risk Matrix identifies research areas and technologies that do not overlap or supersede existing legal controls associated with national security or commercial restrictions.

3.4 How to Work with the National Laboratories

The National Laboratory complex stewards an abundance of DOE resources and provides opportunities to foster partnerships to tackle difficult problems beyond the capabilities of private industry or individual universities. This section outlines the various opportunities to partner with the National Laboratories.

3.4.1 Partnership Agreements

To successfully transition technologies developed by the National Laboratories, DOE encourages and facilitates the use of a variety of partnering mechanisms with nonfederal entities. In recent years, DOE has explored new avenues to streamline partnership mechanisms and increase the impact of technology transfer efforts. For example, the ACT was piloted and ultimately established in 2017 to provide an additional agreement mechanism with unique flexibilities to address barriers, such as performance guarantees and required contract terms that have hindered non-federal access to National Laboratory capabilities. Through ACT, an Management and Operating (M&O) contractor can negotiate and accept financial and performance risks and accept terms and conditions (T&Cs) more consistent with industry risk-sharing practices that are otherwise not permitted under the T&Cs of CRADAs and SPPs. The FedACT Pilot authorizes Laboratories, for a period of three years to use the ACT mechanism, under certain circumstances, to engage partners that plan to use federal funding for work at DOE facilities. This reduces some of the difficulties that SBIR/STTR and other federal grant recipients experience with standard partnering mechanisms.

Table 1 displays the number of active agreements in a given year between 2015 and 2019, with many agreements spanning more than one year. Most notably, in FY 2019, DOE and the National Laboratories managed and executed more than 1,000 CRADAs; 2,248 SPPs involving nonfederal entities (NFEs); and 126 ACTs. Partners contributed about $380 million to R&D efforts via these agreements in FY 2019 and nearly $1.7 billion between FY 2015 and FY 2019. Non-federal SPPs are the most significant component of industrial interactions in terms of number of agreements, with an

[5] *https://www.energy.gov/sites/prod/files/2020/09/f79/h2-at-scale-crada-projects-2020.pdf*

[6] *https://www.prnewswire.com/news-releases/zeiss-and-oak-ridge-national-laboratory-partner-for-advancement-of-powder-bed-additive-manufacturing-300959519.html*

[7] *https://3dprintingindustry.com/news/addup-and-ornl-enter-2-7-million-agreement-to-advance-laser-powder-bed-fusion-technology-166944/*

TABLE 1: CRADAs, SPPs, AND ACTs AT DOE NATIONAL LABS (FY2015-FY2019)

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
CRADAs, total active in the FY	666	739	924	1,011	1,002
CRADA funds in ($ thousands)	$60,497	$60,435	$61,031	$68,102	$62,102
SPPs (non-federal), total active in the FY	2,259	2,234	2,090	2,411	2,248
SPP (non-federal) funds in ($ thousands)	$247,230	$255,443	$204,308	$250,583	$271,545
ACTs, total active in the FY	75	78	101	122	126
ACT funds in ($ thousands)	$30,506	$17,108	$23,754	$38,173	$46,303

average of about 2,250 active agreements annually, and funds, with an average of nearly $245 million annually.

In total, the National Laboratories used these mechanisms to partner with approximately 2,650 industry, academic, and non-profit partners between FY 2015 and FY 2019. Small businesses represented the largest segment of non-federal partnerships, with more than 1,200 different partners entering into agreements with the Laboratories. During the same timeframe, the Laboratories partnered with nearly 300 additional organizations, ranging from state and local governments to other FFRDCs.

User Facility Spotlight: Space Exploration Collaborations:

DOE's User Facilities contribute immensely to science, research, and technology development of mutual interest to DOE, NASA, and other space-program agencies. The National Synchrotron Light Source – II at BNL has performed non-destructive analysis of samples returned from NASA space missions. In addition, the National Energy Research Scientific Computing Center and Oak Ridge Leadership Computing Facility have been used for high-speed processing of data from ground and space-based science missions and for simulations leveraged in planning upcoming missions. DOE's 88-inch cyclotron at LBNL allows researchers to better understand the effects of radiation on materials and electronics. Finally, the Z-Pulsed Power Facility at SNL produces conditions of extreme temperature and pressure, enabling high energy density research in materials, astrophysics, and planetary science.

3.4.1.1 DOE User Facilities

Another measure of the extent to which the National Laboratories partner externally is the use of DOE User Facilities. An important reason for establishing the National Laboratory system was to provide a home for large-scale, costly scientific facilities that universities could not afford but were critical for sustaining America's effort in science. The DOE maintains and operates various User Facilities spanning across each of the energy, science, and national security Laboratories as shared resources for the scientific community, with access determined on a competitive basis using peer review. These facilities include high-performance computers, particle accelerators, large x-ray light sources, neutron scattering sources, specialized facilities for nanoscience and genomics. Additional detail and Laboratory specific missions of the facilities is provided in Appendix A and the strategic planning process for the DOE User Facilities is addressed in Section 4.

User Facility Spotlight: Pharmaceutical Industry:

Pharmaceutical companies have extensively used macromolecular crystallography at the APS to aid in drug design. One example is Januvia®, a type 2 diabetes medication manufactured by Merck & Co. Januvia® helps lower blood sugar levels in adults with type 2 diabetes, and is the top-selling brand in its class. The drug has been approved by the U.S. Food and Drug Administration (FDA) and is one of the most popular type 2 diabetes drugs on the market.

The DOE User Facilities are not only vital tools for scientific discovery but also an important component of national economic competitiveness in a competitive international environment where discovery and innovation are moving faster than ever before. In FY 2019, nearly 35,000 researchers leveraged the User Facilities at the National Laboratories. Although a slight decline from the previous two years, the number of users in FY 2019 still represents a more than 40% increase in users from FY 2015, after which the number of users each year trended upwards. The average number of users annually during FY 2016 – FY 2019 was more than 34,000, as compared to about 26,000 during FY 2012 – FY 2015. Many of these are graduate students carrying out their research to obtain their PhDs.

3.4.2 Intellectual Property

Intellectual property is an important component of the National Laboratory system. In FY 2019, DOE's National Laboratories and associated research facilities disclosed 1,891 new inventions and received 919 U.S. patents.

The data indicates that, in FY 2019, inventions were disclosed at a higher rate than any time in the previous eight years. Going back farther, data indicates that FY 2019 invention disclosures were the highest since at least FY 2008. In addition, copyright assertions have remained fairly consistent in recent years with an average of about 475 annual assertions from FY 2016 to FY 2019. In parallel, the National Laboratories have continually added to the number of open source products (mostly software) available for licensing.

3.4.3 Return on Investment (ROI)

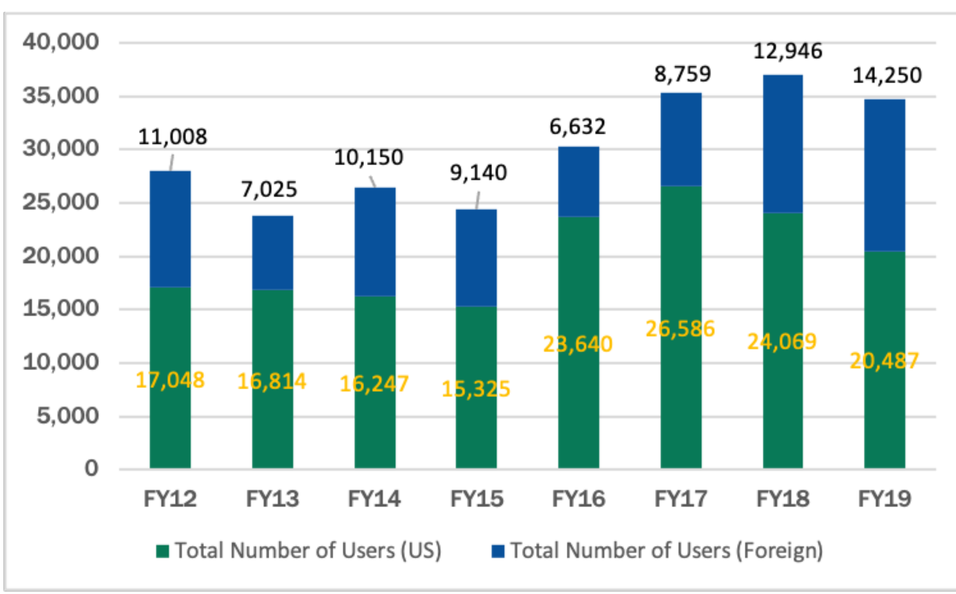
DOE and OTT are focused on expanding the commercial impact of DOE research and accelerating taxpayer ROI. The ability to measure these returns is critical for continuous improvement. National efforts have been undertaken to address the ROI of Federal R&D investments, including the National Institute of Standards and Technology (NIST) "Green Paper" that is part of its ROI initiative in support of the President's Management Agenda. DOE remains responsive to these initiatives at the Department level and has also undertaken internal initiatives to define and implement practices for measuring ROI and responding accordingly. The DOE technology transfer working group's metrics committee established a subcommittee focused on developing an approach to measuring ROI of technology transfer activities at the National Laboratories. The sub-committee is leveraging the OTT data call, DOE literature, benchmarking from the Association of University Technology Managers, and other external literature to develop an approach to measuring ROI.

3.4.4 Awards

3.4.4.1 R&D 100 Awards

The quality and the impact of technologies that reach the commercial sector are important success metrics for DOE's technology development and commercialization efforts. Certain outcomes are tracked by DOE and the National Laboratories to determine impact, but indirect and independent assessments are also needed.

FIGURE 2: TOTAL NUMBER OF USERS AT DOE USER FACILITIES (FY2012-FY2019)

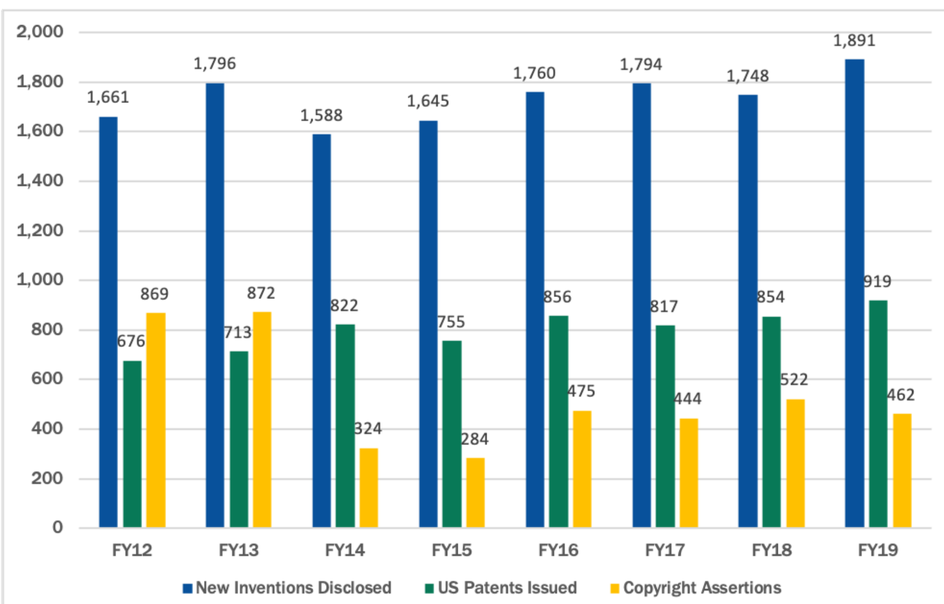


The R&D 100 Awards are widely recognized in industry, government, and academia as a mark of excellence for the most innovative ideas of the year. The awards are the only industry-wide competition rewarding the practical applications of science. They are given annually to recognize exceptional new products or processes that were developed and introduced into the marketplace during the previous year. To be eligible for an award, the technology or process must be in marketable condition and available for purchase or licensing. The awards are selected by an independent panel of judges from industry, government, and academia, based on the technical significance, uniqueness, and usefulness. The DOE National Laboratories are highly successful and receive many R&D 100 Awards annually.

3.4.4.2 Federal Laboratory Consortium (FLC) Excellence in Technology Transfer Awards

FLC was formally chartered by the Federal Technology Transfer Act of 1986 to promote and strengthen technology transfer nationwide. Its members include about 250 Federal laboratories, including the 17 DOE National Laboratories and five DOE production facilities.[8] Each year, FLC presents awards to organizations that serve as conduits for technology transfer and collaborate to develop and commercialize products and processes for commercial use. One of the most prestigious awards in technology transfer is FLC's Excellence in Technology Transfer (ETT) Award. Since the ETT Award program began in 1984, researchers at the National Laboratories have been recognized with awards in the category every year and the National Laboratories' overall share of awards is significant. For example, in 2020, the National Laboratories won 57% of the FLC ETT awards, which was one of DOE's highest years in terms of award percentage.

FIGURE 3: INVENTION DISCLOSURES AND PATENTS: FY2012-FY2019



[8]As required by law, DOE contributes 0.008% of its R&D funding at FFRDCs to support FLC. This funding provides support for FLC- TT's operational costs such as website maintenance, publications, conference and meeting support/management.

4. DOE'S STRATEGY AND THE FUTURE OF THE NATIONAL LABORATORY SYSTEM

DOE conducts strategic planning and provides oversight management to maintain the scientific excellence and lasting impact of the entire enterprise, especially the National Laboratories. DOE has instituted several processes and efforts, described below, that encourage and enhance collaboration and strategic partnerships. These efforts ensure that the DOE and the National Laboratory complex are equipped to face current and future challenges, strive to further scientific discovery, and continue to benefit all Americans.

4.1 Establishment of New Offices for Effectiveness and Coordination

DOE's leadership is responsible for the overall success and stewardship of the Department, especially the National Laboratories. DOE oversees a wide range of critical missions and capabilities, most of which are multi-disciplinary and crosscutting. Since 2017, the Secretary of Energy created new offices and realigned the organizational structure of the Department to foster better collaboration. These newly established offices facilitate complex-wide strategic planning and formulation of partnerships both within and outside of DOE. Figure 4-1 shows DOE's organization as of December 2020.

4.1.1 The Office of Strategic Planning and Policy

OSPP was created in 2020 to coordinate policy formulation across DOE and serve as the principal advisory body for Secretarial policy decisions. The office is made up of senior advisors who are responsible for streamlining the formulation, development, and advancement of Departmental and Secretarial energy policy. The OSPP team has three primary functions in service to the Secretary. First, it shapes long-term strategic planning and policy consistent with the Secretary's vision across DOE and its complex. Second, it leads cross-program coordination groups to address long-standing challenges in critical mission areas. Third, it collaborates with the White House and other agencies to leverage DOE expertise in advancing national priorities. Taken together, these primary responsibilities allow the OSPP team to shape the long-term strategic direction of DOE while providing daily tactical support for the Secretary's decision-making and communications.

Secretarial Cross-Cutting Priorities:

- Nuclear Energy and Security
- Quantum Technologies
- Oil & Gas/Renewable Fuel Standard (RFS)
- Energy Security
- Artificial Intelligence
- Bio-economy/Bio-security
- Advanced Manufacturing
- Critical Minerals/Materials
- Space/National Space Council
- Energy Storage
- Microgrids/Integrated Energy Systems
- Carbon Capture, Utilization, and Storage

4.1.2 The Laboratory Operations Board

In 2020, the LOB was reorganized to report under OSPP to ensure effective coordination between DOE strategic planning and policy decision making and the National Laboratories. The LOB Director reports to the OSPP Executive Director and acts as the OSPP Deputy Director to ensure alignment.

The LOB is a committee composed of senior leaders from DOE Headquarters and the National Laboratory complex whose mission is to strengthen and enhance the partnership between DOE and the National Laboratories. The LOB works to improve management and performance to more effectively and efficiently

FIGURE 4-1: DOE ORGANIZATIONAL CHART

U.S. DEPARTMENT OF ENERGY

execute the collective missions of DOE across the National Laboratory system. The LOB also plays a vital role in strategic planning and operations of the National Laboratories by searching for creative ways to unleash the innovative power of the Laboratories and to attract and retain talent (people), modernize infrastructure (plant), and reduce the burden on how the Laboratories' work (processes). To contribute to an enterprise-wide effort to identify, manage, and resolve strategic issues pertaining to the effectiveness and efficiency of the Laboratories, the LOB Director maintains a close working relationship with the NLDC. This relationship improves visibility and aligns strategic direction between the Laboratory Directors and DOE's most senior leadership.

4.1.3 The Artificial Intelligence and Technology Office (AITO)

The AITO was established in 2019 to elevate, accelerate, and expand DOE's transformative work in AI. Based in the Office of the Under Secretary for Science, AITO coordinates existing AI efforts, facilitates partnerships with external stakeholders in the private sector and with universities and other research institutions, and builds on the efforts to enhance the future of AI.

As the DOE's center for AI, AITO works to accelerate the delivery of AI-enabled capabilities and the Department-wide development of AI, synchronize AI applications to advance DOE's core missions, and expand public and private sector strategic partnerships, all in support of American AI leadership. Since its establishment, AITO has created the AI Exchange (AIX) data base to help capture and align AI projects with DOE and Administration priorities. Currently, DOE and its National Laboratories are leading more than 600 AI projects designed to strengthen core missions in energy, cyber, and national security and to accelerate scientific discovery. In addition, AITO has launched two cross-cutting AI projects, focused on saving lives:

- **First Five**: This consortium is co-chaired by AITO and Microsoft with the mission of providing AI-enabled tools and real-time information to First Responders to help them save lives and protect assets and our nation's resources. The first line of effort in this Humanitarian Aid and Disaster Relief (HADR) space is an AI system that addresses key research areas such as damage assessment, search and rescues, natural disasters, and wildfire prediction and fire line containment.
- **COVID Insights**: This partnership between the Department of Health and Human Services, Department of Veterans Affairs (VA), and DOE consists of an unprecedented framework of policy driven data-sharing that facilitates multimodal research, combining DOE's multi-disciplinary research scientists, advanced technologies, and AI capabilities with the power of Summit, ORNL's supercomputer.

4.1.4 The Arctic Energy Office (AEO)

In 2020, the Secretary of Energy reestablished DOE's AEO, which is headquartered on the campus of the University of Alaska in Fairbanks. The AEO reports to the Under Secretary of Energy and coordinates DOE's Arctic activities across the enterprise, bringing together DOE's wide range of assets, stakeholders, and equities to serve communities and U.S. interests in the Arctic region.

The AEO drives coordination and collaboration on DOE's programs in the Arctic region, including international cooperation on Arctic issues, research on methane hydrates, development of advanced microgrids, and the potential deployment of nuclear power systems such as small modular reactors. The reestablishment of this office strengthens DOE's work in energy, science, and national security in order to build an Arctic future of prosperity and increased opportunity. AEO brings the power of DOE innovation and expertise to the region and will ensure the Department plays an important role in its energy future. As the region's geopolitical importance increases, the AEO will also better facilitate strategic coordination with other Arctic nations.

4.1.5 The Office of Cybersecurity, Energy Security, and Emergency Response (CESER)

CESER was established in 2018 and reports to the Under Secretary of Energy. This office fulfills a dual purpose: first, to work with industry to increase cybersecurity and physical security across multiple energy subsectors and interdependent sectors of critical infrastructure; and second, to coordinate emergency support function response for the energy sector. CESER was created from the Office of Electricity Delivery and Energy Reliability, which is now the Office of Electricity (OE), by divesting two legacy OE divisions (Cybersecurity for Energy Delivery Systems and Infrastructure Security and Energy Restoration).

CESER's mission is to improve the security of the U.S. energy infrastructure against all hazards, through the three office divisions: Cybersecurity; Infrastructure Security & Energy Restoration; and Innovation, Research, & Development. CESER's efforts facilitate better communication and coordinated responses, to better position DOE to protect the Nation's energy infrastructure from emerging threats and natural disasters and support the Department's national security responsibilities.

4.2 Fostering Collaboration through Crosscutting Initiatives and Reports

The Secretary uses advisory councils and coordinating committees to provide input and advise leadership on M&O within the Department. This effort strengthens the effectiveness of the DOE and provides an opportunity for counsel and management review.

4.2.1 The Research and Technology Investment Committee (RTIC)

The RTIC was established in 2019 to convene key DOE elements and leaders to advise and make decisions that support R&D activities, coordinate their strategic research priorities, and identify potential cross-cutting opportunities in both basic and applied S&T. The RTIC has explored many cross-cutting topics, including:

• **Energy Storage**: RTIC established the Energy Storage Subcommittee, which was charged with establishing a comprehensive strategy on energy storage. The subcommittee chairs, EERE and the OE, analyzed and recommended strategies to position the United States as the global leader in energy storage. Through the subcommittee's efforts and approval by the RTIC, DOE then developed the Energy Storage Grand Challenge to accelerate development, commercialization, and use of next-generation energy storage technologies and achieve U.S. global leadership. As a complex-wide comprehensive strategy, the Energy Storage Grand Challenge engages with DOE offices and industry partners to better coordinate in five areas: technology development, technology transition, policy and valuation, manufacturing and supply chain, and workforce development. The subcommittee is currently developing the Energy Storage Grand Challenge roadmap, to ensure U.S. leadership in energy storage use and exports, with a secure domestic manufacturing supply chain that does not depend on foreign sources of critical materials.

• **AI**: In July 2019, the RTIC established the AI subcommittee to assess whether DOE and the AITO are strategically positioned to drive U.S. global leadership in AI. Led by the AITO and other relevant program offices, the subcommittee provided observations and recommendations to the RTIC, to further the missions of the DOE and AITO. These included the use of an automated system to track and collaborate on DOE AI activities, the development of a Departmental strategy for coordinating AI, and the prioritization of jointly funding AI partnerships within DOE and with industry.

• **Critical Materials**: In November 2019, the RTIC established the Critical Materials subcommittee to assess DOE's critical material needs and cross-cutting strategies. The subcommittee, chaired by EERE, FE, and NNSA, recommended the establishment of a council to assess and coordinate DOE's critical material requirements and the development of an action plan to address DOE's long-term critical materials challenges. OSPP is chairing a multi-program coordination committee to directly support the work of the council, which is overseeing the development of a DOE-wide critical minerals and materials strategy and action plan.

• **STEM**: Established by the RTIC in April 2020, a STEM working group was created after an initial DOE STEM workshop that assessed duplicative STEM efforts at DOE and the National Laboratories. A clear outcome from the workshop was recognition of the need to better coordinate STEM goals and efforts across the complex. The working group developed a DOE STEM framework and is conducting a landscape analysis of all DOE STEM activities. The working group then will develop an action plan to implement the recommendations.

4.2.2 The Secretary of Energy Advisory Board (SEAB)

The SEAB provides the Secretary with timely, balanced, external advice on issues concerning the entire DOE and Laboratory complex. Composed of technical experts, business executives, academics, and former government officials, SEAB provides recommendations to the Secretary on DOE's basic and applied R&D development activities, economic and national security policy, educational issues, operational issues, and any other matters charged by the Secretary. Most recently, four SEAB working groups were established to provide recommendations on the maximization of AI and machine learning to support DOE's mission, promoting innovation in DOE policies and practices, optimizing DOE efforts to support space exploration, and elevating the profile of DOE's vital missions through improved branding. Since all of these topics are cross-cutting and overlap throughout the Department, the SEAB advises on how to best coordinate efforts and maximize efficiency.

4.2.3 OSPP

As previously described, OSPP guides the coordination and implementation of DOE-wide cross-cutting strategy and policy. To minimize duplication of effort, OSPP frequently adopts and executes the recommendations of RTIC and SEAB working groups. Through its senior advisors, OSPP establishes, maintains, and chairs continuing DOE-wide coordination groups for the development and implementation of strategies. Three key examples of these efforts include the following:

• Establishment of a DOE and an interagency implementation plan for the Strategy to Restore American Nuclear Energy Leadership, the DOE-published interagency strategy based upon the President's Nuclear Fuel Working Group of 2019-2020;

• Drafting and coordination of a critical minerals and critical materials strategy, as recommended by the relevant RTIC working group; and

• Establishment of a DOE space strategy, the Energy for Space Exploration: U.S. Department of Energy Strategy to Support U.S. Space Preeminence that directly supports the recent National Space Strategy and is coordinated with other agencies to support long-term national space goals.

4.3 Executing the Strategic Planning Process

The strategic planning process is crucial to successfully funding and operating the DOE complex, especially the National Laboratories. This process is important in funding decisions and the budget process between DOE programs and the Laboratories. Flow of funding from DOE program offices to each of the 17 National Laboratories can be found on individual National Laboratory At a Glance pages.

Each Laboratory's involvement in strategic decisions and planning is key when determining technical and policy areas for each mission. The National Laboratories have an opportunity to present their strategic plans and feedback through the annual strategic planning process, described below.

4.3.1 DOE's Federal Advisory Committees

In accordance with the Federal Advisory Committee Act of 1972, Advisory Committees are utilized by the DOE to provide independent advice and guidance on a variety of complex scientific and technical issues. The DOE provides management support to more than 22 Federal Advisory Committees, involving over 900 members, whose recommendations are used to inform research program directions and investments. These Committees play a paramount role in strategic planning for entire fields of science by utilizing established processes for collecting independent input from the entire scientific community to formulate long-range plans for DOE programs.

4.3.2 Strategic Management of Science, Energy, and NNSA Laboratories

The long-term vision and success of the DOE National Laboratories is a shared responsibility between DOE headquarters and the National Laboratory directors and senior leaders. To effectively manage and operate the Laboratory complex, the DOE program offices and National Laboratories must maintain a mutual understanding of the DOE and Administration evolving vision, long-term priorities, and operational goals. DOE and the Laboratories must work together, as a whole, to address the evolution of Laboratory capabilities, needs, and mission priorities.

To support and facilitate strategic development, DOE formulates and issues annual planning guidance for the energy, science, and NNSA National Laboratories. The guidance may include particular topic areas that DOE asks the Laboratories to address in their plans, and typically requests the following information:

- A top-level summary of the Laboratory's mission;
- An outline of major funding sources and overall costs of operation;
- An overview of the Laboratory's current core capabilities;
- In-depth discussion about the Laboratory's S&T strategy for the future;
- The strategy and vision for technology transfer activities and strategic partnerships;
- An overview of site facilities and campus strategy for infrastructure;
- Relevant information on the current human capital situation and obstacles with respect to developing mission-ready workforce; and
- The strategy and approach used for cost management at the Laboratory.

Each National Laboratory then produces a strategic plan that is presented to and reviewed by respective DOE leadership. The science and energy National Laboratories present their strategic plans in June and July of each year, and the NNSA National Laboratories, Plants, and Sites present their strategic plans every April.

NNSA uses a tiered approach to strategic planning. NNSA-level strategic planning documents specify strategic goals and objectives and set NNSA-specific expectations for program execution. Most recently, these laboratory-level strategic plans included an emphasis on anticipated challenges, areas of effort, and the state of health for each Laboratory, Plant, and Site over the near-term (five year), mid-term (10 year), and long-term (25 year) planning horizon.

While the planning processes may differ slightly, each Laboratory's strategic planning process is essential to addressing and coordinating key priorities and research goals. Each year, the planning process is evaluated and additional mechanisms are implemented to improve the process and coordination across the Department.

The National Synchrotron Light Source II at Brookhaven National Lab. Nations with the fastest supercomputers and most advanced light sources will have a distinct advantage in the race for discovery and innovation.

The current DOE leadership has taken steps to strengthen the National Laboratory system by allowing all Laboratories and DOE program offices to participate in each of the science and energy Laboratory reviews. In addition, NNSA has also allowed leadership from headquarters, field offices, program offices and the NNSA Laboratories, Plants, and Sites to participate in the strategic planning briefs. This important step increases the transparency across the complex and encourages the Laboratories to receive DOE and Laboratory-wide feedback. The strategic planning process provides an opportunity for the program offices to become more engaged with Laboratories across the entire enterprise. During the annual Laboratory planning presentations, DOE participants are able to provide critical verbal feedback to each Laboratory and have an opportunity to ask questions. After the briefings, written feedback is also provided to each Laboratory for review and consideration. Once there is agreement on a path forward for the Laboratory, DOE is able to use the input to inform the budget process and planning.

Throughout the annual Laboratory planning process, DOE engages and coordinates with appropriate program stakeholders across the complex. The primary importance of this annual exercise is to develop a shared understanding of the future direction of the National Laboratories and how each Laboratory will contribute to DOE's current and future mission needs by both senior Laboratory and DOE leadership.

4.3.3 Strategic Planning Process for User Facilities

As described in Section 3, DOE operates national scientific User Facilities that provide thousands of researchers with the most advanced tools of modern science and are an important component of national economic competitiveness. Today the international competition is fierce to develop and deploy the most advanced scientific facilities. Nations with the fastest supercomputers and most advanced light sources, for example, will have a distinct advantage in the race for discovery and innovation across a broad range of fields, from physics, materials science, chemistry, and genomics to medicine.

While each DOE User Facility exists through investment by a program sponsor, the DOE provides funds through congressional appropriations for construction and operations. The decision to invest in a User Facility is a complex one that requires input from the scientific community. DOE works extensively with outside partners in industry, academia, and other organizations when planning to construct the next generation of User Facilities. The decision ultimately emerges through long-term strategic planning that engages the scientific community (see 4.3.1) to help identify research tools that will deliver the greatest scientific impact to advance the DOE mission. Each User Facility represents a substantial commitment on the part of its sponsoring program, which provides oversight and works closely with the facility management to maximize scientific impact and productivity.

4.4 Envisioning and Building Toward the Future of DOE

DOE recognizes the value of advancing the mission and working to build future opportunities. A successful strategic plan and management of the complex includes efforts that look toward a bright future for the Department. As pioneers of scientific innovation that reshapes our lives, America's National Laboratories have always been focused on the future.

In addition, a major focus is addressing today's nuclear security challenges, as well as those that our nation will confront in the future. To that end, DOE is committed to recruiting, training and retaining the next generation of world-class scientists, engineers, and technicians, as well as taking proactive steps to ensure that the NNSA infrastructure is modern, robust, resilient, and able to meet our nation's nuclear security mission today, and into the future.

Acting as a central part of an ecosystem of discovery that also includes universities and industrial companies, the National Laboratories create breakthroughs that require strategic long-term planning that aligns missions, capabilities, and societal need.

4.4.1 NLDC "Future S&T Opportunities"

To deliver on the promise of public investment in R&D that promotes U.S. prosperity and security, in 2020 the NLDC analyzed and identified key opportunities that could make our society healthier, wealthier, and more secure. Through a forward-looking (20- to 30-year horizon) strategic planning effort, the NLDC laid out five key paths forward for further inquiry and innovation, which include the future of five broad fields of endeavor:

- Biotechnology and the future bioeconomy
- Accelerator science, technology, and engineering
- Deterrence
- Computing
- Energy systems

As a whole, these mission areas represent the broad purview of research at America's National Laboratories as well as describe their global impact. The three broad S&T platforms—biotechnology, computing, and accelerators—help drive discoveries in the crosscutting themes of deterrence and energy systems.

Through a history of prioritizing the formation of tightly focused, well-coordinated and fully supported teams that can communicate across disciplines, the National Laboratories, in support of DOE's mission, engage with leaders in both the public and private sector, which allows for further development of their ideas and implementation of a robust R&D agenda over the coming decades focused on significant global and national challenges.

4.4.2 Looking to the Future: DOE's SC "Laboratories of the Future"

The Laboratories of the Future initiative was created to consider future possibilities without being concerned about limitations or constraints presented by the current Laboratory structure or legal environment. This initiative is asking a set of questions of former and current DOE and Laboratory leaders, early and mid-career researchers at the Laboratories, and external stakeholders including university researchers and leaders, scientific professional societies, industrial partners, and international partners. Participants provide DOE answers to these questions on an individual basis, and do not work together to reach a consensus.

The core question being asked is, "What would the DOE National Laboratories be like if we had the power to make them any way we wanted?" Embedded in that question are inquires such as "What makes the DOE National Laboratories so special? What has allowed them year after year to produce the groundbreaking research for which they are so well respected?"

Although this project is in its initial stages and ongoing, several themes have already started to emerge. The Laboratories of the Future initiative not only gives the current DOE and Laboratory employees an opportunity to provide anonymous feedback, but it also strives to enhance the workplace for future generations of employees all across the complex.

4.4.3 Developing the Future Workforce

Developing the Nation's current and future workforce is key to the Department's success. DOE is actively working to retain and grow the current workforce through several projects and initiatives. In addition, training the next generation of STEM employees is important when preparing for the future. DOE and the National Laboratories have a variety of on-going workforce and STEM education development efforts to engage K-12, undergraduate, and graduate students in order to develop a pipeline of future employees. A few specific efforts are described below.

4.4.3.1 LOB's Efforts to Identify Policy Implementations to Enhance the Workforce

The LOB has formed several working groups to identify opportunities to enhance DOE's workforce development efforts, recommend possible policy changes, and work toward implementation. Specifically, the LOB explored ways to enhance the innovation culture and collaboration through physical and virtual structures. An example includes enhancing and leveraging virtual platforms that enable the connection of the community and the DOE complex, such as the OTT LPS.

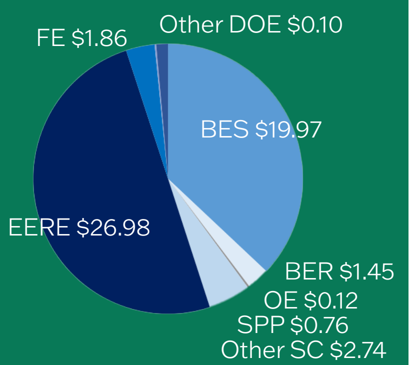
The LOB also explored ways to retain, grow, and inspire the top talent at the DOE. The recommendations were based on ways to invest in the people and enhance the workforce development efforts. The recommendations focused on sharing best attraction and retainment practices, developing leadership, especially early-career individuals, and recognizing and rewarding top talent.

AT A GLANCE: AMES LABORATORY

Ames Laboratory delivers critical-materials solutions to the United States. For more than 73 years, Ames has successfully partnered with Iowa State University of Science and Technology to lead in the discovery, synthesis, analysis, and use of new materials, novel chemistries, and transformational analytical tools. Building upon its core strengths in the science of interfaces, science of synthesis, science of quantum materials, and science of rare earths—plus a proven track record of transitioning basic energy science through early-stage research to licensed technologies and commercialization—Ames leads the nation in translating foundational science for energy and chemical conversion into critical-technology innovation.

FUNDING BY SOURCE

FY 2019 Costs (in $M)
Total Laboratory Operating Costs: $53.99
DOE/NNSA Costs: $53.23
SPP (Non-DOE/Non-DHS) Costs: $0.76
SPP as % of Total Laboratory Operating Costs: 1.4%
DHS Costs: $0.0



FACTS

Location: Ames, Iowa
Type: Single-program Laboratory
Contractor: Iowa State University of Science and Technology
Site Office: Ames Site Office
Website: ameslab.gov

PHYSICAL ASSETS

10 acres and 13 buildings
340,968 gross square feet (GSF) in buildings
Replacement Plant Value: $105M
0 GSF in 0 Excess Facilities
0 GSF in 0 Leased Facilities

HUMAN CAPITAL

300 full-time equivalent (FTE) employees
47 joint faculty
38 postdoctoral researchers
88 undergraduate students
98 graduate students
104 visiting scientists

CORE CAPABILITIES

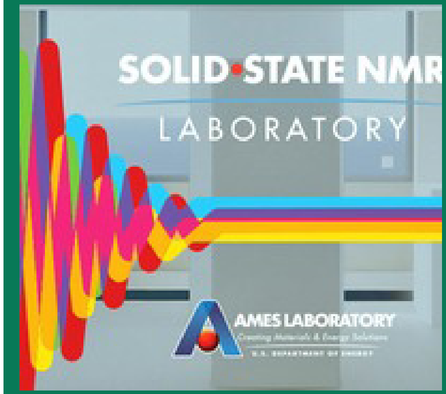
Applied Materials Science and Engineering
Chemical and Molecular Science
Condensed Matter Physics and Materials Science

MISSION UNIQUE FACILITIES

Critical Materials Intitute
Materials Preparation Center
Sensitive Instrument Facility
Powder Synthesis and Development
Dynamic Nuclear Polarization and Nuclear Magnetic Resonance (NMR)
Institute for the Cooperative Upcycling of Plastics (iCOUP)
Center for the Advancement of Topological Semi-metals (CATS)

AT A GLANCE: AMES LABORATORY

ACCOMPLISHMENTS



Unique Facility: Solid-State NMR Laboratory In FY 2020, Ames Laboratory cut the ribbon on a newly remodeled and expanded space to house its state-of-the-art NMR capabilities. Among the instruments is the dynamic nuclear polarization (DNP) solid-state NMR spectrometer endowed with fast magic angle spinning capabilities – the first instrument of its kind in the United States dedicated exclusively to chemical and materials sciences. Conventional and DNP-enhanced solid-state NMR spectroscopy are used in multiple Ames research projects that develop heterogeneous catalysts, semiconductor nanomaterials, polymer recycling strategies, and address other energy-related challenges.

Tech-to-Market Highlight: Recycling Rare Earth Metals from Electronic Waste TdVib, LLC, an Iowa manufacturing company, was awarded a Department of Energy Phase I Small Business Technology Transfer (STTR) grant for $200,000 from the Office of Energy Efficiency and Renewable Energy (EERE) in 2020. The funding supports a goal to demonstrate the feasibility and proof-of-concept for commercially viable and environment-friendly approaches to reclaiming rare earth elements and cobalt from magnets in electronic waste generated in the United States. This Research and Development (R&D) 100 award-winning technology was developed and patented at the Critical Materials Institute; an Energy Innovation Hub led by Ames Laboratory.

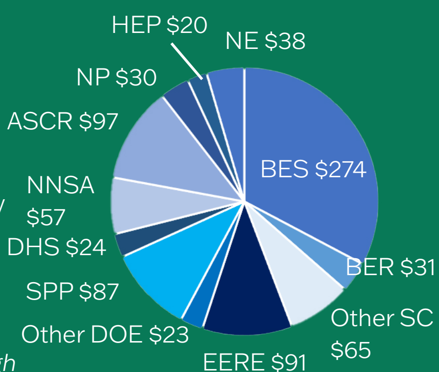
Research Highlight: iCOUP Plastic waste is everywhere in the United States, rapidly piling up in our landfills and leaching into and clogging our waterways. The nearly 27 million tons of plastic waste generated annually in the U.S are full of energy and carbon value, which is currently lost. Ames Laboratory is leading the multi-institutional Energy Research Frontier Center, which is developing methods to selectively "chop" long polymer chains into smaller pieces that will transform them into upcycled products—providing new raw materials for the chemical industry to manufacture useful chemicals, such as lubricants, detergents, and fuels.

AT A GLANCE: ARGONNE NATIONAL LABORATORY

Argonne National Laboratory accelerates science and technology (S&T) to drive U.S. prosperity and security. The laboratory is recognized for seminal discoveries in fundamental science, innovations in energy technologies, leadership in scientific computing and analysis, and excellence in stewardship of national scientific user facilities. Argonne's basic research drives advances in materials science, chemistry, physics, biology, and environmental science. In applied science and engineering, the laboratory overcomes critical technological challenges in energy and national security. The laboratory's user facilities propel breakthroughs in fields ranging from supercomputing and AI applications for science, to materials characterization and nuclear physics, and climate science. The laboratory also leads nationwide collaborations spanning the research spectrum from discovery to application, including the Q-NEXT quantum information science center, Joint Center for Energy Storage Research, and ReCell advanced battery recycling center. To take laboratory discoveries to market, Argonne collaborates actively with regional universities and companies and expands the impact of its research through innovative partnerships.

FUNDING BY SOURCE

FY 2019 Costs (in $M)
Total Laboratory Operating Costs: $837*
DOE/NNSA Costs: $727
SPP (Non-DOE/Non-DHS) Costs: $87
SPP as % of Total Laboratory Operating Costs: 13%
DHS Costs: $24
**Excludes expenditures of monies received from other DOE contractors and through joint appointments of research staff.*



FACTS

Location: Lemont, Illinois, near Chicago
Type: Multiprogram Laboratory
Contractor:UChicago Argonne, LLC
Site Office: Argonne Site Office
Website: anl.gov

PHYSICAL ASSETS

1,517 acres
156 buildings
$3.9 billion replacement plant value
5.1 million GSF in buildings
0.3 million GSF in leased facilities
0.02 million GSF in 16 exess facilities

HUMAN CAPITAL

3,448 FTE employees
379 joint faculty
317 postdoctoral researchers
297 undergraduate students
224 graduate students
8,035 facility users
809 visiting scientists

CORE CAPABILITIES

Accelerator S&T
Advanced Computer Science, Visualization, and Data
Applied Materials Science and Engineering
Applied Mathematics
Biological and Bioprocess Engineering
Chemical and Molecular Science
Chemical Engineering
Climate Change Science and Atmospheric Science
Computational Science
Condensed Matter Physics and Materials Science
Cyber and Information Sciences
Decision Science and Analysis
Large-Scale User Facilities/Advanced Instrumentation
Nuclear Engineering
Nuclear Physics
Nuclear and Radio Chemistry
Particle Physics
Systems Engineering and Integration

MISSION UNIQUE FACILITIES

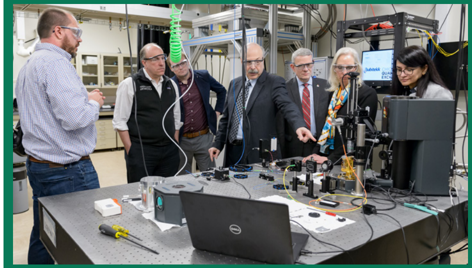
Advanced Photon Source
Argonne Leadership Computing Facility
Argonne Tandem Linear Accelerator System
Atmospheric Radiation Measurement Southern Great Plains Site
Center for Nanoscale Materials
Materials Engineering Research Facility

AT A GLANCE: ARGONNE NATIONAL LABORATORY

ACCOMPLISHMENTS

Unique Facility: X-rays for Discovery The Advanced Photon Source (APS) is the Nation's highest-energy light source and is used for studies in nearly every scientific discipline. More than 5,000 researchers use the APS annually, making it one of the world's most productive X-ray light source facilities. It has paved the way for better batteries, numerous new therapeutic drugs, more-efficient vehicles, stronger infrastructure materials, and more powerful electronics. Research at the APS has directly led to two Nobel Prizes and contributed to a third. The APS has also made significant contributions in the fight against COVID-19 by supporting research to both identify the protein structures of the virus and find potential pharmaceutical treatments and/or vaccines. The APS upgrade project now underway will make it up to 500 times brighter and vastly expand available research opportunities.

Tech-to-Market Highlight: Argonne Cathode Technology "Game Changer" in Battery Industry The battery that helps power General Motors' plug-in hybrid Chevy Bolt, the 2017 Motor Trend Car of the Year, is based in part on a chemistry breakthrough by Argonne scientists. The researchers used the Advanced Photon Source as part of their toolkit to better understand in real time the reactions that occur inside a battery. The nickel manganese cobalt (NMC) blended cathode structure developed at Argonne offers the longest-lasting energy available in the smallest, lightest package—a 50 to 100 percent increase in energy storage capacity over conventional cathode material. The NMC technology has been licensed to General Motors (Detroit, M.I.), BASF Corporation (Florham Park, N.J.), TODA America, Inc. (Battle Creek, M.I.), and LG Chem.



Research Highlight: The Birth of the Quantum Internet Building systems to communicate using quantum mechanics represents one of the most important technological frontiers of the 21st century. Argonne scientists took an important step toward achieving this goal in 2020 when they demonstrated entanglement of photons across a 52-mile "Quantum Loop" in the Chicago suburbs. To ultimately make a national quantum internet a reality, Argonne is leading efforts to develop quantum technologies. Those technologies include quantum repeaters enabling development of "unhackable" networks for information transfer, sensors with unprecedented sensitivities for transformational applications in the physical and life sciences, and "test beds" for both quantum simulators and quantum computers. Argonne's multi-partner Q-NEXT quantum information science center, established in 2020, is accelerating the development of quantum technology.

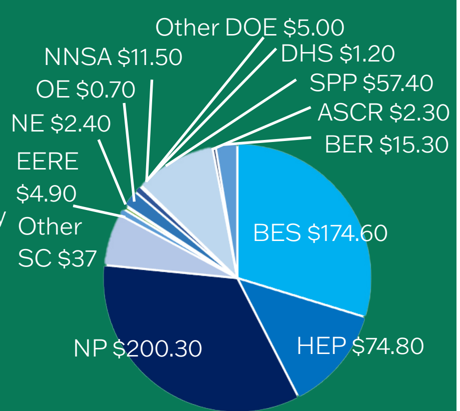
AT A GLANCE: BROOKHAVEN NATIONAL LABORATORY

BROOKHAVEN NATIONAL LABORATORY

With seven Nobel Prize-winning discoveries and more than 70 years of pioneering research, Brookhaven National Laboratory (BNL) delivers discovery science and transformative technology to power and secure the Nation's future. The laboratory leads and supports diverse research teams including other National Laboratories, academia, and industry, by designing, building, and operating major scientific user facilities in support of its DOE mission. These facilities reflect BNL/DOE stewardship of national research infrastructure critical for researchers—such as response to national emergencies (e.g., COVID-19 research). Energy and data science, nuclear science and particle physics, accelerator S&T, quantitative plant science, and quantum information science are Brookhaven's current initiatives. Managed by a partnership between Stony Brook University (SBU) and Battelle plus six universities—Columbia, Cornell, Harvard, MIT, Princeton, and Yale—Brookhaven manages programs that also help prevent the spread of nuclear weapons, protect astronauts on future space missions, and produce medical isotopes to diagnose and treat disease.

FUNDING BY SOURCE

FY 2019 Costs (in $M)
Total Laboratory Operating Costs: $587.5
DOECosts: $528.9
SPP (Non-DOE/Non-DHS) Costs: $57.4
SPP as % of Total Laboratory Operating Costs: 10%
DHS Costs: $1.2



FACTS

Location: Upton, NY
Type: Multiprogram Laboratory
Contractor: Brookhaven Science Associates
Site Office: Brookhaven Site Office
Website: bnl.gov

PHYSICAL ASSETS

5,322 acres and 314 buildings
4.83M GSF in buildings
Replacement plant value: $5.8 B
159,912 GSF in 27 excess facilities
0 GSF in leased facilities

HUMAN CAPITAL

2,421 FTE employees
139 joint faculty
159 postdoctoral researchers
286 undergraduate students
200 graduate students
3,555 facility users
1,523 visiting scientists

CORE CAPABILITIES

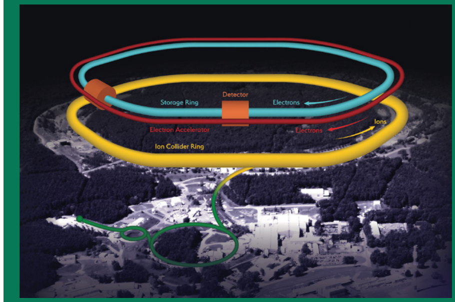
Accelerator S&T
Advanced Computer Science, Visualization, and Data
Applied Materials Science and Engineering
Applied Mathematics
Biological System Science
Chemical and Molecular Science
Chemical Engineering
Climate Change Science and Atmospheric Science
Computational Science
Condensed Matter Physics and Materials Science
Large-Scale User Facilities/R&D Facilities/Advanced Instrumentation
Nuclear and Radio Chemistry
Nuclear Physics
Particle Physics
Systems Engineering and Integration

MISSION UNIQUE FACILITIES

Accelerator Test Facility
Center for Functional Nanomaterials
National Synchrotron Light Source II
Relativistic Heavy Ion Collider

AT A GLANCE: BROOKHAVEN NATIONAL LABORATORY

ACCOMPLISHMENTS



Unique Facility: Electron-Ion Collider In January 2020, DOE named Brookhaven Laboratory as the site for a future Electron-Ion Collider (EIC), a one-of-a-kind nuclear physics research facility to be built in partnership with Thomas Jefferson National Accelerator Facility and New York State. The EIC will reuse key infrastructure from Brookhaven Laboratory's Relativistic Heavy Ion Collider (RHIC) and will serve as a 3D "microscope" for studying quarks and gluons—the building blocks of the protons, neutrons, and atomic nuclei that make up all visible matter in the universe. Scientists from across the Nation and around the world will use the EIC to study the properties of these building blocks of matter and unlock the secrets of the strongest force in nature. Technological advances being developed for the EIC will have widespread benefits for science and society.

Tech-to-Market Highlight: Application-Specific Integrated Circuits Several companies have licensed Brookhaven Laboratory intellectual properties that cover application-specific integrated circuits (ASICs) that were originally conceived by laboratory scientists for detectors in nuclear and particle physics experiments. These physics experiments generally require hundreds of integrated circuits produced within specified constraints of low noise, high precision, and high speed while maintaining low power consumption and low cost—attributes attractive to many industrial applications. Licensees of Brookhaven's intellectual properties are incorporating such ASICs in products designed for imaging and monitoring applications in the security, nuclear power, and medical industries.

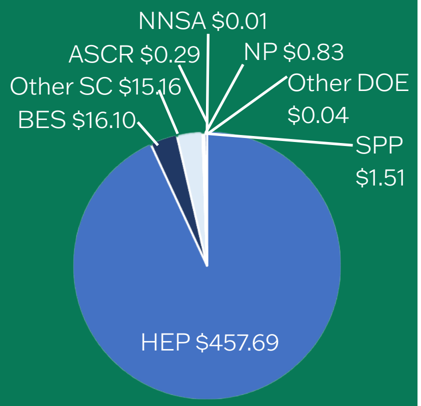
Research Highlight: Going the Distance for Quantum Networking Scientists from Brookhaven Laboratory and SBU recently demonstrated a three-node quantum network prototype, extending the reach and potential of future quantum communication systems. Such networks are based on the extraordinary phenomena of quantum physics, including quantum entanglement—where the properties of photons are intertwined even when those particles are separated by vast distances. The team recently transmitted single-photon level polarized quantum bits ("qubits") in a looping configuration for approximately 87 miles, using commercially available telecommunications fiber connecting the SBU and Brookhaven campuses. The achievement marks the longest successful quantum communication link experiment in the United States and is a significant step toward achieving a secure quantum network that could revolutionize the way people communicate.

AT A GLANCE: FERMI NATIONAL ACCELERATOR LABORATORY

Fermilab's mission is to be the frontier laboratory for particle physics discovery. The accelerator complex powers research into the fundamental nature of the universe and is the only one in the world to produce both low- and high-energy neutrino beams for science and also enable precision science experiments. The construction of the Long-Baseline Neutrino Facility (LBNF) and Deep Underground Neutrino Experiment (DUNE), along with the world's most intense neutrino beams made possible by the Proton Improvement Plan II (PIP-II) project, will be the first international mega-science project based at a DOE National Laboratory. Fermilab integrates U.S. researchers into the global particle physics enterprise through its experiments and programs in neutrino, collider, precision, and cosmic science. The laboratory's scientific R&D advances accelerator, detector, computing, and quantum technology for use in science and society.

FUNDING BY SOURCE

FY 2019 Costs (in $M)
Total Laboratory Operating Costs: $491.64*
DOE Costs: $490.12
SPP (Non-DOE/Non-DHS) Costs: $1.51
SPP as % of Total Laboratory Operating Costs: 0.3%
DHS Costs: $0.0
**Reflects funding of $15.537M provided by SLAC for LCLS-II work.*



HUMAN CAPITAL

1,810 full-time equivalent (FTE) employees
22 joint faculty
95 postdoctoral researchers
65 undergraduate students
30 graduate students
2,610 Fermilab accelerator complex users
1,162 other Fermilab users (including US-CMS)
27 visiting scientists

CORE CAPABILITIES

Accelerator S&T
Advanced Computer Science, Visualization, and Data
Large-Scale User Facilities/Advanced Instrumentation
Particle Physics

MISSION UNIQUE FACILITIES

Fermilab Accelerator Complex

FACTS

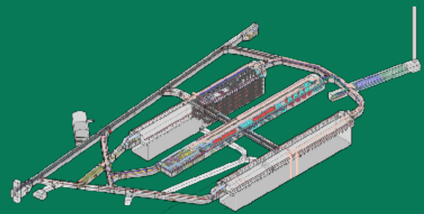
Location: Batavia, Illinois (40 miles west of Chicago)
Type: Single-program Laboratory
Contractor: Fermi Research Alliance, LLC
Site Office: Fermi Site Office
Website: fnal.gov

PHYSICAL ASSETS

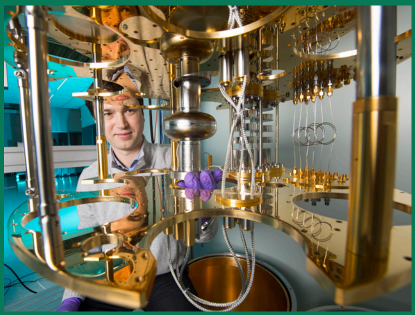
6,800 acres and 365 buildings
2.4 million GSF in buildings
Replacement plant value: $2.44 billion
28,913 GSF in 10 excess facilities
22,155 GSF in leased facilities

AT A GLANCE: FERMI NATIONAL ACCELERATOR LABORATORY

ACCOMPLISHMENTS



Unique Facility: Long-Baseline Neutrino Facility Construction for two major projects with international contributions is underway at Fermilab to advance the DOE High Energy Physics program: the LBNF, which will host DUNE, and the PIP-II project. More than 1,000 scientists from over 30 countries are working on the DUNE experiment to explore the mysteries of neutrinos. They are seeking to answer some of the biggest questions regarding our understanding of the universe, such as the origin of matter and the nature of subatomic particles. The PIP-II project will upgrade the Fermilab Accelerator Complex facility with a 700-foot-long, state-of-the-art superconducting particle accelerator. PIP-II will also enable the world's most intense neutrino beam for DUNE, plus a broad physics research program that will power new discoveries for many decades to come.



Tech-to-Market Highlight: From Particle Physics Technologies to Quantum Computers and the Quantum Internet Fermilab scientists have demonstrated that superconducting radiofrequency cavities can increase the length of time that a quantum device can maintain information, which is crucial to engineering the next-generation quantum computers and sensors. Building upon this technological breakthrough, together with Rigetti Computing and other partners, Fermilab scientists are using their expertise in superconducting radiofrequency (SRF) cavities and cryogenics to build scalable superconducting quantum computing systems at the DOE-funded Superconducting Quantum Materials and Systems Center. Also, in 2017, Fermilab planted the seeds for a quantum internet by installing the Fermilab Quantum Network (FQNET), a long-term partnership with AT&T, Caltech, and Fermilab. FQNET successfully demonstrated quantum teleportation in 2018. Fermilab and its partners are now expanding the point-to-point network to a multinode system that will crisscross Chicagoland—the third largest metropolitan area in the U.S.

Research Highlight: World Record Magnets for Future Proton Accelerators Powerful niobium-tin superconducting magnets are key components of high-energy proton accelerators and have applications in many other areas, including medical imaging. In a multiyear effort involving Fermilab, Brookhaven, and Berkeley National Laboratories, researchers successfully designed, built, and tested the first of 16 powerful beam-focusing magnets that the laboratories will provide for the High-Luminosity Large Hadron Collider at CERN. The effort set a world record for the highest field strength in a focusing magnet, reaching up to 13 teslas. Also, Fermilab and its partners in the U.S. Magnet Development Program are developing steering magnets for a potential successor to the Large Hadron Collider (which operates with a steering field of 7.8 teslas). In 2020, the program set the world record for the highest field strength for a steering magnet, achieving 14.5 teslas.

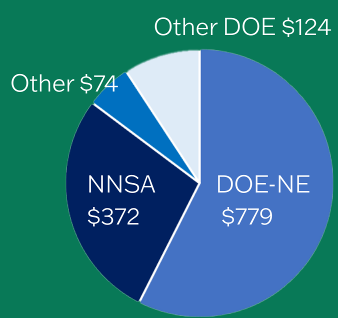
AT A GLANCE: IDAHO NATIONAL LABORATORY

Idaho National Laboratory (INL) serves as the U.S. leader for advanced nuclear energy R&D and is home to an unparalleled combination of nuclear energy test-bed facilities, including those that focus on fuel development and fabrication, steady-state and transient irradiation, and macro- and microscale post-irradiation examination. INL's applied science and engineering discipline and problem-solving approach helps the Departments of Defense and Homeland Security, as well as industry, solve significant national security challenges in critical infrastructure protection, cybersecurity, and nuclear nonproliferation. INL's strategic initiatives include research related to resilient cyber-physical security, integrated energy systems (including clean energy technologies) and advanced manufacturing.

Under the DOE Office of Nuclear Energy (DOE-NE)'s direction, INL leads multipe initiatives to provide the nuclear community with access to the technical, regulatory, and financial expertise necessary to move innovative nuclear energy technologies (e.g., microreactors) toward commercialization while ensuring the continued safe, economical operation of the existing nuclear fleet.

FUNDING BY SOURCE

FY 2019 Costs (in $M)
Total Laboratory Operating Costs: $1,349
DOE/NNSA Costs: $980
SPP (Non-DOE/Non-DHS) Costs: $300
SPP as % of Total Laboratory Operating Costs: 22%
CRADA: $9
DHS Costs: $61



FACTS

Location: Idaho Falls, Idaho
Type: Multiprogram Laboratory
Contractor: Battelle Energy Alliance
Site Office: Idaho Operations Office (DOE-ID)
Website: inl.gov

PHYSICAL ASSETS

569,180 acres
540 buildings or real property assets (DOE-owned assets operating or on standby)
$5.6 billion replacement plant value
2.3 million GSF in owned operating buildings; 9,609 GSF in operational standby buildings
1 million GSF in leased facilities
20,363 GSF in three excess facilities

HUMAN CAPITAL

4,888 FTE employees
36 joint faculty
68 postdoctoral researchers
20 high school student interns
265 undergraduate students
200 graduate students
691 facility users
12 visiting scientists

CORE CAPABILITIES

Advanced Computer Science, Visualization, and Data
Applied Materials Science and Engineering
Biological and Bioprocess Engineering
Chemical Engineering
Chemical and Molecular Science*
Condensed Matter Physics and Materials Science*
Cyber and Information Sciences
Decision Science
Environmental Subsurface Science and Analysis
Large-Scale User Facilities and Advanced Instrumentation
Mechanical Design and Engineering
Nuclear Engineering
Nuclear and Radiochemistry Power Systems and Electrical Engineering
Systems Engineering and Integration Physics
**Emerging Capabilities*

MISSION UNIQUE FACILITIES

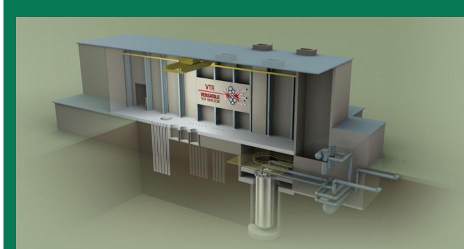
Transient Reactor Test Facility
Irradiated Materials Characterization Laboratory
Fuel Manufacturing Facility
Experimental Fuels Facility
Space and Security Power Systems Facility
Critical Infrastructure Test Range Complex
Biomass Feedstock National User Facility
Wireless Security Institute
Cybercore Integration Center
Advanced Test Reactor
Specific Manufacturing Capability

AT A GLANCE: IDAHO NATIONAL LABORATORY

ACCOMPLISHMENTS

Unique Facilities: Nuclear Energy R&D No other place in the nation hosts as many capabilities for assessing the technical and operational feasibility of new types of nuclear fuels and materials as INL. The Advanced Test Reactor is the only research reactor in the country capable of providing large-volume, high-flux neutron irradiation in a prototype environment. Its unique serpentine core allows its corner lobes to be operated at different power levels, meaning it can conduct multiple simultaneous experiments under different testing conditions. The Transient Reactor Test (TREAT) facility is helping to re-establish U.S. leadership in an essential nuclear research field, as TREAT's unique design monitors in real time a fuel or other material's behavior under postulated reactor accident conditions. Resources such as the Hot Fuel Examination Facility and the Irradiated Materials Characterization Laboratory provide state-of-the-art tools for microstructural and thermal characterization of irradiated materials. The results of these examinations are then used to advance fuel or material design and qualification.

Tech-to-Market Highlight: Advanced Electrolyte Model Computer Simulation Program INL is well-known for its Battery Testing Center and research capabilities, which have yielded numerous innovations in battery testing and development. One such technology is INL's R&D 100 Award winning Advanced Electrolyte Model (AEM). This computer simulation program is designed to give fast information on the properties of complex electrolyte formulations and how they can influence battery performance. AEM accelerates the speed at which new cell designs with new electrolytes can be developed. Since its debut in 2010, AEM has been licensed broadly to universities, major consumer product companies and industrial users—including chemical and automotive companies as well as a major lithium-ion cell manufacturer.



Research Highlight: Digital Engineering As a result of proven benefits in other industries, INL launched a digital engineering program to support new projects such as the Versatile Test Reactor (VTR). Digital engineering (DE) strategies can predict reactor performance and design issues early in the process, minimizing cascading risk. Numerous advances in the VTR design and engineering processes have already been achieved using DE. For example, a 3D model was developed in the first three months of the project—10 times faster than similar past efforts. The VTR is the first DOE nuclear program using cloud computing to reduce technical barriers such as computer performance—reducing latency by a factor of 100 during peak use.

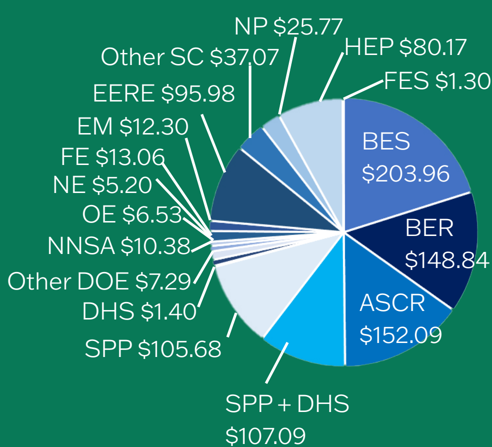
AT A GLANCE: LAWRENCE BERKELEY NATIONAL LABORATORY

BERKELEY LAB

Berkeley Laboratory creates useful new materials, advances the frontiers of computing, develops sustainable energy and environmental solutions, and probes the mysteries of life, matter and the universe. Deep integration of basic and applied science, advanced instrumentation, large-scale team science, and collaboration with the international scientific community enhance the laboratory's strengths, which lie in materials, chemistry, physics, biology, Earth and environmental science, mathematics, and computing. Berkeley's five national user facilities provide 14,000 researchers each year with capabilities in high-performance computing and data science, materials synthesis and characterization, and genomic science. Founded in 1931, Berkeley Laboratory's research and its scientists have been recognized with 14 Nobel Prizes.

FUNDING BY SOURCE

FY 2019 Costs (in $M)
Total Laboratory Operating Costs: $907.07
DOE/NNSA Costs: $800
SPP (Non-DOE/Non-DHS) Costs: $105.68
SPP as % of Total Laboratory Operating Costs: 11.7%
DHS Costs: $1.4



FACTS

Location: Berkeley, CA
Type: Multiprogram Laboratory
Contractor: University of California
Site Office: Bay Area Site Office
Website: lbl.gov

PHYSICAL ASSETS

202 acres and 97 buildings
1.7M GSF in DOE-owned and operated buildings
Replacement plant value: $1.49B
16,449 GSF in excess buildings
315,471 GSF in leased facilities
20,363 GSF in three excess facilities

HUMAN CAPITAL

3,398 FTE employees
1,699 scientists and engineers
245 joint faculty
513 postdoctoral researchers
332 graduate students
159 undergraduates
13,990 facility users
1,611 visiting scientists and engineers

CORE CAPABILITIES

Accelerator S&T
Advanced Computer Science, Visualization, and Data
Applied Materials Science and Engineering
Applied Mathematics
Biological and Bioprocess Engineering
Biological Systems Science
Chemical Engineering
Chemical and Molecular Science
Climate Change Science and Atmospheric Science
Computational Science
Condensed Matter Physics and Materials Science
Cyber and Information Sciences
Decision Science and Analysis
Earth Systems Science and Engineering
Environmental Subsurface Science
Large-Scale User Facilities/Advanced Instrumentation
Mechanical Design and Engineering
Nuclear and Radio Chemistry
Nuclear Physics
Particle Physics
Power Systems and Electrical Engineering

MISSION UNIQUE FACILITIES

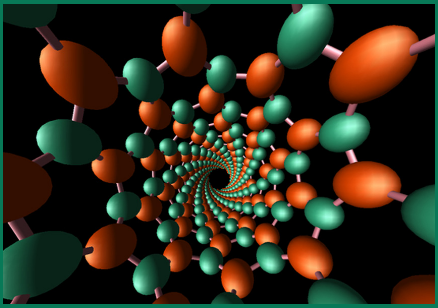
Advanced Biofuels Process Demonstration Unit
Advanced Light Source (ALS)
BELLA (Berkeley Laboratory Laser Accelerator)
Joint Genome Institute (JGI)
Energy Sciences Network (ESnet)
FLEXLAB (Integrated Building and Grid Technologies Testbed)
Joint BioEnergy Institute (JBEI)
The Molecular Foundry
National Energy Research Scientific Computing Center (NERSC)
88-Inch Cyclotron

AT A GLANCE: LAWRENCE BERKELEY NATIONAL LABORATORY

BERKELEY LAB

ACCOMPLISHMENTS

Unique Facility: Integrative Genomics Building The Integrative Genomics Building (IGB) at Lawrence Berkeley National Laboratory is a four-story research and office building that accommodates three DOE research programs: the Joint Genome Institute (JGI), the Systems Biology Knowledgebase (KBase), and the National Microbiome Data Collaborative (NMDC). JGI provides integrated high-throughput sequencing, DNA design and synthesis, metabolomics, and computational analysis that enable systems-based scientific approaches to these challenges. KBase, a collaboration with laboratories including Argonne, Oak Ridge, and Brookhaven, gives users data and tools designed to help build increasingly realistic models for biological function. The NMDC empowers the research community to harness microbiome data exploration and discovery through a collaborative integrative data science ecosystem. By uniting experts and world-class technologies under one roof—to increase resource efficiencies and scientific synergies for these programs—the IGB will help transform plant and microbial genomics research into solutions for today's most pressing environmental and energy issues. or material design and qualification.



Tech-to-Market Highlight: Next-generation Boron Nitride Nanotubes The boron nitride nanotube (BNNT) is a breakthrough material for energy, aerospace, electronics, and medicine applications. Invented by Lawrence Berkeley National Laboratory, the technology allows the quality scale-up of a material that is 100 times stronger than steel, heat resistant to 900°C, radiation-absorbing, hydrophobic, and capable of hydrogen storage. Additional advantages of BNNTs include high functionalization and thermal conductivity as well as band gap tunability, lending them as superior to carbon nanotubes. The patented technology is now being manufactured by EPIC Advanced Materials. Notably, one potential application is a breathalyzer to detect the COVID-19 virus.

Research Highlight: PDK: The First Truly Recyclable Plastic Even the most recyclable plastic, PET, or polyethylene terephthalate is only recycled at a rate of 20 to 30 percent, with the rest typically going to incinerators or landfills, where the carbon-rich material takes centuries to decompose. Lawrence Berkeley National Laboratory has designed a recyclable plastic that, like a Lego playset, can be disassembled into its constituent parts at the molecular level, and then reassembled into a different shape, texture, and color again and again, without loss of performance or quality. The new material, called polydiketoenamine (PDK) was reported in the journal Nature Chemistry.

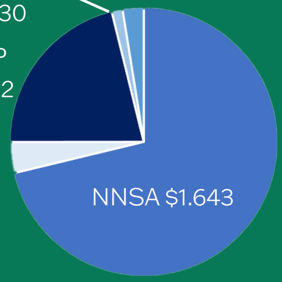
AT A GLANCE: LAWRENCE LIVERMORE NATIONAL LABORATORY

Lawrence Livermore National Laboratory

S&T on a mission—this is the hallmark of Lawrence Livermore National Laboratory (LLNL). In service to DOE/National Nuclear Security Administration (NNSA) and other federal agencies, LLNL develops and applies world-class S&T to ensure the safety, security, and reliability of the nation's nuclear deterrent. Founded in 1952, LLNL also applies S&T to confront dangers ranging from nuclear proliferation and terrorism to energy shortages and climate change that threaten national security and global stability. Using a multidisciplinary approach that encompasses all disciplines of science and engineering—and that utilizes unmatched facilities—the laboratory pushes the boundaries to provide breakthroughs for counterterrorism and nonproliferation, defense and intelligence, and energy and environmental security.

FUNDING BY SOURCE

FY 2019 Costs (in $M)
Total Laboratory Operating Costs: $2.21 billion
DOE/NNSA Costs: $1.9 billion
SPP (Non-DOE/Non-DHS) Costs: $306 million
SPP as % of Total Laboratory Operating Costs: 13.9%
DHS Costs: $23 million



FACTS

Location: Livermore, California
Type: Multidisciplinary National Security Laboratory
Contractor: Lawrence Livermore National Security, LLC
Site Office: Livermore Field Office
Website: llnl.gov

PHYSICAL ASSETS

7,700 acres
517 buildings
$20.2 billion replacement plant value*
6.4 million GSF in active buildings
0.6 million GSF in 88 non-operational buildings
24,000 GSF in leased facilities

**In FY 2019 NNSA implemented a new tool (BUILDER) to calculate the replacement plant value (RPV) for buildings and trailers. The change in modeling platforms produced new values and we are in the process of validating the updated figures with NNSA. In FY20+, the utility and other structures and facilities (OSF) assets will start migrating into BUILDER.*

HUMAN CAPITAL

7,378 FTE employees
18 joint faculty
253 postdoctoral researchers
184 undergraduate students
138 graduate students
531 contractors (non-LLNS employees)

CORE CAPABILITIES

Advanced Materials and Manufacturing
All-Source Intelligence Analysis
Bioscience and Bioengineering
Earth and Atmospheric Sciences
High-Energy-Density Science
High-Performance Computing, Simulation and Data Science
Lasers and Optical S&T
Nuclear, Chemical and Isotopic S&T
Nuclear Weapons Design and Engineering

MISSION UNIQUE FACILITIES

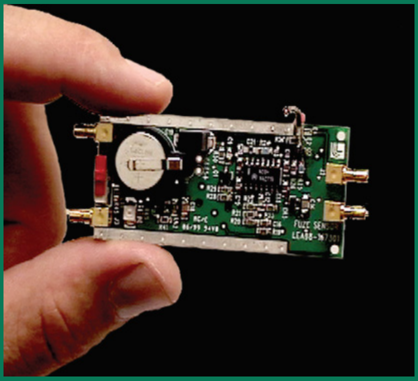
Advanced Manufacturing Laboratory
Center for Accelerator Mass Spectrometry
Center for Bioengineering
Center for Micro and Nanotechnology
Contained Firing Facility
Forensic Science Center
High-Explosives Applications Facility
Livermore Computing Complex
National Atmospheric Release Advisory Center
National Ignition Facility

AT A GLANCE: LAWRENCE LIVERMORE NATIONAL LABORATORY

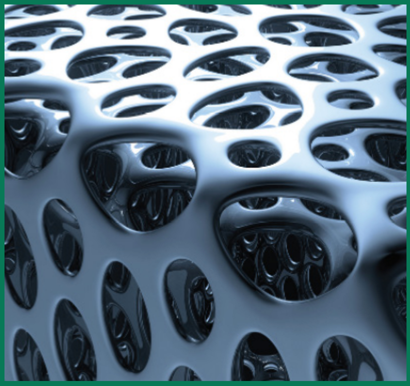
Lawrence Livermore National Laboratory

ACCOMPLISHMENTS

Unique Facility: One of the World's Premier High-Performance Computing (HPC) Facilities LLNL is home to Livermore Computing (LC), one of the world's premier HPC facilities. LC boasts more than 188 petaflops of computing power and numerous TOP500 systems, including the 125-petaflop Sierra. Continuing the long lineage of world-class LLNL supercomputers, Sierra represents the penultimate step on the road to exascale computing, expected to be achieved by 2023 with an LLNL system called El Capitan. These flagship systems are GPU-enabled and produce multi-physics simulations in 3D at never-before-seen resolutions for a variety of mission-critical needs. In 2020, LLNL and Cerebras Systems integrated the world's largest computer chip into the Lassen system, upgrading the top-tier supercomputer with cutting-edge AI technology. This combination creates a radically new type of computing solution, enabling researchers to investigate novel approaches to predictive modeling.



Tech-to-Market Highlight: Micropower Impulse Radar (MIR) The laboratory's compact, lightweight MIR uses very short electromagnetic pulses and can detect objects at a much shorter range than conventional radar can. MIR has been used in, among other applications, fluid-level sensing, medical applications, nondestructive evaluation, motion detection, and devices to detect breathing through walls or rubble to assist in rescue after disasters. The portable radar system was the first that SWAT and land-mine detection teams were able to use in the field. Search and rescue missions, including those on 9/11, have used MIR devices to detect lung or heart movements of people buried under rubble. Since 1994, MIR has held 197 patents and 44 licenses—more than any other technology in LLNL history. It was developed using $10 worth of off-the-shelf materials.



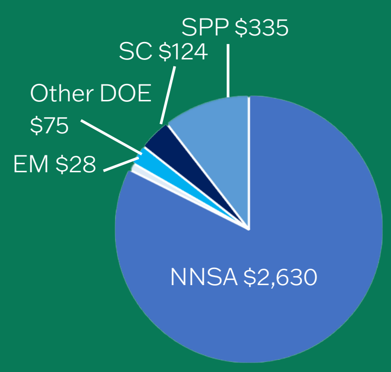
Research Highlight: Advanced Materials and Manufacturing In support of national security applications and to meet broader national needs, LLNL is making significant advances in capabilities to develop specialized materials together with processes and systems for product manufacturing and qualification. LLNL researchers are approaching advanced manufacturing as a fully integrated process from discovery and development of optimized materials to manufactured product. The goal is to achieve better products at reduced cost, infrastructure footprint, and development times. Successes include printed glass, aerospace-grade carbon fiber composite, and marine-grade stainless steel, as well as micro-structured materials with unprecedented properties (e.g., graphene aerogels for supercapacitors). In addition, advances in underlying science, experimentation and high-performance computing with machine learning are being combined to develop innovative means for improving fabrication, printing speeds, and product quality. Partnerships with industry and academia make vital contributions to these efforts.

AT A GLANCE: LOS ALAMOS NATIONAL LABORATORY

As a premier national security science laboratory, Los Alamos National Laboratory applies innovative and multidisciplinary science, technology, and engineering to help solve the toughest challenges of the nation—and to protect it as well as the world. In delivering mission solutions, Los Alamos ensures the safety, security, and effectiveness of the U.S. nuclear deterrent and reduces emerging national security and global threats. The multidisciplinary focus of the laboratory's mission extends to nuclear nonproliferation, counterproliferation, energy and infrastructure security, and technology—to counter chemical, biological, radiological, and high-yield explosives threats.

FUNDING BY SOURCE

FY 2019 Costs (in $M)
Total Laboratory Operating Costs: $2,609
DOE/NNSA Costs: $2,361
SPP (Non-DOE/Non-DHS) Costs: $299
SPP as % of Total Laboratory Operating Costs: 9%
DHS Costs: $9



HUMAN CAPITAL

9,831 FTE employees
31 joint faculty
460 postdoctoral researchers
604 graduate students (688 during summer peak)
847 undergraduate students
995 faculty users
855 visiting scientists
1,080 craft employees

CORE CAPABILITIES

Complex Natural and Engineered Systems
Information, Science, and Technology
Materials for the Future
Nuclear and Particle Futures
Science of Signatures
Weapons Systems

FACTS

Location: Los Alamos, NM
Type: Multiprogram Laboratory
Contractor: Triad National Security, LLC
Site Office: NNSA Los Alamos Field Office
Website: lanl.gov

PHYSICAL ASSETS

24,612 acres
896 buildings
8,240,164 GSF in buildings
Replacement Plant Value: $39.1 billion
1 million GSF in leased facilities

MISSION UNIQUE FACILITIES

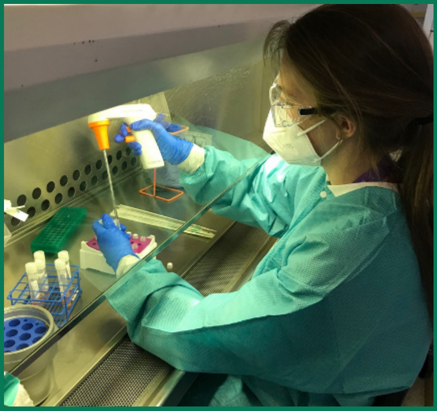
Atmospheric Radiation Measurement (ARM) (user facility)
Center for Explosives Science
Center for Integrated Nanotechnologies (CINT) (user facility)
Chemistry and Metallurgy Research Facility
Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT)
Electron Microscopy Laboratory
Ion Beam Materials Laboratory
Los Alamos Neutron Science Center (LANSCE) (user facility)
National Criticality Experiments Research Center (NCERC), Nevada
Nonproliferation & Internal Security Facility
Plutonium Science & Manufacturing Facility
National High Magnetic Field Laboratory (NHMFL) (user facility)
NNSA's Plutonium Center of Excellence
Proton Radiography (pRad) @ LANSCE
SIGMA Complex for Materials Manufacturing & Machining
Strategic Computing Complex (SCC)
National High Magnetic Field Laboratory (NHMFL)
Weapons Neutron Research Facility @ LANSCE

AT A GLANCE: LOS ALAMOS NATIONAL LABORATORY

ACCOMPLISHMENTS

Unique Facility: Los Alamos Neutron Science Center (LANSCE) LANSCE is a national user facility with one of the nation's most powerful linear accelerators. For more than 30 years, LANSCE has provided the scientific underpinnings in nuclear physics and material science needed to ensure the safety and surety of the nuclear stockpile into the future. In addition to national security research, the LANSCE user facility has a vibrant research program in fundamental science, providing the scientific community with intense sources of neutrons and protons—to perform experiments supporting civilian research as well as the production of medical and research isotopes.

Technology to Market: Next-Generation Fuel Cells To address the high cost of precious metal catalysts used in conventional fuel cells, Los Alamos scientists developed electrocatalysts that use inexpensive, Earth-abundant, and easily sourced precursor materials—instead of precious metals. Los Alamos partnered with Pajarito Powder, LLC, which is taking the lead in commercializing the technology for numerous applications. These clean-energy electrocatalysts without precious metals generate performance quickly approaching that of precious metal catalysts—but at a fraction of the cost, thus reducing the time-to-market for fuel cell technologies that provide clean, reliable, and now affordable energy.



Research Highlight: Biotechnology Los Alamos is advancing biotechnology research that is leading to innovations in energy, health, and sustainability. The Los Alamos expertise in synthetic biology, synthetic organic chemistry, biochemistry, and cell and molecular biology provides the basis for strong biotechnology capabilities. These capabilities address national needs such as producing bio-based alternatives to fossil fuels and petroleum-based products, as well as developing new therapeutics through natural products discovery. Biotechnology at Los Alamos is strengthened by a robust, interdisciplinary approach to science, including access to high performance computing and modeling, machine learning and artificial intelligence, next-generation sequencing, unique bioinformatics, flow cytometry and cell sorting, and customizable affinity reagents.

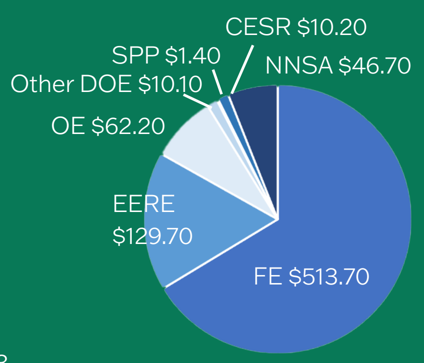
AT A GLANCE: NATIONAL ENERGY TECHNOLOGY LABORATORY

NATIONAL ENERGY TECHNOLOGY LABORATORY

The National Energy Technology Laboratory's (NETL) mission is to discover, integrate and mature technology solutions to enhance the Nation's energy foundation and protect the environment for future generations. NETL's advanced technology development is crucial to U.S. energy innovation. Through R&D, partnerships, and initiatives, NETL enables production of the clean, reliable, and affordable energy required to increase domestic manufacturing, improves our nation's energy infrastructure, enhances electrical grid reliability and resilience, expands domestic energy production, educates future scientists and engineers, promotes workforce revitalization, and supports U.S. energy and national security goals. As the only government-owned and government-operated laboratory in the DOE complex, NETL and its predecessor laboratories support DOE goals by maintaining nationally recognized technical competencies and collaborating with partners in industry, academia, and other research organizations to nurture emerging technologies.

FUNDING BY SOURCE

FY 2019 Costs (in $M)
Total Laboratory Operating Costs: $303
DOE/NNSA Costs: $773
SPP (Non-DOE/Non-DHS) Costs: $1.4
SPP as % of Total Laboratory Operating Costs: 0.46%
DHS Costs: $0
Active Research (DOE + Performer Share): $6.953 billion



FACTS

Location: Pittsburgh, PA; Morgantown, WV; Albany, OR; Houston, TX; Anchorage, AK
Type: Multiprogram Laboratory*
Website: netl.doe.gov
**The only government-owned and government-operated laboratory among the 17 National Laboratories.*

PHYSICAL ASSETS

237 acres
110 buildings
$686.5 million replacement plant value
1,137,097 GSF in buildings
13,225 GSF in leased facilities
15,078 GSF in 3 excess facilities

HUMAN CAPITAL

1,712 FTE employees
108 joint faculty
121 postdoctoral researchers
54 undergraduate students
115 graduate students

CORE CAPABILITIES

Applied Materials Science and Engineering
Chemical Engineering
Computational Science
Decision Science and Analysis
Environmental Subsurface Science
Systems Engineering and Integration

MISSION UNIQUE FACILITIES

Pittsburgh, PA
Carbon Capture Materials Synthesis Laboratory
Subsurface Experimental Laboratory
Center for Data Analytics and Machine Learning
Biogeochemistry and Water Laboratory

Albany, OR
Severe Environment Corrosion Erosion Research Facility
Magnetohydrodynamics (MHD) Laboratory
Metals Fabrication Laboratory / Metals Melting Facility

Morgantown, WV
Center for High Performance Computing (Joule 2.0 Supercomputer)
Reaction Analysis and Chemical Transformation (ReACT) Facility
Solid Oxide Fuel Cell Manufacturing and Test Laboratory
Center for Advanced Imaging and Characterization

AT A GLANCE: NATIONAL ENERGY TECHNOLOGY LABORATORY

ACCOMPLISHMENTS

Unique Facility: Key Computational Science and Engineering Facilities Supercomputing is essential in achieving NETL's mission to discover, integrate, and mature technology solutions that enhance the nation's energy foundation and protect the environment for future generations. By expediting technology development through computational science and engineering, NETL can cut costs, save time, and spur valuable economic investments with a global impact. NETL's Center for High-Performance Computing is home to NETL's supercomputer, Joule 2.0. This supercomputer enables the numerical simulation of complex physical phenomena. Joule 2.0 provides computational throughput to run high-fidelity modeling tools at various scales, ranging from molecules, to devices, to entire power plants and natural fuel reservoirs. Facilities associated with Joule allow for enhanced visualization and data analysis, as well as data storage capabilities that enable researchers to discover new materials, optimize designs, and predict operational characteristics.

Tech-to-Market Highlight: Breakthroughs in Laser-induced Breakdown Spectroscopy NETL researchers revolutionized a laser-induced breakdown spectroscopy (LIBS) subsurface monitoring tool that, because of its simplified construction, reduces the amount of fabrication and alignment needed, thereby minimizing costs. Developed for use in harsh, remote environments, the improved technology requires only two mirrors—as opposed to four in previous versions. By reducing the complexity and cost of the laser head, the probe maximizes the amount and quality of light returned for improved analysis and increases the usefulness of LIBS research. This effort won a 2019 R&D 100 Award and was awarded a U.S. patent.

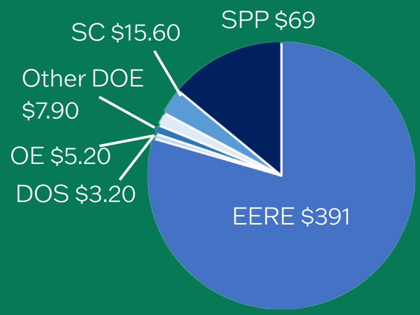
Research Highlight: IDAES Computational Platform The Institute for the Design of Advanced Energy Systems (IDAES) develops and utilizes multi-scale, optimization-based computational tools to improve the design and operation of fossil energy systems—both the existing fleet and the innovative, advanced coal energy systems of the future. The open-source, next-generation IDAES computational platform revolutionizes industry decision-making by enabling large-scale optimization to gain system-wide insights—to enhance the operation, profitability, efficiency, and design of energy systems. In 2019, IDAES worked extensively with the Escalante Generating Station to improve flexibility and efficiency, while also rolling out the computational platform to multiple stakeholders through its initial open-source release and two major workshops. This effort won a 2020 R&D 100 Award.

AT A GLANCE: NATIONAL RENEWABLE ENERGY LABORATORY

National Renewable Energy Laboratory (NREL) is DOE's primary National Laboratory for renewable energy and energy efficiency R&D. The laboratory delivers impactful scientific discoveries, innovations, and insights that transform clean energy technologies, systems, and markets. Also, the laboratory's research focuses on engineering of energy efficiency, sustainable transportation, and renewable power technologies and provides the knowledge to integrate and optimize energy systems. Finally, NREL's mission space delivers foundational knowledge, technology and systems innovations, and analytic insights to catalyze a transformation to a renewable and sustainable energy future.

FUNDING BY SOURCE

FY 2019 Costs (in $M)
Total Laboratory Operating Costs: $491.8
DOE/NNSA Costs: $420.2
TPP (Non-DOE/Non-DHS) Costs: $71
TPP as % of Total Laboratory Operating Costs: 14.5%
DHS Costs: $0.6



CORE CAPABILITIES

Computer Science and Analysis
- Advanced Computer Science, Visualization, and Data
- Decision Science and Analysis

Innovation and Application
- Biological and Bioprocess Engineering
- Chemical Engineering
- Mechanical Design and Engineering
- Power Systems and Electrical Engineering

Foundational Knowledge
- Applied Materials Science and Engineering
- Biological Systems Science
- Chemical and Molecular Science

System Integration
- Systems Engineering and Integration
- Large-Scale User Facilities

FACTS

Location: Golden, Colorado
Type: Single-program Laboratory
Contractor: Alliance for Sustainable Energy, LLC
Site Office: Golden Field Office
Website: nrel.gov

PHYSICAL ASSETS

630 acres
58 buildings and 4 trailers (owned)
$503,332,504 replacement plant value
1,082,068 GSF in buildings/trailers (owned)
169,949 GSF in leased facilities (five buildings, whole or partial)

HUMAN CAPITAL

2,265 FTE and part-time employees
27 joint faculty
189 postdoctoral researchers
79 undergraduate students
85 graduate students
39 facility users
2 visiting scientists

MISSION UNIQUE FACILITIES

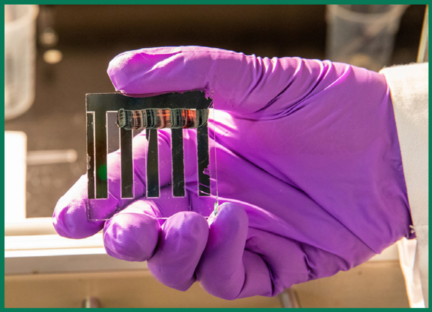
Battery Thermal and Life Test Facility
Controllable Grid Interface Test System
Distributed Energy Resources Test Facility
Energy Systems Integration Facility
Field Test Laboratory Building
High-Flux Solar Furnace
Hydrogen Infrastructure Testing and Research Facility
Integrated Biorefinery Research Facility
Outdoor Test Facility
Renewable Fuels and Lubricants Laboratory
S&T Facility
Solar Energy Research Facility
Thermal Test Facility
Thermochemical Process Development Unit
Thermochemical Users Facility
Vehicle Testing and Integration Facility
Wind Dynamometer Test Facilities
Wind Structural Testing Laboratory
Wind Turbine Field Test Sites

AT A GLANCE: NATIONAL RENEWABLE ENERGY LABORATORY

ACCOMPLISHMENTS

Unique Facilities: Centers for Bioenergy, Energy Systems Integration, Photovoltaics, and Wind NREL is home to three national research centers—the National Bioenergy Center, the National Center for Photovoltaics, and the National Wind Technology Center, which is located at NREL's Flatirons Campus. The laboratory is developing the latter, which offers specialized facilities and provides technical support critical to the development, primarily, of wind energy, to allow for testing at the 20 megawatt (MW) scale. Other unique facilities at NREL include the 185,000-square-foot Energy Systems Integration Facility (ESIF), which is the only facility that can conduct integrated MW-scale testing of the components and strategies needed to reliably move significant amounts of clean energy onto the electrical grid.

Tech-to-Market Highlight: Record Year for Technology Partnerships NREL is the only National Laboratory dedicated to the research, development, commercialization, and deployment of renewable energy and energy efficiency technologies. The laboratory accelerates the commercialization of energy technologies through licensing and partnerships with industry. NREL just closed the books on the best partnership year in its history, inking nearly 300 new, high-impact agreements. The laboratory now has more than 900 active technology partnerships with 500+ unique partners across businesses, governments, nonprofits, and academia. NREL has executed 260+ licenses since 2000 and has approximately 700 patented or patent-pending technologies—plus 250+ software solutions available for licensing. For the U.S. and beyond, our analysis informs policy and investment decisions leading to more resilient, reliable, and efficient energy systems. With objective, technology-neutral analysis, NREL aims to increase understanding of energy policies, technologies, and more to address U.S. economic and other priorities.



Research Highlight: Circular Economy, Electrons to Molecules, and Integrated Energy Pathways NREL's research vision centers around three critical objectives. A circular economy for energy materials focuses on reducing waste and preserving resources through the design of materials and products with reuse, recycling, and upcycling in mind from the start. Electrons to molecules explores the use of renewable, affordable electricity as the driving force for the conversion of low-energy molecules (e.g., water) to generate other molecules that could be used as chemicals, materials, fuels, or energy storage. Integrated energy pathways focuses on replacing today's outdated grid with a modern, intelligent infrastructure that, for one, looks to expand our options for mobility. One highlight, among many, from NREL's research vision, has involved building on their ground-breaking discovery of perovskites' use in solar cells. A team of NREL researchers has uncovered a change in chemical composition shown to boost the longevity and efficiency of a perovskite solar cell by resisting a stability problem that has so far thwarted the commercialization of perovskites.

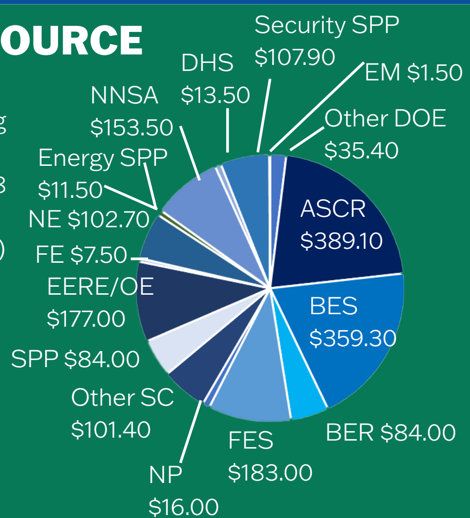
AT A GLANCE: OAK RIDGE NATIONAL LABORATORY

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is the largest multiprogram science and energy laboratory in the DOE system. Its mission is to deliver scientific discoveries and technical breakthroughs that accelerate the development and deployment of solutions in clean energy and national security, creating economic opportunity for the Nation. Established in 1943 as part of the Manhattan Project, ORNL pioneered plutonium production and separation, then focused on nuclear energy and later expanded to other energy sources and their impacts. Today, the laboratory manages one of the Nation's most comprehensive materials programs; two of the world's most powerful neutron science facilities, the Spallation Neutron Source and the High Flux Isotope Reactor; unique resources for fusion and fission energy and science; production facilities for life-saving isotopes; leadership-class computers including Summit, the Nation's fastest; and a diverse set of programs linked by an urgent focus on clean energy, Earth system sustainability, and national security.

FUNDING BY SOURCE

FY 2019 Costs (in $M)
Total Laboratory Operating Costs: $1,824.6 million
DOE/NNSA costs: $1,607.8 million
SPP (Non-DOE/Non-DHS) costs: $203.4 million
SPP as % of Total Laboratory Operating Costs: 11.9%
DHS costs: $13.5 million



FACTS

Location: Oak Ridge, Tennessee
Type: Multiprogram Laboratory
Contractor: UT-Battelle, LLC
Responsible Site Office: ORNL Site Office
Website: ornl.gov

PHYSICAL ASSETS

4,421 acres
272 buildings
$7.3 billion replacement plant value
4.85 million GSF in buildings
1.1 million GSF in leased facilities
1.4 million GSF in 63 excess facilities

HUMAN CAPITAL

4,856 FTE employees
194 joint faculty
323 postdoctoral researchers
556 undergraduate students
532 graduate students
2,928 facility users
1,691 visiting scientists

CORE CAPABILITIES

Accelerator S&T
Advanced Computer Science, Visualization, and Data
Applied Materials Science and Engineering
Applied Mathematics
Biological and Bioprocess Engineering
Biological Systems Science
Chemical Engineering
Chemical and Molecular Science
Climate Change Science and Atmospheric Science
Computational Science
Condensed Matter Physics and Materials Science
Cyber and Information Sciences
Decision Science and Analysis
Earth Systems Science and Engineering
Environmental Subsurface Science
Large-Scale User Facilities/Advanced Instrumentation
Mechanical Design and Engineering
Nuclear Engineering
Nuclear Physics
Nuclear and Radio Chemistry
Plasma and Fusion Energy Science
Power Systems and Electrical Engineering
Systems Engineering and Integration

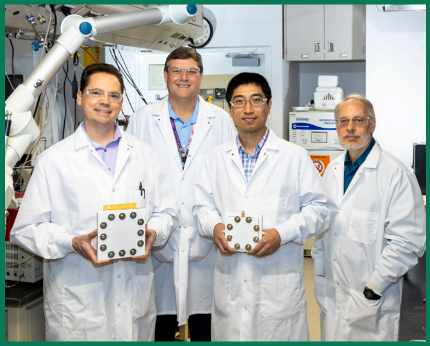
MISSION UNIQUE FACILITIES

Building Technologies Research and Integration Center
Carbon Fiber Technology Facility
Center for Nanophase Materials Sciences
Center for Structural Molecular Biology
Grid Research, Integration and Deployment Center
High Flux Isotope Reactor
Manufacturing Demonstration Facility
National Transportation Research Center
Oak Ridge Leadership Computing Facility
Spallation Neutron Source

AT A GLANCE: OAK RIDGE NATIONAL LABORATORY

ACCOMPLISHMENTS

Unique Facility: High Flux Isotope Reactor (HFIR) Operating at 85 MW, HFIR is the most powerful reactor-based source of neutrons in the United States. More than 500 researchers from around the world use the thermal and cold neutrons and specialized instruments at HFIR each year for fundamental and applied research on the structure and dynamics of matter, with applications in physics, chemistry, materials science, engineering, and biology. Discoveries enabled by HFIR lead to improvements in products including solar cells, hard drives, drugs, and biofuels. HFIR also produces isotopes for medical, industrial, and research uses as well as new element discovery. It is the western world's only supplier of californium-252, a versatile isotope used to start up new reactors, detect impurities in coal and cement, and provide port security. HFIR also produced plutonium-238 for NASA's Mars Rover. Additionally, HFIR is used for studies of the effects of radiation on materials.



Tech-to-Market Highlight: Laboratory Technology Converts Carbon Dioxide Into Ethanol ReactWell, LLC, licensed Voltanol, a novel ORNL waste-to-fuel technology that converts carbon dioxide directly into ethanol using tiny spikes of carbon and copper to turn the greenhouse gas into a sustainable liquid. It is being incorporated into the company's existing process, allowing refineries to upgrade their feedstock or to convert biomass to oil while removing a refinery's need to purchase or produce additional hydrogen, resulting in significant savings in capital investments and long-term operating costs. Another key benefit: The ORNL catalyst uses no rare earth elements, which are expensive and can be difficult to acquire. In addition to recycling carbon dioxide that would otherwise be released, ORNL's technology can offer a useful alternative to batteries for long-term or portable storage of renewable electricity.

Research Highlight: Artificial Intelligence for Breakthrough Science As home to the Nation's most powerful supercomputer, ORNL is pioneering the application of AI to diverse fields through its lab-wide AI Initiative. Experts in data science apply algorithms in both machine learning (allowing computers to learn from data and predict outcomes) and deep learning (which uses neural networks inspired by the human brain to uncover patterns of interest in datasets) to accelerate breakthroughs across the scientific spectrum. For instance, AI extracts new insights from mountains of health data (e.g., medical tests) to help providers diagnose and treat problems ranging from PTSD to cancer. In additive manufacturing, AI enables consistency in 3D printing of specialized aerospace components by instantly locating defects and adapting in real time. Through partnerships with power companies, ORNL has used AI in many other areas, including complex materials and structures, as well as improvements to the security and reliability of power grids.

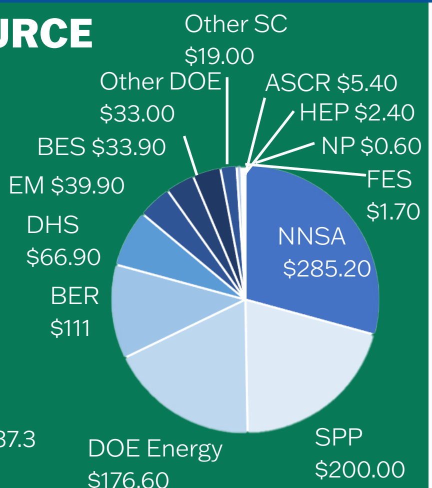
AT A GLANCE: PACIFIC NORTHWEST NATIONAL LABORATORY

Pacific Northwest National Laboratory (PNNL) advances the frontiers of knowledge, taking on some of the world's greatest S&T challenges. Distinctive strengths in chemistry, Earth sciences, biology and data sciences are the heart of PNNL's science mission, enabling innovations for energy resiliency and national security. PNNL advances theoretical and applied foundations of these disciplines, applying them to critical, complex challenges such as predicting ecosystem responses to climate change, power grid modernization, energy storage, cybersecurity, and nonproliferation.

PNNL stewards the Environmental Molecular Sciences Laboratory, a DOE user facility focused on deeper understanding of environmental processes from the molecular to the Earth system level. PNNL also manages the nine-laboratory DOE Atmospheric Radiation Measurement Program, a unique, distributed user facility with fixed and mobile sites worldwide gathering essential data on Earth's climate. PNNL's Energy Sciences Center, opening in 2021, will be a landmark research facility for the development of new materials and technologies for advanced clean energy systems.

FUNDING BY SOURCE

FY 2019 Costs (in $M)
FY 2019 Laboratory Operating Costs: $938.3
FY 2019 DOE/NNSA Costs: $708.7
FY 2019 SPP (Non-DOE/Non-DHS) Costs: $200
FY 2018 SPP % of Total Laboratory Operating Costs: 21.3%
FY 2018 DHS Costs: $66.9
FY 2018 EM-Related Costs*: $37.3
**Reflected in Total Laboratory Operating Costs.*



FACTS

Location: Richland, Washington
Type: Multiprogram Laboratory
Contractor: Battelle
Site Office: Pacific Northwest Site Office
Website: pnnl.gov

PHYSICAL ASSETS

781 acres (including 117 in Sequim, Wash.)
76 buildings
2,316,000 GSF total buildings
1,180,000 GSF of DOE-owned buildings
969,000 GSF in 30 leased buildings or third-party agreements
166,500 GSF in 11 Battelle-owned buildings and 21 OSFs
Replacement plant value: $934,315,000

HUMAN CAPITAL

4,301 FTE; headcount ~4,700
150 joint appointments
287 postdoctoral researchers
398 undergraduate students
414 graduate students
1,557 facility users
71 visiting scientists

CORE CAPABILITIES

Advanced Computer Science, Visualization, and Data
Applied Materials Science and Engineering
Applied Mathematics
Biological and Bioprocess Engineering
Biological Systems Science
Chemical and Molecular Science
Chemical Engineering
Climate Change Sciences and Atmospheric Science
Computational Science
Condensed Matter Physics and Materials Science
Cyber and Information Sciences
Decision Science and Analysis
Earth Systems Science and Engineering
Environmental Subsurface Science
Nuclear and Radiochemistry
Nuclear Engineering
Power Systems and Electrical Engineering
Systems Engineering and Integration
User Facilities and Advanced Instrumentation

MISSION UNIQUE FACILITIES

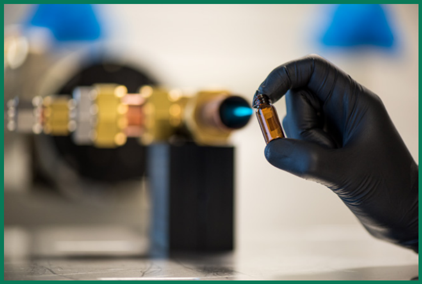
Atmospheric Radiation Measurement User Facility
Bioproducts, Sciences, and Engineering Laboratory
Electricity Infrastructure Operations Center
Energy Sciences Center
Environmental Molecular Sciences Laboratory
Marine and Coastal Research Laboratory
Radiochemical Processing Laboratory

AT A GLANCE: PACIFIC NORTHWEST NATIONAL LABORATORY

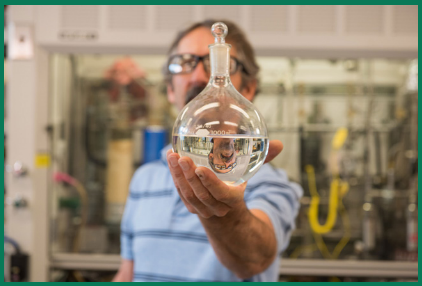
Pacific Northwest NATIONAL LABORATORY

ACCOMPLISHMENTS

Unique Facility: Energy Sciences Center The Energy Sciences Center—opening in late 2021—is a research facility at PNNL that will focus on fundamental research in chemistry, materials science and computing. PNNL researchers will apply their findings to develop faster, safer and more efficient chemical processes; turn wastes into commercial fuels; and create more advanced energy storage materials for energy and transportation technologies. Along with specialized equipment and expertise, the center is designed to encourage a collaborative environment, which aims to spur accelerated scientific discovery and technology advancement.



Research Highlight: Keeping America Safe PNNL researchers are contributing much of the science that underlies detection technologies that are keeping America and the world safe from threats posed by nuclear and chemical weapons of mass effect. PNNL discoveries and innovations form the heart of the radionuclide detection technology used in the International Monitoring System, a global network designed to monitor for nuclear explosions worldwide. The measurements are incredibly sensitive, detecting ultra-trace levels of radioactive xenon hundreds or even thousands of miles away. On the chemical front, an ultrasensitive technology detects explosive vapors, deadly chemicals, and illicit drugs with unparalleled accuracy. And it works in seconds. The non-contact technology is a potential game-changer for transportation hubs, mail facilities, and other safety and security screening applications.



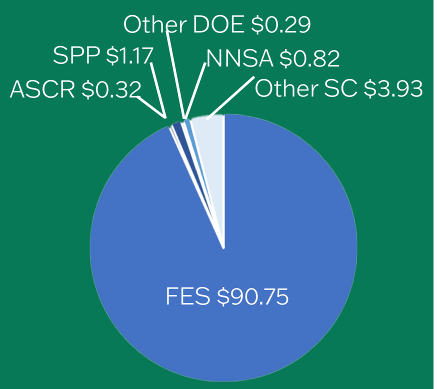
Technology-to-Market Highlight: Jet Fuel from Waste Recycled carbon from waste is the future of aviation and it's here now, thanks in part to PNNL. In 2018, a blend of jet fuel created from industrial waste gas powered a Virgin Atlantic flight from Orlando to London. LanzaTech—a biotech and carbon recycling company that uses bacteria to convert wastes into chemicals and ethanol—turned to PNNL for its unique catalytic process and proprietary catalysts, to upgrade ethanol to drop-in jet fuel. LanzaTech recently launched LanzaJet, with commercial investors and a DOE grant, to build a demonstration plant that will produce 10 million gallons per year of sustainable aviation fuel from ethanol starting in 2022. LanzaTech's bioconversion process can create ethanol from many waste sources, and PNNL's licensed conversion technology transforms it to sustainable aviation fuel.

AT A GLANCE: PRINCETON PLASMA PHYSICS LABORATORY

Princeton Plasma Physics Laboratory (PPPL), a collaborative national center for fusion energy science, basic sciences, and advanced technology, has three major missions: (1) to develop the scientific knowledge and advanced engineering to enable fusion to power the U.S. and the world; (2) to advance the science of nanoscale fabrication for future industries; and (3) to further the scientific understanding of plasmas from nano- to astrophysical scales. PPPL has been a world leader in magnetic confinement experiments, plasma science, fusion science, and engineering. As the only DOE National Laboratory with a Fusion Energy Sciences mission, PPPL aspires to be the nation's premier design center for the realization and construction of future fusion concepts (e.g., next wave of scientific innovation in plasma nanofabrication technologies). The laboratory is evolving, broadening its expertise to more effectively contribute to U.S. economic health and competitiveness by being a national leader in computation, nanofabrication, surface science, and technology.

FUNDING BY SOURCE

FY 2019 (Costs in $M)
Total Laboratory Operating Costs: $97.28
DOE/NNSA Costs: $96.11
SPP (Non-DOE/Non-DHS) Costs: $1.17
SPP as % of Total Laboratory Operating Costs: 1.2%



HUMAN CAPITAL

531 FTE employees
8 joint faculty
36 postdoctoral researchers
24 undergraduate students
45 graduate students
318 facility users
28 visiting scientists

CORE CAPABILITIES

Large-Scale User Facilities/Advanced Instrumentation
Mechanical Design and Engineering
Plasma and Fusion Energy Sciences
Power Systems and Electrical Engineering
Systems Engineering and Integration
**Proposed new core capabilities: Computational Science, and Condensed Matter Physics and Materials Science.*

FACTS

Location: Princeton, NJ
Type: Single-program Laboratory
Contractor: Princeton University
Site Office: Princeton Site Office
Website: pppl.gov

PHYSICAL ASSETS

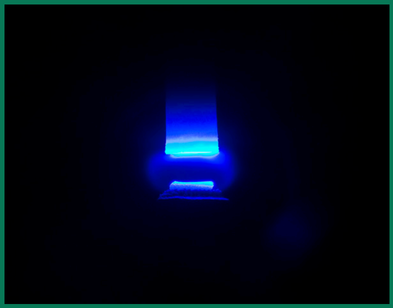
90.7 acres
30 buildings
$744.1 million replacement plant value
758,000 GSF in buildingsinfrastructure assets (OSFs)

MISSION UNIQUE FACILITIES

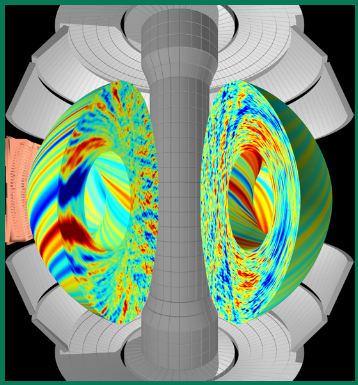
Laboratory for Plasma Nanosynthesis
Lithium Tokamak Experiment
Magnetic Reconnection Experiment
National Spherical Torus Experiment-Upgrade
Facility for Laboratory Reconnection Experiment

AT A GLANCE: PRINCETON PLASMA PHYSICS LABORATORY

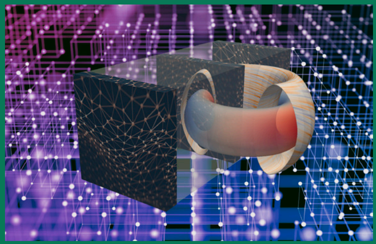
ACCOMPLISHMENTS



Unique Facility: Princeton Collaborative Research Facility on Low Temperature Plasma Low temperature plasma, a dynamic state of nature, has applications in fields ranging from golf clubs and swimwear to aerospace and biomedical equipment. Princeton Plasma Physics Laboratory has for years been exploring such plasmas and recently launched a facility open to researchers from across the country—to advance understanding and control of this practical state. The Princeton Collaborative Research Facility on Low Temperature Plasma, housed at PPPL, makes the extensive diagnostic and computational resources at PPPL and Princeton readily available to the U.S. academic, scientific, and industrial communities. “It’s important for the nation’s plasma physics laboratory to make a major contribution to understanding the physics of low-temperature plasmas,” said Jon Menard, deputy director for research at PPPL. “This facility will open all the tools in the laboratory’s low-temperature area for wider use.”



Tech-to-Market Highlight: Innovation Network for Fusion Energy PPPL is sharing its state-of-the-art computer codes and world-class research expertise with five companies developing facilities to produce fusion energy. The five partners are Commonwealth Fusion Systems in Massachusetts, developing high-temperature superconducting magnets to build smaller, lower-cost fusion reactors; TAE Technologies in California, working toward developing a fusion reactor based on the field-reversed configuration (FRC) concept; Tokamak Energy in Britain, developing a compact spherical tokamak with high-temperature superconducting magnets; HelicitySpace in California, designing a combined magnetic and inertial plasma confinement system to drive spacecraft and generate electricity; and General Fusion in Canada, pursuing a novel magnetized fusion device that uses pistons to compress plasma tightly to produce fusion energy. These public-private partnerships are drawing on decades of PPPL scientific and engineering advances to speed the arrival of commercial fusion power to generate electricity.



Research Highlight: Fusion Disruption Predictions PPPL scientists have opened promising new pathways to the capture and control of fusion energy, the power that drives the sun and stars as a source of safe, clean, and abundant energy for generating electricity. In recent years the laboratory has applied AI, the branch of computer science that is transforming scientific inquiry, to forecast sudden disruptions that can halt fusion reactions and damage the doughnut-shaped tokamaks that house the reactions. The deep learning AI code that researchers have produced has demonstrated its ability to predict true disruptions within a 30-millisecond time frame. Even more significant for risk mitigation, the code now can move well beyond those 30 seconds to provide warnings for more than 100 milliseconds before disruptions occur. The next step will be to move from the prediction of disruptions to their control.

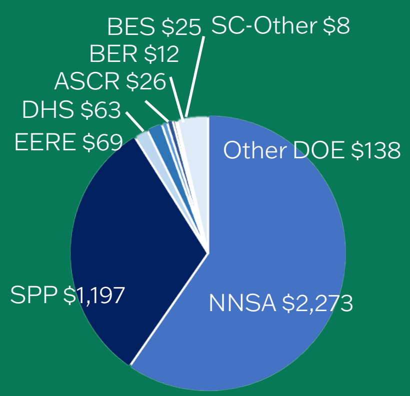
AT A GLANCE: SANDIA NATIONAL LABORATORIES

Sandia grew out of the effort to develop the first atomic bombs. Today, maintaining the U.S. nuclear stockpile is a major part of Sandia's work as a multimission national security engineering laboratory. Its role has evolved to address the complex threats facing the United States through R&D in the following: Supporting U.S. deterrence policy by ensuring a safe, secure, and effective nuclear stockpile; protecting nuclear assets and materials, and addressing nuclear emergency response and global nonproliferation; supplying new capabilities to U.S. defense and national security communities; ensuring a stable energy supply and infrastructure; and creating science-based, systems engineering solutions to the Nation's most challenging national security problems.

After 70 years, Sandia's highly specialized research staff remains at the forefront of innovation, collaborating with government, academia, and industry to live up to its mandate of providing exceptional service in the national interest.

FUNDING BY SOURCE

FY 2019 (Costs in $M)
Total Laboratory Operating Costs: $3,811
DOE/NNSA Costs: $2,551
SPP (Non-DOE/Non-DHS) Costs: $1,197
SPP as % of Total Laboratory Operating Costs: 33%
DHS costs: $63



HUMAN CAPITAL

12,783 FTE employees
32 joint faculty
251 postdoctoral researchers
948 undergraduate and graduate students

CORE CAPABILITIES

Cyber technology
High-reliability engineering
Micro and nano devices and systems
Modeling and simulation and experiment
Natural and engineered materials
Pathfinder engineered systems
Radiation-hardened, trusted microelectronics development/production
Systems engineering
Safety, risk, and vulnerability analysis

FACTS

Location: Albuquerque, NM; Livermore, CA; Carlsbad, NM; Amarillo, TX; Tonopah, NV; Kauai, HI
Type: Multiprogram Laboratories
Contractor: National Technology and Engineering Solutions of Sandia LLC
Site Office: Sandia Field Office
Website: sandia.gov

PHYSICAL ASSETS

196,192 acres
1,001 buildings/trailers (all sites)
$16,397,460,863 replacement plant value (includes structures)
7,695,261 GSF in buildings/trailers
375,289 GSF in leased facilities
42,603 GSF in 16 excess facilities

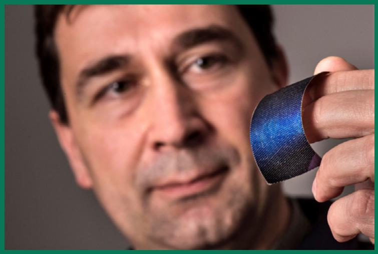
MISSION UNIQUE FACILITIES

Center for Integrated Nanotechnologies (CINT)
Combustion Research Facility
Microsystems Engineering, Science and Applications (MESA) complex
National Solar Thermal Test Facility
Z Machine

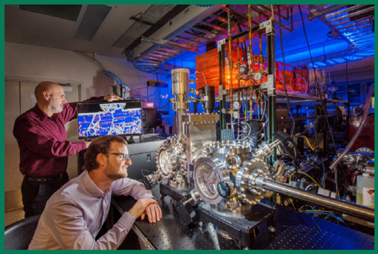
AT A GLANCE: SANDIA NATIONAL LABORATORIES

ACCOMPLISHMENTS

Unique Facility: The Z Machine Sandia's Z machine, Earth's most powerful pulsed-power facility and generator of gamma and X-rays, provides the fastest, most accurate method to determine how materials will react under extreme pressures and temperatures and to study the dense plasmas that make up the Sun and other stars. Data generated in hundreds of experiments at Z over the years have advanced mankind's understanding of the fundamentals of physics. Visiting researchers who use Z have gained important insights into how materials behave, how black holes grow, how hot the Sun is, and how old the planets in the solar system are. Z also serves as a vital source for studies of nuclear weapon effects and of the optimal methods to increase neutron output in the quest to generate fusion energy.



Tech-to-Market Highlight: Microsystems Enabled Photovoltaics With Laboratory Directed R&D funds, Sandia designed Microsystems Enabled Photovoltaics (MEPV) to reduce semiconductor size and material costs and enhance solar cell performance. The smaller photovoltaic cells are flexible, nearly unbreakable, and can be integrated into many different materials. They harness energy that can power devices in flexible, moldable, or flat-plate formats for a wide range of applications, including space satellites, UAVs, or portable power for soldiers or campers. A small, New Mexico-based startup, mPower Technologies, licensed MEPV in 2017 and is now developing and testing solar modules for the U.S. Army and others based on its DragonSCALES™ (SemiConductor Active Layer Embedded Solar) design. The technology provides the freedom to integrate solar power capability into buildings, clothing, portable electronics, or vehicles in nearly any shape.



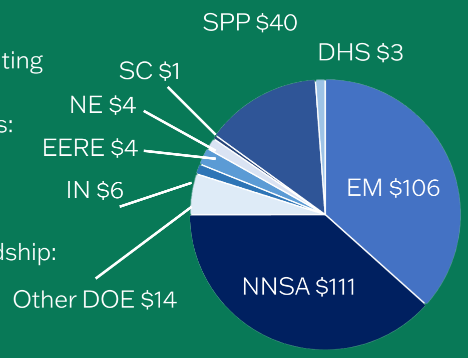
Research Highlight: The Friction Behavior of Metals Sandia researchers have designed computer models that predict the limits of friction behavior of metals based on materials properties—how much pressure can be put on materials or how much current can go through them before they stop working properly. Their model is especially valuable for electrical contacts, with impacts on everything from small electronic devices to electric vehicles to wind turbines. By extrapolating from models of friction and wear at the fundamental level in pure metals—down to how tiny differences in grain size produce big changes in friction—to more complex materials and structures, the researchers developed models that provide guidelines valuable in developing a variety of new materials.

AT A GLANCE: SAVANNAH RIVER NATIONAL LABORATORY

From the beginning, Savannah River National Laboratory (SRNL) has put science to work to protect our nation. When it was established in the early 1950s, the laboratory's primary focus was the start-up and operation of the Savannah River Site (SRS), including its five reactors, to produce tritium and plutonium—the basic materials for the U.S. nuclear weapons used to maintain the balance of power during the Cold War. Today, SRNL protects our Nation by supporting multiple federal agencies in providing practical, cost-effective solutions to nuclear materials management, national security, environmental stewardship, and energy security challenges. Building upon its pioneering work at SRS, SRNL now performs cutting-edge scientific research and technology development in various fields to protect the country's interests here and around the world.

FUNDING BY SOURCE

FY 2019 Costs (in $M)
Total Laboratory Operating Costs: $289
National Security Costs: 41%
Nuclear Materials Management: 29%
Environmental Stewardship: 26%
Secure Energy Manufacturing: 4%



FACTS

Location: Aiken, SC
Type: Multiprogram Laboratory
Contractor: Savannah River Nuclear Solutions
Site Office: Savannah River Site
Website: srnl.doe.gov

PHYSICAL ASSETS

39 acres
13 nuclear facilities with more than 200,000 GSF of radiologically controlled laboratory and process space, with 155 laboratories and 326 offices
$2 billion (approx.) replacement plant value
829,800 GSF in buildings/trailers/etc.
58,850 GSF in leased facilities

HUMAN CAPITAL

1,000 FTE employees
500+ engineers and scientists (200+ Ph.D.s)
26 postdoctoral researchers
50 student interns

CORE CAPABILITIES

Environmental Remediation and Risk Reduction
Nuclear Materials Detection, Characterization, and Assessment
Nuclear Materials Processing and Disposition
Tritium Processing, Storage, and Transfer Systems

MISSION UNIQUE FACILITIES

Atmospheric Technology Center
FBI Radiological Evidence Examination Facility
Outfall Constructed Wetland Cell Facility
Radiological Testbed Facilities
Shielded Cells Facility
Ultra-Low-Level Underground Counting Facility

AT A GLANCE: SAVANNAH RIVER NATIONAL LABORATORY

ACCOMPLISHMENTS

Unique Facility: Improving Energy Storage SRNL developed novel, high-temperature thermal energy storage (TES) material based on a ternary alloy of low-cost and highly abundant elements. The novel metal hydride has higher gravimetric and volumetric energy densities than other materials, as well as enhanced thermal conductivity and reaction rates under operating conditions. This allows for a reduction in heat exchangers, thereby reducing system costs.

Tech-to-Market Highlight: Recovering Rare Nuclear Material In an ongoing project to harvest Pu-244, a material not found anywhere else within the United States and maybe the world, SRNL built a full-scale mock-up of equipment for training and process development. The equipment, training, and processes will be used for the future transfer of the MK-18A targets into SRNL hot cells. The targets will be reduced in size, and chemical processes will be applied to recover plutonium, americium/curium, and other isotopes, that will then be packaged for shipment.

Research Highlight: SRNL Collaboration Across the DOE Complex SRNL led a multi-laboratory Technical Review Team (TRT) to assess the potential reactivity of LANL remediated nitrate salt drums stored at the Waste Control Specialists facility. The TRT concluded that the drums remain vulnerable because of the content uncertainty, but the nitric acid chemistry has caused an increased stability, which should improve with engineering controls (temperature and venting) during removal and transport.

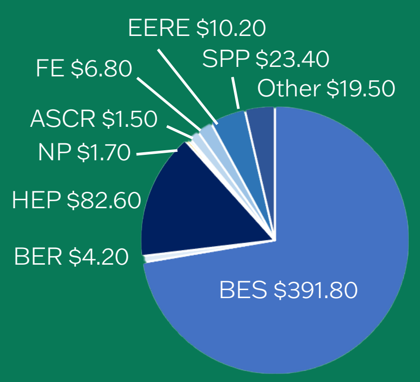
U.S. DEPARTMENT OF ENERGY

AT A GLANCE: SLAC NATIONAL ACCELERATOR LABORATORY

Managed by Stanford University and located in Silicon Valley, SLAC is a vibrant multiprogram laboratory whose mission is to explore how the universe works at the biggest, smallest, and fastest scales and invent powerful tools that scientists around the globe use. Since its founding in 1962, SLAC has made revolutionary discoveries that have established the laboratory's leadership in high energy physics. Today, SLAC is the world's leading laboratory in X-ray and ultrafast science due in large part to its X-ray user facilities, the Stanford Synchrotron Radiation Lightsource (SSRL), and the Linac Coherent Light Source (LCLS). Through diverse research programs in materials, chemical, biological and energy sciences, high-energy density science, cosmology, particle physics, bioimaging and technology development, SLAC helps solve real-world problems and advances the interests of the Nation.

FUNDING BY SOURCE

FY 2019 (Costs in $M)
Total Laboratory Operating Costs: $541.5
DOE/NNSA Costs: $518.1
SPP (Non-DOE/Non-DHS) Costs: $23
SPP as % of Total Laboratory Operating Costs: 4%
DHS costs: $0.4



FACTS

Location: Menlo Park, California
Type: Multiprogram Laboratory
Contractor: Stanford University
Site Office: Bay Area
Website: slac.stanford.edu

PHYSICAL ASSETS

426.3 acres
150 buildings
$3.1 billion replacement plant value
1.8 million GSF in buildings
0 GSF in leased facilities
1,170 GSF in 1 excess facility

HUMAN CAPITAL

1,620 FTE employees
22 joint faculty
227 postdoctoral researchers
121 undergraduate students
241 graduate students
2,608 facility users*
22 visiting scientists
**Facility users as reported to DOE by the user facilities LCLS, SSRL, and FACET, and test facilities ASTA, LSST, ESTB, and NLCTA.*

CORE CAPABILITIES

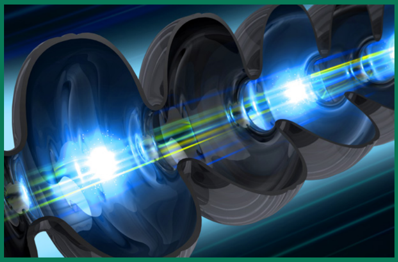
Accelerator S&T
Advanced Computer Science, Visualization, and Data*
Chemical and Molecular Science
Condensed Matter Physics and Materials Science
Large-Scale User Facilities/Advanced Instrumentation
Particle Physics
Plasma and Fusion Energy Science
**Emerging core capability*

MISSION UNIQUE FACILITIES

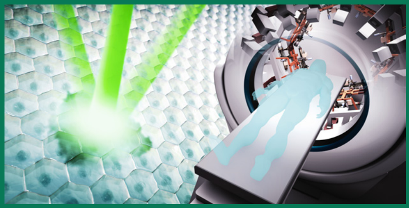
Facility for Advanced Accelerator Experimental Tests (FACET)
Linac Coherent Light Source (LCLS)
NIH Common Fund Stanford-SLAC Cryo-EM Center (S2C2)
NIH Common Fund Stanford-SLAC CryoET Specimen Preparation Service Center (SCSC)
Stanford-SLAC cryogenic electron microscopy (cryo-EM) facilities
Stanford Synchrotron Radiation Lightsource (SSRL)
Ultrafast Electron Diffraction facility (MeV-UED)
**Also leading DOE contributions to the construction and operation of the Vera C. Rubin Observatory, as well as the joint DOE-National Science Foundation (NSF) construction of the next-generation dark matter experiment SuperCDMS-SNOLAB.*

AT A GLANCE: SLAC NATIONAL ACCELERATOR LABORATORY

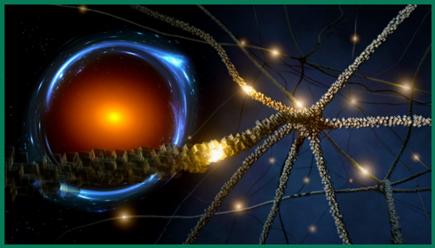
ACCOMPLISHMENTS



Unique Facility: X-ray and Electron Beams Draw Thousands
Thousands of scientists come to SLAC each year to explore the natural world at the largest, smallest, and fastest scales with powerful X-ray and electron beams. It's a combination found nowhere else: the pioneering Linac Coherent Light Source (LCLS) X-ray free-electron laser, being upgraded to increase its firing rate to a million pulses per second; Stanford Synchrotron Radiation Lightsource (SSRL), a forefront light source providing bright X-rays and outstanding user support; and the MeV-UED "electron camera," which tracks atomic motions in a broad range of materials in real time. Our advanced instrumentation and facilities for cryogenic electron microscopy make us one of the world's leading centers for cryo-EM research, training, technology development and service to the scientific community.



Tech-to-Market Highlight: Inventions Enhance and Save Lives
Working with industry, universities, and federal partners, SLAC scientists are developing valuable and sometimes life-saving technologies—for instance, a new type of pocket-sized antenna that enables mobile communication where conventional radios don't work, a low-cost emergency ventilator that could save the lives of COVID-19 patients, and, in collaboration with Stanford University, accelerator-based cancer treatments that zap tumors with X-rays or electrons, decreasing treatment times from minutes to seconds. This would make radiation therapy more precise with fewer side effects.



Research Highlight: Machine Learning Boosts Research Across the Laboratory SLAC's big scientific facilities produce enormous amounts of data, and when our LCLS-II X-ray laser upgrade and Vera C. Rubin Observatory come online the data torrents will become tsunamis. One of the ways SLAC is meeting this challenge is machine learning, where computer programs carry out tasks by looking for patterns in examples. Machine learning is enhancing research and operations across the laboratory, allowing SLAC to operate accelerators more efficiently, speed the discovery of new materials, and uncover distortions in space-time 10 million times faster than before. At SLAC's X-ray facilities, scientists can use machine learning to analyze data in real time so they can adjust their experiments on the fly for maximum efficiency.

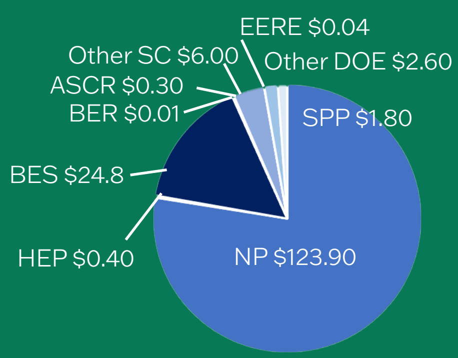
AT A GLANCE: THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY

Jefferson Lab

Thomas Jefferson National Accelerator Facility (TJNAF) is the preeminent laboratory in precision studies of the fundamental nature of confined states of quarks and gluons, including the protons and neutrons that make up the mass of the visible universe. Central to that is the Continuous Electron Beam Accelerator Facility (CEBAF), the first large-scale application of superconducting radiofrequency technology. Tools, techniques, and technologies developed in pursuit of the laboratory's scientific mission enable an ever-increasing array of applications—from detectors for medical and biological use, to advanced particle accelerators for environmental remediation.

FUNDING BY SOURCE

FY 2019 (Costs in $M)
Total Laboratory Operating Costs: $159.9
DOE/NNSA Costs: $158.1
SPP (Non-DOE/Non-DHS) Costs: $1.8
SPP as % of Total Laboratory Operating Costs: 1.1%
DHS Costs: $0.0



HUMAN CAPITAL

693 FTE employees
28 joint faculty
33 postdoctoral researchers
20 undergraduate students
42 graduate students
1,630 facility users
1,491 visiting scientists

CORE CAPABILITIES

Accelerator S&T
Large-Scale User Facilities/Advanced Instrumentation
Nuclear Physics

MISSION UNIQUE FACILITIES

Continuous Electron Beam Accelerator Facility

FACTS

Location: Newport News, Virginia
Type: Program-dedicated, Single-purpose Laboratory
Contractor: Jefferson Science Associates, LLC
Site Office: Thomas Jefferson Site Office
Website: jlab.org

PHYSICAL ASSETS

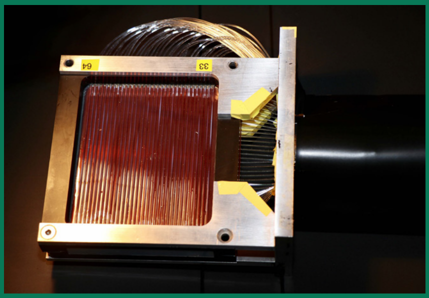
169 acres and 69 buildings
883,000 GSF in buildings
Replacement plant value: $480M
0 GSF in excess facilities
66,289 GSF in leased facilities

AT A GLANCE: THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY

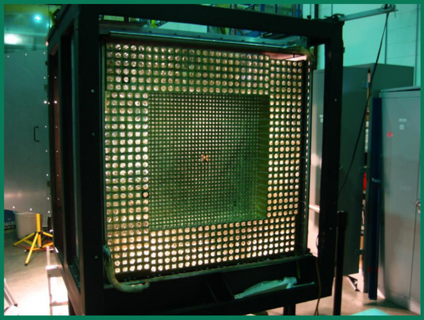
Jefferson Lab

ACCOMPLISHMENTS

Unique Facility: CEBAF The centerpiece of TJNAF's research program is the CEBAF—an electron accelerator based on SRF technology—which produces a stream of charged electrons that scientists use to probe the nucleus of the atom. As the first large-scale application of SRF technology in the world, CEBAF is the world's most advanced particle accelerator for investigating the quark structure of the atom's nucleus. The CEBAF's energy has been upgraded from 6 GeV to 12 GeV to expand the scientific reach of Jefferson Lab in support of the highest-energy experiments. The laboratory is a world leader in CEBAF-enabled SRF accelerator technology—and continues to advance accelerator technology as well as expand its applications beyond scientific research.



Tech-to-Market Highlight: Scintillating Medical Imaging In 2018, a new cancer treatment monitoring system, built by Radiadyne with detector technologies developed for Jefferson Lab's nuclear physics (NP) program, won an R&D 100 Award and the Medical Device Engineering Breakthrough Award. The OARtrac© monitoring system allows clinicians to monitor and adjust radiation delivered to patients through a novel application of scintillating fiber material used in NP to identify experiment-produced particles. The FDA cleared the system to use patient-specific Plastic Scintillating Detector sensors utilized during cancer treatments. Jefferson Lab's Cynthia Keppel, staff scientist and Halls A and C leader, collaborated with Radiadyne early in developing this technology—nearly a decade in moving from laboratory to market. This is the latest in a number of medical imaging applications based on Jefferson Lab particle detection technologies developed into successful products that are impacting cancer detection and treatment.



Research Highlight: The Size of the Proton All ordinary matter, from the sun that powers our solar system to the Earth we inhabit, is built on protons inside the atom's nucleus. In the early 2010s, new experiments measuring the size of the well-studied proton, in terms of its charge radius, yielded a smaller size than expected. Nuclear physicists carefully re-measured this basic quantity using a new experimental technique and the high-quality electron beam at TJNAF, finding an even smaller proton size of approximately .83 femtometers.

APPENDIX B: DOE ACCOMPLISHMENTS

Since the beginning of this Administration, DOE has made significant progress across its entire mission space, having...

• **Established U.S. Energy Dominance** for the first time, America became the world's number one producer of oil and natural gas;

• **Led substantial increases in exports of U.S. Liquefied Natural Gas (LNG)** by nearly five-fold and issued 20 long-term authorizations for LNG exports to non-free trade agreement countries since January 2017 the U.S now exports LNG to 38 countries on 5 continents;

• **Increased oil production at the Alaska Field Lab project by more than 700 barrels per day** over the first 20 months of polymer injection, which more than doubles the previous production;

• **Established 15 resource basin-specific field labs** since January 2017, aimed at maximizing resource recovery with a goal to double well productivity in a safe and environmentally prudent manner.

• **Published the Small-Scale LNG Rule** to expedite approval for small-scale natural gas exports;

• **Published the 2050 LNG Policy Statement** to allow companies to export LNG through 2050 as an alternative to our original 20-year authorizations;

• **Stabilized oil markets during the COVID-19 pandemic** by facilitating discussions among the world's leading oil producers through DOE's leadership in the International Energy Agency and G20;

• **Used the Strategic Petroleum Reserve, for the first time, as a temporary storage option for U.S. small and mid-sized crude oil producers** to help stabilize oil markets following the demand destruction caused by COVID-19;

• **Launched the Science-informed Machine Learning to Accelerate Real Time (SMART) Decisions in Subsurface Applications Initiative,** bringing together seven DOE national laboratories, industry, and academia to apply artificial intelligence and machine learning to carbon storage and oil and natural gas applications;

• **Founded the NVBL** to provide interdisciplinary and multi-lab support to the national COVID-19 response;

The Trump Administration and the Department of Energy unleashed American energy dominance, making us the world's leading energy producing nation and advancing innovative technologies to keep our energy sector competitive in the global marketplace. By establishing an economic climate of certainty and supporting private enterprise, Americans can look forward to a safe and prosperous energy future.

– Secretary of Energy Dan Brouillette

• **Co-led the COVID-19 HPC Consortium,** a unique public-private effort, bringing together federal government, industry, and academic leaders to volunteer free compute time and resources to halt the spread of COVID-19;

• **Launched the COVID-19 Technical Assistance Program,** an initiative to allow National Lab experts to provide free, targeted assistance to American innovators in the fight against COVID-19;

• **Launched the LPS COVID-19 portal,** offering users a curated access point to National Lab research, facilities, and intellectual property that could prove useful in the fight against COVID-19;

• **Launched the Coal FIRST Initiative** to develop the power plant of the future, which can produce electricity and hydrogen from coal, biomass, and waste, with zero or even negative CO2 emissions;

• **Continued to promote 21st Century Coal** by advancing research and development in the conversion of coal to high-value carbon products like building materials and manufactured products, which can help sustain coal community jobs;

• **Implemented the Nuclear Fuel Working Group's Strategy** to Restore American Nuclear Energy Leadership;

• **Supported the First Nuclear Power Plant (Vogtle) to be built in the U.S. in Nearly 30 Years** by providing an additional $3.7 billion in loan guarantees;

• **Established the National Reactor Innovation Center (NRIC)** to provide a platform for private sector technology developers to assess the performance of their nuclear reactor concepts through testing and demonstration;

• **Launched the Advanced Reactor Demonstration Program** to competitively-select two advanced reactor projects to result in fully functional advanced nuclear reactors within seven years;

• **Successfully returned electric power** to communities affected by multiple catastrophic hurricanes and typhoons;

• **Developed the NAERM** to understand risks to electricity infrastructure and identify needed investments to improve system resilience across the U.S., Canada, and Mexico;

• **Established the Office of CESER** to improve the cybersecurity and resilience of the Nation's energy critical infrastructure;

• **Delivered on the President's Cyber Workforce Executive Order** through the DOE CyberForce Competition, with over 100 colleges and universities competing across 10 National Labs to grow capabilities in industrial control system cybersecurity;5

• **Strengthened Protections for the Nation's Electric Grid against Foreign Adversaries** by implementing Executive Order 13920, Securing the U.S. Bulk-Power System, which the President signed on May 1, 2020;

• **Established the Cyber Testing for Resilience of the Industrial Control Systems (CyTRICS) program** to secure the Nation's Energy Supply Chain and support the Bulk Power System Executive Order;

• **Oversaw the expansion of renewable power,** including a doubling of solar production from 2016 through 2019 and a 32 percent increase in wind production, making the U.S. the world's second largest producer of both wind and solar;

• **Launched the American-Made Challenges,** by investing more than $40 million in 16 different American-Made prizes and competitions to advance energy innovation and American manufacturing;

• **Launched the Energy Storage Grand Challenge,** a comprehensive strategy to position the U.S. for global leadership in the energy storage technologies of the future;

• **Launched the American-Made Solar Prize,** a competition designed to revitalize solar manufacturing in the United States, leading to four rounds that will result in $12 million in prizes;

• **Created the Energy-Water Desalination Hub** as part of the White House Water Security Grand Challenge, announcing nearly $100 million for the National Alliance for Water Innovation to address water security issues in the United States;

• **Launched the American-Made Solar Desalination Prize,** a $9 million prize competition designed to accelerate the development of low-cost desalination systems that use solar-thermal power to produce clean water from salt water;

• **Funded the development of the first renewable jet fuel used on a commercial flight** from Orlando to London Gatwick;

• **Initiated the Plastics Innovation Challenge** which launched a comprehensive program to design new highly recyclable or biodegradable plastics, develop novel methods for deconstructing and upcycling existing plastic waste, and address plastic waste;

• **Rolled back unnecessary regulations** supporting a presidential priority by refocusing energy conservation standards to increase consumer choice and save over $300 million for the American people;

• **Protected consumer lighting choices** by preventing more stringent regulations on common incandescent lightbulbs that would have essentially regulated those products out of existence, denying families the ability to make their own lighting choices;

• **Initiated the Sustainability in Manufacturing Partnership** to help drive manufacturing productivity improvements resulting in partners saving over $6 billion in energy costs;

• **Reduced the price of batteries by more than 80% over 10 years,** culminating in 2019, from just over $1,000 per kilowatt-hour to $185 per kilowatt-hour for the useable energy of a full battery pack;

• **Established the ReCell Battery Recycling R&D Center and launched the Lithium-Ion Battery Recycling Prize** to develop technologies to profitably capture 90% of all lithium-based battery technologies in the United States and recover 90% of the key materials from the collected batteries;

• **Reduced the cost of electrolyzers,** which produce hydrogen from water and electricity, by 80% and automotive fuel cell costs by 60% in the past decade, while quadrupling their durability to over 120,000 miles;

• **Completed the first science-based high-level radioactive waste (HLW) interpretation shipment,** removing 8 gallons of recycle wastewater from the Defense Waste Processing Facility at the Savanah River Site for treatment and disposal, a model for new pathways to address tank waste and expedite cleanup of DOE sites across the country;

• **Approved commencement of operations at the Savannah River SWPF,** which will allow DOE to address the bulk of the remaining tank waste within a decade;

• **Transferred 70 sites to the Office of Legacy Management (LM)** across the Nevada Test and Training Rand, including the Tonopah Test Range, the first transfer of active Environmental Management Sites to long-term LM stewardship since 2012;

• **Completed "Vision 2020" at Oak Ridge's East Tennessee Technology Park,** the first time a uranium enrichment complex has been fully deactivated and decommissioned, and completed four years ahead of schedule, saving taxpayers $500 million;

• **Reached agreement with the state of California to allow active cleanup to resume** at the Energy Technology Engineering Center (ETEC) site after more than a decade. Nine out of an initial set of 10 buildings are down, and by the end of the year the final building will be demolished.

• **Won 106 R&D 100 Awards** for exceptional new products and processes that were developed and introduced into the marketplace, pushing the DOE total to over 900;

• **Established DOE's first ever Chief Commercialization Officer,** who is tasked with bridging the gap between our 17 National Labs and commercialization in the private sector;

• **Celebrated the 2020 Nobel Prize in Chemistry win by a DOE Lab Researcher** (Dr. Jennifer Doudna) who was originally funded by DOE's Lawerence Berkeley National Laboratory for her foundational work in understanding the structure of RNA, which led to her co-invention of the gene editing technology known as CRISPR.

• **Celebrated two DOE-supported researchers winning the 2019 Nobel Prize in Chemistry** (Dr. M. Stanley Whittingham and Dr. John Goodenough) for their foundational work in the development of lithium-ion batteries;

• **Established the AI and Technology Office** to serve as the central point for the coordination and development of broad and extensive artificial intelligence (AI) capabilities for the Department and its National Laboratories;

• **Improved Veteran's Health** through a partnership with the VA to leverage next-generation AI and supercomputing technologies;

• **Maintained Global Leadership in Supercomputing** by building and operating two of the world's fastest supercomputers at DOE National Laboratories;

• **Launched the Quantum Internet** to evolve from today's limited local quantum network experiments and revolutionize how information is transmitted in the future;

• **Selected the first QIS Research Centers** to provide training and collaboration opportunities for the next generation of QIS scientists and engineers;

• **Supported the exploration of the Universe in Partnership with NASA** by providing the power source and the SuperCam detector for the Mars Perseverance Rover, and winning a Gears of Government award for developing an electrical power source to support long-duration crewed missions on the Moon, Mars and destinations beyond;

• **Established the DOE-NASA Joint Executive Committee** to ensure alignment and collaboration in the furtherance of the Administration's national space goals of landing the first woman and next man on the surface of the moon by 2024, establishing a sustainable presence on the moon by 2028, and ultimately putting the first human boots on the surface of Mars;

• **Supported American's Innovate Small Business** by providing $1.1 billion in funding through DOE's SBIR and STTR grants across 49 States;

• **Funded Energy Frontier Research Centers** by providing over $445 million to support 64 Centers in diverse energy and science related fields;

• **Launched the Pathfinder Program** with U.S. Department of Defense and U.S. Department of Homeland Security to better prevent and protect against attacks on Defense Critical Energy Infrastructure;

• **Increased private sector follow-on-funding** for DOE's ARPA-E projects by 100% to $3.6 billion and nearly doubled the number of filed patents stemming from ARPA-E funded research to 385, since 2017;

• **Engaged over 1,800 partners in research agreements through the DOE National Laboratories** bringing in $337,924,445 in funding and earning $21,084,539 in licensing income in FY2018 to propel American innovation forward;

• **Launched the Innovation Network for Fusion Energy** (INFUSE) program as the first public-private partnership for accelerating fusion as a future energy source;

• **Increased Global Nuclear Security** by removing or confirming disposition of significant quantities of highly enriched uranium (HEU), bringing the program's lifetime total to more than 7,215 kilograms of highly enriched uranium (HEU) and plutonium downblended or eliminated from nearly 50 partner countries — enough material for more than 320 nuclear weapons;

• **Flight Tests** and other key milestones for nuclear warhead sustainment and modernization programs in cooperation with DoD;

• **Completed the W76-1 Life Extension Program** under budget and ahead of schedule, strengthening U.S. safety and security by extending the warhead's service life from 20 years to 60 years;

• **Developed Five Developmental Plutonium Pits** in support of a strategic effort to recapitalize production of a key component of nuclear weapons;

• **Made Significant Progress on Nuclear Weapons Infrastructure Initiatives** that will enable the use of strategic materials including uranium, plutonium, lithium, tritium, and high explosives to maintain the nuclear deterrent;

• **Issued four cooperative agreement awards to produce Molybdenum-99** without the use of highly enriched uranium, a medical isotope used in over 40,000 medical procedures each day in the United States, including the diagnosis of heart disease and cancer;

• **Enhanced the Federal Bureau of Investigation's (FBI) regional capabilities to disrupt weapons of mass destruction (WMD) attack**s by providing advanced equipment and training for the "Capability Forward" initiative, through which fourteen major U.S. cities will receive new advanced capabilities by FY2022;

• **Replaced fixed-wing Aerial Measuring System (AMS) aircraft**, used to provide rapid wide-area assessments of releases of radioactive materials in the environment;

• **Met milestones for the Columbia-class ballistic missile submarine,** including contracts for the lead ship construction and reactor plant heavy equipment including the lead ship reactor core;

• **Placed the U.S. Navy's 192nd spent fuel canister into dry storage** at the Naval Reactors Facility at Idaho National Laboratory;

• **Launched the Partnership for Transatlantic Energy Cooperation (P-TEC)** with partner countries from Central and Eastern Europe to push back against Russian energy-based malign influence;

• **Completed a Deal with Australia to lease space and store U.S. crude oil** in the U.S. Strategic Petroleum Reserve for the first time since Congress provided DOE with this authority;

• **Fostered the Development of the Eastern Mediterranean Gas Forum** bringing together Israel, the Palestinian authority, Egypt, Jordan, and other regional partners to facilitate natural gas trade and economic growth; and

• **Launched the U.S.-India Strategic Energy Partnership** to enhance energy security, expand energy and innovation linkages, bolster our strategic alignment, and facilitate increased industry and stakeholder engagement in the energy sector.

ACRONYMS AND ABBREVIATIONS

ACT: Agreement for Commercializing Technologies

AEO: Arctic Energy Office

AI: Artificial Intelligence

AITO: Artificial Intelligence & Technology Office

AIX: AI Exchange

AM: Additive Manufacturing

AMS: Aerial Measuring System

ANL: Argonne National Laboratory

API: Application Programming Interface

ARPA-E: Advanced Research Projects Agency – Energy

BIRC: Bioenergy Research Center

CARES: Coronavirus Aid, Relief, and Economic Security Act

CCUS: Carbon Capture, Utilization and Storage

CESER: Office of Cybersecurity, Energy Security, and Emergency Response

CMI: Critical Materials Institute

CoEPP: Centre of Excellence for Particle Physics at the Terascale

CRADA: Cooperative Research and Development Agreement

CRISP: Cybersecurity Risk Information Sharing Program

CSGF: Computational Science Graduate Fellowship

CyTRICS: Cyber Testing for Resilience of the Industrial Control Systems

DART: Double Asteroid Redirection Test

DoD: Department of Defense

DOE: United States Department of Energy

DOI: Department of the Interior

DOT: Department of Treasury

ECI: Exascale Computing Initiative

EERE-AMO: Energy Efficiency and Renewable Energy – Advanced Manufacturing Office

EFRC: Energy Frontier Research Center

ELI-Beamlines: European Union Extreme Light Infrastructure Beamlines Facility

ETEC: Energy Technology Engineering Center

ETT: Excellence in Technology Transfer

FBI: Federal Bureau of Investigation

FFRDC: Federally Funded Research and Development Center

FIRST: Flexible, Innovative, Resilient, Small & Transformative

FLC: Federal Laboratory Consortium for Technology Transfer

FNAL: Fermi National Accelerator Laboratory

GOCO: Government-owned, contractor-operated

GOGO: Government-owned, government-operated

HADR: Humanitarian Aid and Disaster Relief

HEU: Highly Enriched Uranium

HHS: Department of Health and Human Services

HLW: High Level Waste

HPC: High Performance Computing

IEWO: Inter Entity Work Order

INFUSE: Innovation Network for Fusion Energy

INL: Idaho National Laboratory

IRD: Innovation, Research & Development

ITER: International Thermonuclear Experimental Reactor

JCAP: Joint Center for Artificial Photosynthesis

JCESR: Join Center for Energy Storage Research

LANL: Los Alamos National Laboratory

LBNL: Lawrence Berkeley National Laboratory

LDRD: Laboratory Directed Research and Development

LLNL: Lawrence Livermore National Laboratory

LM: Legacy Management

LNG: Liquified Natural Gas

LOB: Laboratory Operations Board

LPBF: Laser Powder Bed Fusion

LPS: Lab Partnering Service

MII: Manufacturing Innovation Institute

MTA: Material Transfer Agreement

MSW: Master Scope of Work

M&O: Management and Operations

NAERM: North American Energy Resilience Model

NASA: National Aeronautics and Space Administration

NAWI: National Alliance for Water Innovation

NETL: National Energy Technology Laboratory

NIST: National Institute of Standards and Technology

NLDC: National Laboratory Directors' Council

NNMI: National Network for Manufacturing Innovation

NNSA: National Nuclear Security Administration

NRIC: National Reactor Innovation Center

NVBL: National Virtual Biotechnology Laboratory

OE: Office of Electricity

OLN: Oppenheimer Leadership Network

ORNL: Oak Ridge National Laboratory

OSELP: Oppenheimer Science and Energy Leadership Program

OSPP: Office of Strategic Planning and Policy

OTT: Office of Technology Transitions

PACT: Practices to Accelerate the Commercialization of Technologies

PMA: President's Management Agenda

PPE: Personal Protective Equipment

PNNL: Pacific Northwest National Laboratory

P-TEC: Partnership for Transatlantic Energy Cooperation

QIS: Quantum Information Science

RFS: Renewable Fuel Standard

ROI: Return on Investment

RPS: Radioisotope Power System

RTIC: Research and Technology Investment Committee

R&D: Research and Development

SBIR: Small Business Innovation Research

SC: Office of Science

SC-BES: Office of Science – Basic Energy Services

SCGSR: Office of Science Graduate Student Research Program

SEAB: Secretary of Energy Advisory Board

SMART: Science-informed Machine Learning to Accelerate Real Time

SNL: Sandia National Laboratories

SPP: Strategic Partnership Agreement

SRF: Superconducting Radio Frequency

STTR: Small Business Technology Transfer

SWPF: Salt Waste Processing Facility

S&T: Science and Technology

TAA: Technical Assistance Agreement

TCF: Technology Commercialization Fund

TIR: Technologist in Residence

TLA: Technology Licensing Agreement

TREAT: Transient Reactor Test Facility

TRL: Technology Readiness Level

T2M: Tech-to-Market

T&Cs: Terms & Conditions

VA: Department of Veterans Affairs

WMD: Weapons of Mass Destruction

U.S. DEPARTMENT OF
ENERGY