ANNUAL REPORT ON THE STATE OF THE DOE NATIONAL LABORATORIES

JANUARY 2017

U.S. DEPARTMENT OF
ENERGY

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About the Cover

The DOE National Laboratories comprise a singular network that spans the United States and works to support DOE's missions in science and energy research, national security, and environmental stewardship. The photos on the cover represent the mission-focused work that these 17 National Laboratories perform. While each Laboratory has its own unique scientific tools, facilities, capabilities, and projects, the National Laboratories also engage in crosscutting science activities and collaborative projects that leverage their talents and assets. From basic research and scientific discovery to development and demonstration of advanced technologies and other innovations, these 17 world-class institutions constitute the most comprehensive research and development network of its kind.

Disclaimer

The financial data presented in this report is drawn from multiple sources and based on data available at the time of the report's production. As a result, some differences exist in the data presented in the report. For example, in some figures and text, the financial data is drawn from all of DOE's National Labs, but not DOE sites and facilities. In other instances, the data is inclusive of the Labs, as well as sites and facilities.

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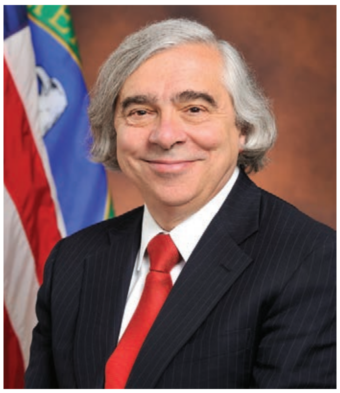
Message from the Secretary of Energy

The Department of Energy (DOE) is responsible for maintaining a safe, secure and effective nuclear deterrent without nuclear explosive testing and for reducing the threat from nuclear proliferation and terrorism from loose nuclear materials anywhere; for advancing a clean, secure and prosperous energy future through innovation; for sustaining America's leadership in scientific research by advancing scientific frontiers and providing cutting-edge facilities for the entire American research community; and for carrying out the legal and moral imperative for environmental cleanup of the massive Cold War nuclear weapons complex. Success in these missions has required that DOE build and nurture a powerful science and technology (S&T) organization, and the need for this will only grow in importance as nuclear security, climate change risk mitigation and American scientific leadership face evolving challenges. DOE's seventeen National Laboratories, operating in fifteen states, form the core of this S&T organization. The special scientific facilities and capabilities of the DOE Labs also serve other key Federal missions, from biomedical research with the National Institutes of Health to technology-demanding national security requirements of the Department of Defense, the intelligence community and the Department of Homeland Security. This extraordinary system of National Labs is unique and, along with America's research universities, underpins our innovation edge for economic productivity and job creation, security and environmental stewardship.

This first Annual Report to Congress on the State of the DOE National Laboratories provides a comprehensive overview of the Lab system, covering S&T programs, management and strategic planning. The Department committed to prepare this report in response to recommendations from the Congressionally mandated Commission to Review the Effectiveness of the National Energy Laboratories (CRENEL) that the Department should better communicate the value that the Laboratories provide to the Nation. We expect that future annual reports will be much more compact, building on the extensive description of the Laboratories and of the governance structures that are part of this first report.

Effective stewardship of the scientific vitality and capability of the Laboratories is a principal responsibility of the DOE and specifically of its senior leadership. All three Under Secretaries—Science and Energy, Nuclear Security, Management and Performance—are stewards of at least one National Lab, and the Office of Science alone operates ten. The Laboratory leadership in turn is responsible for recruiting and retaining outstanding scientific and technical talent and for applying it effectively and efficiently to governmental missions, while also working with academia and industry to advance broader national goals. These complementary responsibilities called for a renewed sense of strategic partnership between the DOE and Laboratory leaders, and substantial steps forward have been taken in the last few years. These include establishment of a Laboratory Policy Council, chaired by the Secretary and engaging Lab directors, and a Laboratory Operations Board to address key management challenges. The impact has been felt in how important S&T directions are set, in progressing from transactional to mission-driven governance, and in a shared commitment to revitalize Lab infrastructure.

Another notable development in the last years has been the increased effectiveness of the National Laboratories in working cooperatively as networks to address major S&T-based challenges, such as electric grid modernization or crosscutting subsurface science and engineering for a variety of energy technologies. This approach builds on long-standing Lab cooperation to advance foundational technologies, such as high performance computing and accelerator development, both of which have had pervasive impact on our economy, health, science and security. The Laboratories have also functioned as "on-call" networks to answer the bell for national and international emergencies, from securing at-risk nuclear materials in the former Soviet Union as it fell apart, to assisting Japan in its Fukushima response, to helping limit the international Ebola outbreak and resolve the Macondo and Aliso Canyon oil and natural gas leaks in the United States. The capabilities needed to respond quickly to such diverse situations cannot be created on demand—it requires sustained nurturing of leading S&T organizations dedicated primarily to governmental functions. All of these facets of the DOE National Laboratory system, and more, are summarized in this Annual Report.



Progress has been made, and work remains to be done. We appreciate the engagement and support in Congress to continuously improve the National Labs as critically important institutions with a unique role within the overall American research enterprise. As we approach the end of this Administration, we feel confident in passing the baton with a DOE National Laboratory system that has continued its tradition of outstanding S&T addressing security, energy, scientific and environmental imperatives and has been strengthened to take on 21st century challenges with distinction.

Ernest J. Moniz
Secretary of Energy

Acknowledgments

The Department of Energy gratefully acknowledges the following individuals and groups that worked to produce and improve this inaugural report on the state of the DOE National Laboratories.

The report was developed by Adam Cohen, Kevin Doran, and David M. Catarious, Jr., with significant contributions from Alison Markovitz and the members of the Laboratory Operations Board, Karen Gibson, Alfred Sattelberger, Vivian Sullivan, Patricia Falcone, Jack Anderson, Margaret Dick, David Keim, Kim Williams, Charles Russomanno, and Alison Doone.

Reviewers for the report include Secretary Ernest Moniz; Arun Majumdar and the members of the SEAB Laboratory Task Force; William Goldstein, Steven Ashby and the members of the National Laboratory Directors' Council and its working groups; Under Secretary Franklin M. Orr, Jr., and members of the Science and Energy organizations; Under Secretary Lt. Gen. Frank Klotz and members of the National Nuclear Security Administration; Deputy Under Secretary David Klaus and members of the Management and Performance organizations; and Joseph Hezir and members of the Chief Financial Officer's organization.

The Oak Ridge Institute for Science and Education provided exceptional assistance in producing the final version of this report.

Executive Summary

At its core, the Department of Energy (DOE) is a science and technology enterprise focused on four principal national missions: clean energy innovation; scientific leadership and discovery; nuclear security; and environmental stewardship of the nuclear weapons complex. DOE's scientific and technical capabilities are rooted in its system of National Laboratories—17 world-class institutions that constitute the most comprehensive research and development network of its kind. This first Annual Report on the State of the DOE National Laboratories describes the DOE National Laboratory System, its role in advancing the frontiers of science and technology, and efforts to ensure it continues as a national resource for the Department's near- and long-term missions.

Formed from strategic national investments in science during and following World War II, the National Laboratories have delivered solutions to some of the most challenging national energy issues. Each Laboratory has distinct but complementary capabilities, and the 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. The Laboratories, with their focus on mission-driven science and engineering, fill an innovation ecosystem gap in research, development, and demonstration (RD&D). Universities emphasize teaching and discovery science and tend to focus on research by a single faculty member or small groups of faculty members, while industries respond to market needs and typically focus their RD&D on near-term solutions or the integration of multiple technologies. National Laboratories tackle multidisciplinary problems with long time horizons, often coupling fundamental discovery research, technology development, and demonstration projects. In addition, the Laboratories conduct RD&D in some areas that are not pursued by either universities or industry, such as high-hazard, classified nuclear security work.

As elements of a system with complementary capabilities, the National Laboratories tackle the energy, science, national security, and environmental stewardship challenges that make up the core missions of the DOE.

Laboratories pursue research to make fossil-based energy sources cleaner at lower cost, to move from a reliance on fossil fuels to renewable sources, to advance the state of the art in nuclear power, to reduce overall energy usage by minimizing energy losses, to reduce the waste footprint of energy systems through carbon sequestration and other approaches, and to develop and test technologies to keep energy infrastructure secure from cyber and physical attacks. The National Laboratories also advance the fundamental understanding of the impacts of energy production and use on the environment, and they develop tools for mitigating and adapting to those impacts.

Scientific discovery expands our knowledge of the natural world and forms the foundation for future technologies. In concert and collaboration with university partners, the National Laboratories work at the forefront of fundamental research, unveiling secrets of the basic building blocks of matter, such as quarks, neutrinos, and the Higgs boson.

They are also peering deep into space, seeking an understanding of the dark matter and dark energy that seem to dominate the universe yet remain mysterious. They are creating a new generation of materials (including biological and bio-inspired materials) to underpin advances in energy generation, storage, transmission, efficiency, and security. Creating such materials requires a level of comprehension of the relationships between structure and function, and across many spatial and time scales, which is not yet fully supported by our understanding of the physical world. As an integral part of the effort, the Laboratories design, build, and operate a world-class network of unique and leading-edge user facilities, such as x-ray and neutron sources, advanced accelerators and laser facilities, and nanomaterials facilities, that benefit the research of over 33,000 researchers from academia, Federal Laboratories, and industry annually. This network is envied worldwide and has often been emulated but not yet duplicated. Since 2008, research affiliated with DOE and the National Laboratories has led to six Nobel Prizes—four in chemistry and two in physics. DOE and its predecessor agencies have been associated with the Nobel Prizes awarded to 115 Nobel Laureates.[1]

The National Laboratories play a vital role in maintaining and enhancing the safety, security, and effectiveness of the U.S. nuclear weapons stockpile. The National Laboratories take the lead in RD&D that supports the national security missions of DOE, and they partner with other Federal departments and agencies to provide innovative solutions in the broader areas of defense, homeland security, cybersecurity, and intelligence. Their ongoing success in this effort lies in their ability to combine cutting-edge research and development (R&D) with deep subject-matter expertise and experience.

Decades of weapons production and energy research during the Manhattan Project and the Cold War left an environmental legacy that the DOE is managing and cleaning up. The Laboratories provide research, development, and analysis that support the cleanup effort to ensure continued progress on reducing the legacy footprint.

National Laboratory Complex at a Glance

Research Output:

- 11,000 peer-reviewed publications annually in 1,500 journals and periodicals
- Collaborations with 450 academic institutions in the U.S. and Canada
- 2,395 Strategic Partnership Projects (SPPs) involving nonfederal entities (NFEs)
- 734 Cooperative Research and Development Agreements (CRADAs)
- 577 commercialized technologies
- 6,310 active technology licenses

Physical Assets:

- 813,000 acres
- 53M gross square feet (GSF) in 4,740 buildings
- Replacement plant value: $53B
- 1.5M GSF in 193 excess facilities
- 5M GSF in leased facilities

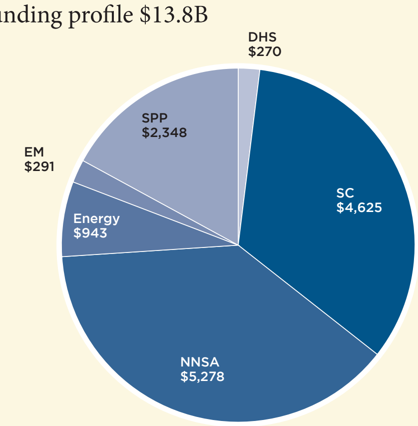
Human Capital:

- 57,600 full-time equivalent employees (FTEs), with over 20,000 scientists and engineers
- 1,285 joint faculty
- 2,300 postdoctoral researchers
- 2,950 undergraduate students
- 2,010 graduate students
- 33,000 facility users
- 10,600 visiting scientists

FY 2015 Costs by Funding Source

(Cost Data in $M)

Labs funding profile $13.8B



FY 2015 Lab operating costs: $13.8B

FY 2015 DOE/NNSA costs: $11.6B

FY 2015 SPP (Non-DOE) costs: $2.6B

FY 2015 SPP/DHS %Total Lab operating costs: 18%

Note: Certain numbers rounded; National Nuclear Security Administration (NNSA); Department of Homeland Security (DHS)

[1] For a full list of 115 Nobel Laureates associated with DOE, see http://science.energy.gov/about/honors-and-awards/doe-nobel-laureates/.

The National Laboratories play an important role in training the next generation of scientists and engineers in DOE mission-relevant disciplines, and in moving innovation to the marketplace to strengthen U.S. competitiveness. With a deep bench of scientific expertise, the National Laboratories are positioned to be among the Nation's most effective "on call" resources for tackling emergent challenges of a technical nature—from oil spills and crises such as the Fukushima nuclear disaster to the threat of unsecured nuclear materials and globally significant imperatives such as the negotiations on Iran's nuclear program.

Among the accomplishments that demonstrate the Laboratories' value to the Nation and to the American taxpayer, DOE's National Laboratories have

- developed energy efficiency technologies and standards that have saved U.S. taxpayers over $1 trillion;
- facilitated cost reductions in wind and solar energy generation, batteries, and light-emitting diode production;
- conducted fundamental and applied research that enabled both the shale gas revolution and the development of nuclear energy, photovoltaics, and energy storage for the transportation industry;
- delivered forefront scientific discoveries, from new chemical elements to new states of matter;
- sustained a safe and secure U.S. nuclear weapons stockpile in the absence of nuclear testing through high performance computing, cutting-edge innovations in facilities, and other advanced technologies; and
- developed process improvements that have achieved life cycle savings of over $5 billion to the DOE Office of Environmental Management programs.

The energy and national security landscapes will continue to change rapidly, presenting many new opportunities and challenges for the Nation. Decades-long investments in RD&D have transformed energy markets. Evolving threats have created significant national security challenges in combating nuclear terrorism and proliferation and throughout the broader national security agenda, while advances in technology have created the need for greater cyber security, especially to safeguard our energy infrastructure. Addressing these opportunities and challenges will require multidisciplinary approaches and a combination of research capabilities—both of which are hallmarks of the National Laboratory System and the partnerships it enables and attracts. To pursue the innovation and world-class science and technology needed to meet the Department's missions and as appropriate to apply the capabilities to other agencies' missions, it is imperative that the vitality of the National Laboratories be maintained, enabling the National Laboratories to work together as an integrated system with their collective capabilities efficiently and effectively leveraged.

State of the Labs

The DOE National Laboratory System continually refreshes its facilities and capabilities to support the Department's evolving missions. From the Atomic Energy Commission's early focus on the design and production of nuclear weapons and nuclear power to the current and expansive operation of the DOE, the system has evolved to tackle compelling problems across the full range of DOE missions and to leverage the capabilities for advancing a broad range of missions for other agencies, from support for the intelligence communities to biomedical research. The vitality of the DOE National Laboratories has improved over the past decade in part due to investments made through the American Recovery and Reinvestment Act and from a focus on enhancing the relationship between the Laboratories and the DOE, but hurdles remain in recruiting and retaining the best and brightest researchers and staff, updating aging infrastructure for 21st century needs, continuing to improve operational efficiencies, and further strengthening the partnership with DOE.

DOE manages the 16 National Laboratories that are Federally funded research and development centers (FFRDCs) through management and operating (M&O) contracts with industrial, academic, or nonprofit institutions. The Department's unique M&O contracting model grew out of the Manhattan Project and ensured government control of fissile material production while utilizing private-sector management expertise and resources. Under the government-owned, contractor-operated (GOCO) model, DOE is responsible for establishing strategic and program direction, while the Labs apply their expertise to determine precisely how to meet technical and scientific challenges and carry out programs, all in the public interest. Rather than merely working as contractors that execute tasks established by DOE, the unique and adaptable M&O model enables the Labs and DOE to work in partnership, ensuring that the system remains agile in addressing changing national needs.

The 17th National Laboratory, the National Energy Technology Laboratory (NETL), is government-owned and government-operated (GOGO), similar to RD&D laboratories in other Federal Government agencies. In the GOGO model, the DOE both establishes strategic and program direction and conducts research and development activities, in support of its applied energy mission. While DOE largely adheres to the GOCO model, the use of this model is not unique to DOE.[2]

The National Laboratory System is an irreplaceable national asset with expertise, facilities and equipment, and science and technology (S&T) capabilities developed over many decades. Effective stewardship is accomplished through strategic leadership; thoughtful and sound management of human, physical, and digital assets; and strong mission execution across all aspects of operations. Stewardship relies on employing best-in-class processes, such as the Contractor Assurance System (CAS) used by M&O contractors to ensure that mission objectives are accomplished as specified in contracts, and best-in-class environmental, safety, health, and security processes. Among the challenges faced by all Laboratories are maintaining a skilled workforce and sustaining the unique, complicated, fragile, and often aging infrastructure that supports the suite of critical facilities and assets.

Recent reviews of the National Laboratory System all noted the value of this system to the Nation. Each of these reviews—including the Commission to Review the Effectiveness of the National Energy Laboratories (CRENEL), the Congressional Advisory Panel on the Governance of the Nuclear Security Enterprise, chaired by Admiral Richard Mies and Norman Augustine (Mies-Augustine), and the Secretary of Energy Advisory Board's (SEAB) Task Force on the DOE National Laboratories—also observed that since the end of the Cold War, oversight by DOE grew increasingly transactional rather than strategically mission-driven. The Secretary has set a priority on reestablishing a mission-oriented relationship in which the government provides strong guidance on what should be done—established in partnership with the Labs through such mechanisms as the Lab Policy Council and the Big Ideas Summit—and the Laboratories have the responsibility for determining how to accomplish the necessary work.

Actions Taken and the Path Forward to Enhance the Vitality of the DOE National Laboratory System

Broadly, DOE is engaged in activities such as the international Mission Innovation initiative and DOE's Portfolio Planning process, which involve developing a framework for RD&D activities over the next five years that include planned investments at the National Laboratories. In addition to these broad planning exercises, over the past few years the Department has taken targeted actions to maintain and enhance the vitality of the Laboratory System, some of which are described below. The CRENEL report organized issues and recommendations into six themes: recognizing value, rebuilding trust, maintaining alignment and quality, maximizing impact, managing effectiveness and efficiency, and ensuring lasting change. These themes, which are used to structure the February 2016 DOE response to the CRENEL report, are also used to organize this report and describe the actions that DOE and the National Laboratory leadership are taking to improve the relationship and strengthen the partnership.

Recognizing Value

DOE has taken several steps to highlight the National Laboratories as a critical national resource, including this inaugural ***Annual Report on the State of the DOE National Laboratories***. The ***Quadrennial Energy Review***

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[2] The Department of Defense uses the GOCO model for the Lincoln Laboratory, operated by the Massachusetts Institute of Technology; and the National Aeronautics and Space Administration uses the model for the Jet Propulsion Laboratory, managed by the California Institute of Technology.

and the ***Quadrennial Technology Review*** drew substantially from Laboratory expertise to delineate energy technology and policy development and the enabling science required for future technology breakthroughs; the ***Annual Technology Transfer and Related Technology Partnering Activities*** report, which details technology-transfer–related transactions, highlights intellectual property and success related to technology transfer and industrial partnering at the Laboratories; the ***Stockpile Stewardship and Management Plan*** and the ***Prevent, Counter, and Respond—A Strategic Plan to Reduce Global Nuclear Threats*** integrate requirements across Laboratories, plants, and sites; the ***U.S. DOE Strategic Plan 2014–2018***, published in April 2014, establishes goals for the core missions of DOE, highlights major priorities, and provides the basis for individual DOE program plans; and the ***National Lab Day on the Hill*** event series shares the Laboratories' extraordinary work with members of Congress.

Rebuilding Trust

DOE and the Laboratories have improved management and performance to more effectively and efficiently execute the missions of both the Department and the Laboratories while reinvigorating an FFRDC relationship built on trust and accountability. The ***Laboratory Policy Counci***l (LPC), chaired by the Secretary and comprising senior DOE leadership and the executive committee of the National Laboratory Directors' Council (NLDC), convenes three times a year; the monthly ***Laboratory Operations Board*** (LOB) meeting includes DOE leadership and NLDC representatives focused on management and operations issues (the Board also will monitor CRENEL implementation and review its effectiveness); the ***Office of Technology Transitions*** provides the vision, high-level goals, and coordination of technology transfer at the Laboratories; other ***DOE committees and councils***, such as the Directives Review Board and the Cyber Council, target specific topics; ***contracting model pilots*** seek to improve efficiency and reduce transactional oversight at Fermi National Accelerator Laboratory and SLAC National Accelerator Laboratory; National Nuclear Security Administration (NNSA) is developing a contracting strategy to better apply ***incentive and fixed award fees*** for NNSA contracts; and a ***CAS*** policy has been updated to better align oversight with risk.

Maintaining Alignment and Quality

DOE is working to improve Laboratory planning and evaluation; manage the Laboratories as a system; and examine procedures to allow Laboratories flexibility to maintain excellence in facilities and expertise in research staff. The ***National Laboratory Big Ideas Summit*** convenes Lab scientists and DOE program leadership to explore innovative solutions to major crosscutting energy issues and has resulted in initiatives such as the Grid Modernization Laboratory Consortium, which is pursuing an adaptive and resilient U.S. electric grid.

The ability to attract and retain the best scientific, technical, management, and operational staff is key to the National Laboratories' success in meeting evolving National needs, and the ***Energy Sciences Leadership Group*** engages emerging Laboratory leaders and academic partners around current scientific and energy challenges. The Laboratories face several ongoing challenges related to ***inclusion and diversity***, including maintaining critical skills as the Laboratories' workforce ages, particularly in areas that are both core and unique to DOE (e.g., stockpile stewardship and accelerator design), and in training of students, postdoctoral researchers, and staff for the continuing challenges in national security, science, and energy technology. A special focus has been placed on increasing workforce diversity and making certain Lab operations are inclusive of all staff to ensure the best ideas are integrated into planning, management, R&D, and operations.

Maximizing Impact

To encourage oversight focused on fulfillment of DOE missions rather than on transactional Laboratory operations, the current Secretary modified the Department's leadership and management structure. The new structure addresses evolving science and energy, security, and environmental challenges while enabling significant crosscutting work across the Complex and engaging the approximately 14,000 Federal employees and over 50,000 employees at the National Laboratories as well as over 50,000 employees at our plants, sites, and other locations. The Directors of each of the Laboratories comprise the ***National Laboratory Directors'***

Council (NLDC), which is organized under a memorandum of understanding among the 17 Laboratories and engages with DOE management on strategic and operational issues. The four members of the NLDC Executive Committee also serve on the DOE Laboratory Policy Council. In addition, DOE has established multiprogram initiatives that cut across traditional budget lines to engage the Laboratories on critical challenges, including grid modernization, resiliency of interdependent energy-water systems, accelerated deployment of advanced materials, and advances in subsurface science, exascale computing, and supercritical CO2 technology. Finally, the new ***Office of Technology Transitions*** and the ***Technology Commercialization Fund*** improve coordination and provide funding to transition early-stage R&D to applied technologies through technology transfer, commercialization, and deployment activities.

Managing Effectiveness and Efficiency

DOE has improved how, when, and why it establishes requirements through ***directives, policy memoranda, and acquisition letters***, developing a streamlined annual prioritized schedule, implementing senior-level line direction, and creating an expedited process for minor changes to directives. DOE is better managing ***Laboratory data calls***, has expanded the Office of Science's project management processes across DOE so that Science's successful approach can benefit other DOE offices, and has established an enterprise-wide initiative through the LOB to improve ***infrastructure planning*** to address the significant challenges created by aging facilities and utilities.

DOE and the National Laboratories worked together to implement ***procurement*** mechanisms such as reverse auctions to increase funds available for R&D missions; reached an agreement with the SBA to include ***small business*** contracting at National Laboratories in the DOE's reporting to SBA; and coordinated ***cybersecurity*** efforts, including the Joint Cybersecurity Coordination Center (JC3) for incident response and the Department's Identity, Credentials, and Access Management (ICAM) initiative. These cybersecurity efforts provide a strong example of how the Department has marshalled enterprise-wide assets—including the deep expertise that resides in the National Labs—to address a mission-critical problem.

Ensuring Lasting Change

DOE is taking several steps to sustain the foundational changes described in this Report and to continue strengthening the relationship with the National Laboratories. The ***Secretary of Energy Advisory Board*** (SEAB), a Federal advisory committee comprising external members, provides key strategic insights that help to establish the Department's long-term research agenda. SEAB has also been charged with reviewing the progress of the Department's implementation of actions and offering further recommendations that build on the previous results. This ***Annual Report on the State of the DOE National Laboratories*** will be updated with new results and improvements annually in the fall. Finally, the ***DOE Transition Plan*** will provide the new administration with an overview of the current Laboratory System and actions necessary for further progress.

Conclusion

The challenges that must be addressed in DOE's mission space—from understanding and predicting climate change impacts and pursuing innovative solutions for energy to continuously improving nuclear security and applying unique capabilities to answer interesting and important scientific questions—underscore the critical need for the DOE National Laboratory System's capabilities and competencies. Through its M&O contracts, the DOE has an adaptable structure for lasting impact and value to the Nation. The reports issued by CRENEL, Mies-Augustine, SEAB, and others describe needed reforms, and DOE and the NLDC are working together to pursue these reforms, as DOE articulated in its responses to those reports. DOE and the National Laboratories recognize their stewardship responsibilities and the need to ensure the vitality of this invaluable resource. Collectively, they have pursued actions to substantially improve the Laboratory System. Together, they will continue to work to maintain and develop the most comprehensive research network of its kind—a system of National Laboratories that can effectively tackle long-term, critical R&D challenges for the Nation.

1 Introduction

The Department of Energy (DOE) is, at its core, a science and technology organization that advances critical missions for the American people: clean energy innovation, energy security, scientific leadership and discovery, nuclear security, and environmental cleanup. In addition, the Department has resources and expertise for emergency response and technology transfer. The science and technology, environmental management, and nuclear security missions of the Department are operationalized through three Under Secretaries who are accountable to the Secretary and Deputy Secretary: the Under Secretary for Science and Energy (US/SE), Under Secretary for Management and Performance (US/MP), and Under Secretary for Nuclear Security (US/NS) (see Figure 1-1.). In each of the Department's mission areas, the pursuit of advances in science and technology plays a foundational role. With capabilities that cut across the needs of the Department's mission areas—such as high performance computing and accelerators—the National Laboratories are key to mission success across the broad spectrum of DOE's responsibilities and are an asset for the Nation as a whole. Particularly given the need for broad innovation in meeting all of the Department's missions, it is critical that the vitality of the National Laboratories is maintained, that the National Laboratories work as a system such that all of the capabilities can be used most effectively and efficiently, and that the National Laboratories are a valuable partner with the Department in pursuing the solutions to the mission needs.

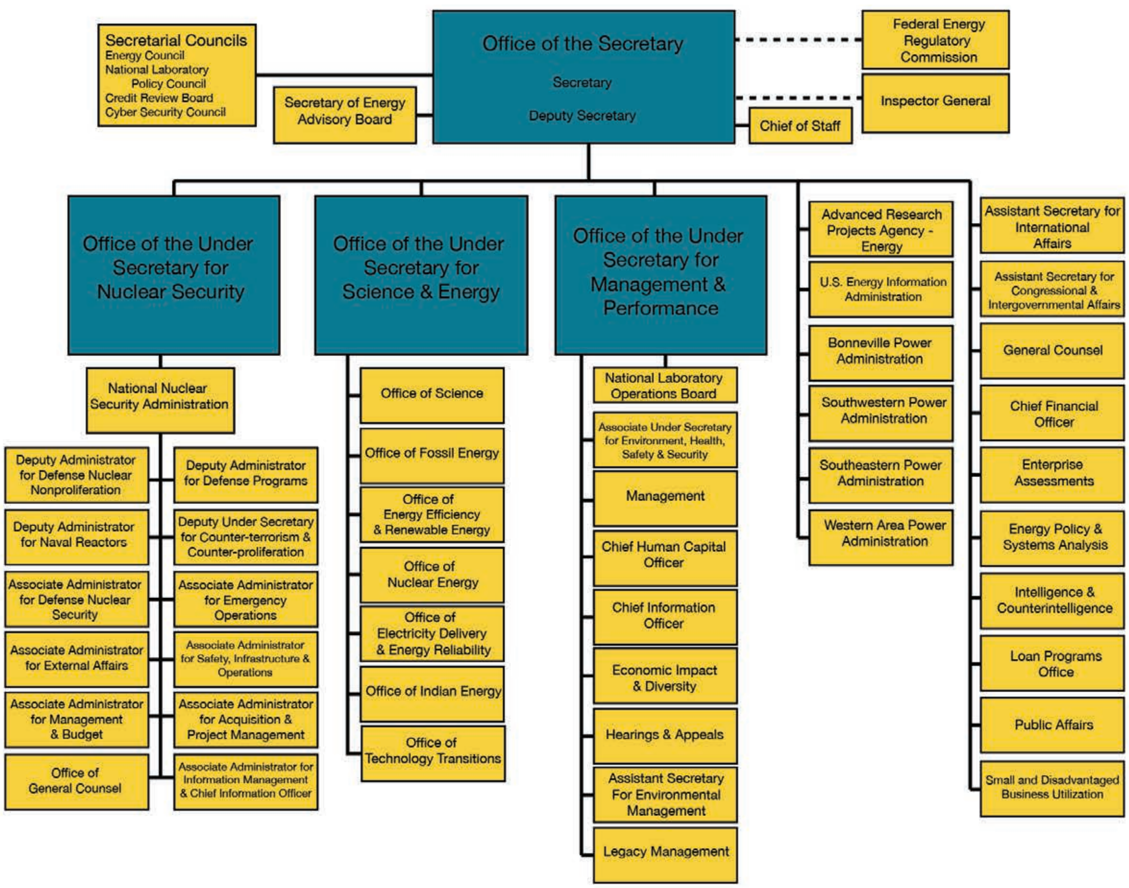
In the "Departmental Response to the Final Report of the Commission to Review the Effectiveness of the National Energy Laboratories," the Department committed to provide an annual report to Congress on the state of the DOE National Laboratory System beginning in 2016. This report is the inaugural edition.

The purpose of this report is to describe key initiatives of the National Laboratory System, including how the system is serving the Nation through collective and crosscutting activities and how the Department is strengthening the strategic partnership with the National Laboratory System. The report also describes DOE's operational successes and continued challenges in its stewardship of the Laboratories, including DOE's progress on implementing improvements. This inaugural report is comprehensive, providing a history and background on the National Laboratories and establishing a foundation for future annual updates. This report represents a collaborative effort among the three Under Secretary offices and the DOE National Laboratories, and facilitated by the Laboratory Operations Board (LOB). The annual report has been reviewed by the Laboratory Policy Council (LPC) and issued by the Secretary.

While the United States remains the world leader in the excellence of its research institutions, international dynamics are changing. Ensuring future U.S. leadership in science and technology research will require sustained and strategic support on such critical issues as maintaining and improving cutting-edge scientific and engineering facilities and infrastructure, supercomputing and big data capabilities, equipment, instrumentation, workforce development, and more.

The remainder of this report describes how the Laboratories are currently fulfilling their mission to be world leaders in their respective mission areas and how DOE and the Labs are collaborating to ensure their edge is maintained into the future. Chapter 2 provides an overview of the Laboratory System, its place within the U.S. innovation enterprise, and its mission. Chapter 3 gives results for each of the major mission areas that have been accomplished by the DOE National Laboratories. Chapter 4 summarizes the core competencies and critical skills that the DOE National Laboratory System maintains on behalf of the Nation, and also gives details on crosscutting and underlying programmatic efforts. Chapter 5 provides details of the management competencies that support the accomplishment of the DOE missions, as well as challenges in the various operational areas. Chapter 6 describes the actions taken by DOE and the DOE National Laboratory System to improve the vitality of the DOE National Laboratories, the support of the DOE missions, and the relationship with DOE. Chapter 7 summarizes the state of the DOE National Laboratory System and the path forward on continued improvement of the system. Finally, appendices detail the history and evolution of the DOE National Laboratory System and provide descriptions of various elements related to running the Laboratories.

Figure 1-1: DOE Organizational Chart



2 Overview of the DOE National Laboratories

The period during and following World War II witnessed an immense investment by the United States Government in science and technology. Spurred on by the contribution of the research and development enterprise in winning the War, and by Vannevar Bush's seminal 1945 report "Science – The Endless Frontier," the U.S. Government laid the groundwork for scientific exploration that has helped sustain the Nation's economic and scientific well-being since 1945. In reference to the time period since World War II, a 2012 report by the President's Council of Advisors on Science and Technology described the changing tide as follows:

> *"The next 50 years witnessed a dramatic rise in Federal support for basic research. It created and drove the university research enterprise. The Federal Government went on to create the National Science Foundation in 1950 and greatly boost funding for the National Institutes of Health. Today, these institutions, along with the newer Department of Energy, remain the primary stewards of basic research in the United States. The partnership between universities and Federal research agencies led to some of the most profound and world-changing discoveries of the 20th century."* [3]

Today, the Federal Government partners closely with government-sponsored Laboratories, with public and private universities, and with industry to advance the Nation's science and technology (S&T) foundation. The groundwork laid by Vannevar Bush established the basis for collaborative team science involving large numbers of investigators and multiple institutions. Coordinated teams of researchers from different disciplines, possessing diverse skill sets and expertise, are a key characteristic of the modern U.S. innovation ecosystem.

Most Federal Laboratories are government-owned, government operated (GOGO) entities. This includes Laboratories run by the National Institutes of Health (NIH), the National Aeronautics and Space Administration (NASA), the Department of Agriculture, and the Environmental Protection Agency (EPA). By contrast, all but one of the U.S. DOE's National Laboratories are government-owned, contractor-operated (GOCO) entities, a model that started in WWII when the Army built Los Alamos and hired the University of California to operate the Laboratory under the leadership of Professor Robert Oppenheimer. In addition to operating under different and distinct legislative authorities, GOGOs and GOCOs also have important differences with respect to licenses, royalties, and other issues related to technology transfer.

As a whole, the Federal Government sponsors 43 Federally funded research and development centers (FFRDCs),[4] which are a specific type of GOCO entity. Formally established under Federal Acquisition Regulation 35.017, FFRDCs exist to support governmental missions, and they are designed to meet special, long-term needs that cannot be met as effectively by governmental or private sector entities. FFRDCs are

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[3] "Transformation and Opportunity: The Future of the U.S. Research Enterprise," PCAST, November 2012.

[4] A complete list of current FFRDCs is available at https://www.nsf.gov/statistics/ffrdclist/.

also required to maintain expertise in areas critical to the national interest, operate with objectivity and a high degree of autonomy, and provide agile and rapid response capabilities. While the general public may not be familiar with the term FFRDC, several FFRDCs are among the most well-recognized names in the S&T enterprise, such as DOE's Los Alamos National Laboratory (LANL) and NASA's Jet Propulsion Laboratory.

While a more complete explanation of the difference between the GOGO and GOCO operating models is provided in Appendix A, briefly, DOE selected the GOCO model for nearly all of its Labs as it was deemed the most effective method of allowing DOE to specify the mission and high-level objectives (the "what") while allowing competitively selected contractors to determine the best method to achieve them (the "how"). The GOCO model also permits the contractors that operate the Labs to invest Laboratory research and development (R&D) funds in areas of S&T that they believe will form the foundation of the most challenging up-and-coming problems. When Laboratory leadership manage their Labs well and exhibit astute planning, they can be rewarded with contract extensions. However, when DOE leadership believes that the Labs are not being managed well or strategically, the GOCO structure allows them to exercise the option to recompete the management of the Labs. This process allows the Department to change the management and leadership of the Labs while ensuring that the knowledge and expertise embodied in the research staff persist throughout leadership changes.

Figure 2-1: DOE National Laboratories

Ames Laboratory (Ames)
Argonne National Laboratory (ANL)
Brookhaven National Laboratory (BNL)
Fermi National Accelerator Laboratory (FNAL)
Idaho National Laboratory (INL)
Lawrence Berkeley National Laboratory (LBNL)
Lawrence Livermore National Laboratory (LLNL)
Los Alamos National Laboratory (LANL)
National Energy Technology Laboratory (NETL)
National Renewable Energy Laboratory (NREL)
Oak Ridge National Laboratory (ORNL)
Pacific Northwest National Laboratory (PNNL)
Princeton Plasma Physics Laboratory (PPPL)
Sandia National Laboratories (SNL)
Savannah River National Laboratory (SRNL)
SLAC National Accelerator Laboratory (SLAC)
Thomas Jefferson National Accelerator Facility (TJNAF)

With 16 GOCO FFRDCs, DOE stewards more FFRDCs than any other Federal agency (with the next-highest being the U.S. Department of Defense with ten and the National Science Foundation with four). In total, these 30 FFRDCs received nearly $84 billion in funding for fiscal years 2008 through 2012, with DOE's 16 FFRDCs receiving about 79 percent of this funding, or on average $13 billion per year.[5]

Including its one GOGO—the National Energy Technology Laboratory (NETL)—DOE's 17 research Laboratories are collectively referred to as the National Laboratories. Located across the United States, the 17 National Laboratories comprise the most comprehensive research network of its kind in the world (Figure 2-1). A summary history of the Laboratories is included in Appendix B. Additionally, while not classified as DOE National Laboratories, DOE and Naval Reactor operate Knolls Atomic Power Laboratory (KAPL) and Bettis Atomic Power Laboratory to provide naval propulsion for the Navy.

Collectively, the National Laboratories are the core assets through which the Energy Department achieves its mission of ensuring America's security and prosperity by addressing its energy, environmental, and nuclear challenges through transformative science and technology solutions.

The strategic engagement and oversight of the National Laboratories is thus one of the Department's most important responsibilities.

The United States is unique in the breadth and depth of scientific and engineering excellence possessed by its National Laboratories. In strategic partnership with DOE, the National Laboratories work individually, as a network, and with industry, academia, and other Federal agencies to focus on complex, mission-critical research, development, and demonstration (RD&D) activities. Through these activities—conducted at large scales and with significant, long-term investments of resources, including world-class scientific and technical expertise—DOE's National Laboratory enterprise serves as an enduring science and technology powerhouse for the Nation.

In support of DOE and other Federal partners, the National Laboratories conduct RD&D activities across multiple primary mission areas to serve specific national needs. These activities are designed to

1. Advance U.S. energy security and leadership in clean energy technologies to ensure the ready availability of clean, secure, reliable, and affordable energy;
2. Deliver discovery and innovation in physical, chemical, biological, engineering, and computational and information sciences that advance our understanding of the world around us;
3. Enhance global, national, and homeland security by ensuring the safety and reliability of the U.S. nuclear deterrent, helping to prevent the proliferation of weapons of mass destruction, and helping to secure nuclear materials around the world;
4. Develop deployable technologies for the safe cleanup of the DOE Nuclear Complex following five decades of nuclear weapons development, production, and testing;
5. Design, build, and operate cutting-edge scientific instrumentation and facilities—often of a scale impractical for universities—and make these resources available to the national research community;
6. Serve the national interest not only as leaders in science and technology, but also as rapidly deployable national assets in times of national need;
7. Move innovation to the marketplace and strengthen U.S. competitiveness; and
8. Train the next generation of scientists and engineers, particularly in DOE core mission areas.

In addition to performing the research, development, demonstration, and deployment activities for much of DOE's portfolio, the Laboratories are also key partners in determining the technological and policy

[5] See Federally Funded Research Center: Agency Reviews of Employee Compensation and Center Performance, GAO-14-593 (Aug 11, 2014), available at http://gao.gov/products/GAO-14-593.

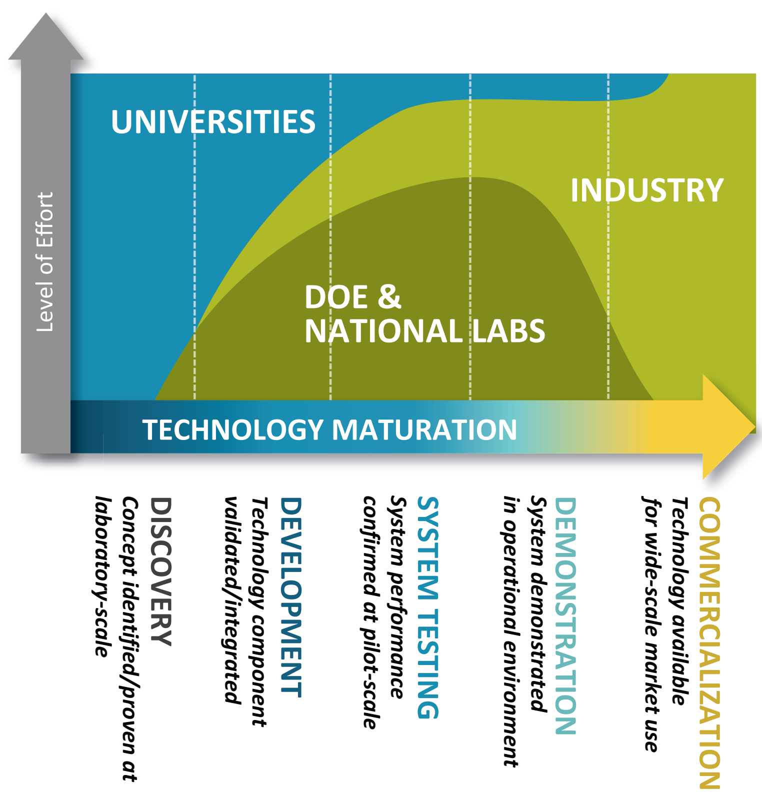
areas of strategic interest to DOE. There is a natural partnership between DOE and the Laboratories in this relationship: DOE, as the steward/owner of the Laboratories, has the inherently governmental responsibility for their missions, while the National Laboratories have the detailed understanding of the state of the field and actions needed for investments to meet the near-, mid- and long-term missions. This partnership has been strengthened appreciably in the last few years. Together, DOE and the National Laboratories can produce the most coherent plans for accomplishing the missions and conducting world-class R&D.

2.1 Occupying a Unique Position in the Nation's Science and Energy Innovation System

The Laboratories are an integral, unique, and indispensable component of the U.S. research enterprise, working together and in partnership with researchers from universities, companies, and other nations to create new knowledge, spur innovation, and address the most pressing S&T problems of the day. DOE's National Laboratories tackle the critical scientific challenges of our time—from combating climate change and discovering the origins of our universe to understanding the nuclear deterrent without testing—and possess unique instruments and facilities, many of which are found nowhere else in the world. They address large-scale, complex R&D challenges with a multidisciplinary approach that places an emphasis on translating basic science to innovation.

DOE National Laboratories help fill a critical gap in the Nation's energy innovation system, as shown in Figure 2-2. While there are areas of overlap, universities emphasize early discovery and tend to focus on research associated with individuals or small groups of faculty members. Companies respond to market needs

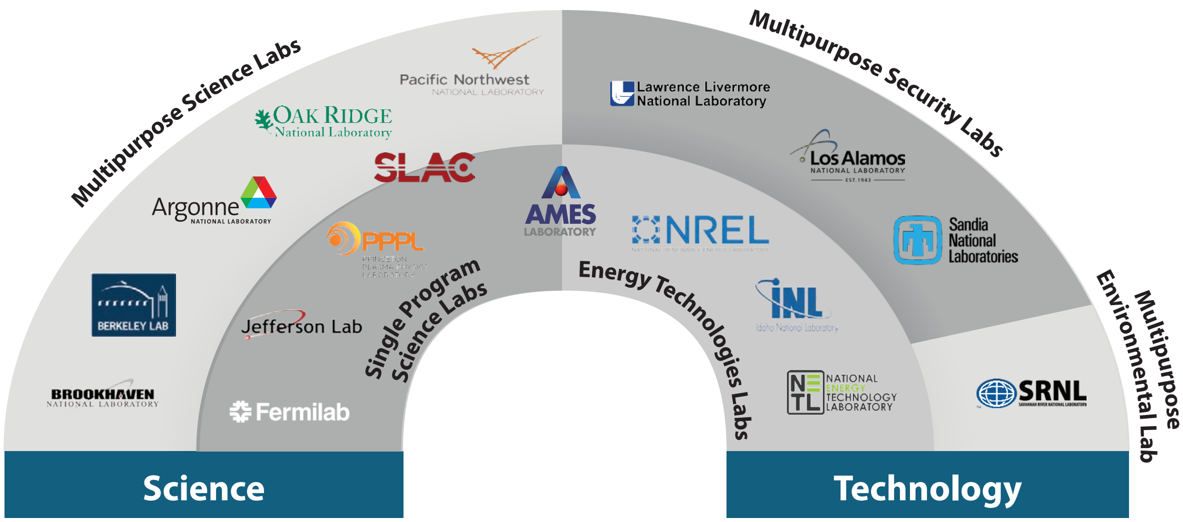
Figure 2-2: DOE National Laboratories' Relationship to Universities and Industry in the Energy Innovation System



and typically focus their R&D on near-term solutions or the integration of multiple technologies. National Laboratories have a particular capability to tackle multidisciplinary problems with long time horizons, often coupling fundamental discovery research, technology development, and demonstration projects. In addition, the National Laboratories conduct R&D in areas that are not pursued by either universities or companies, such as helping to safeguard and manage the Nation's nuclear stockpile.

Generally, National Laboratories are either science-oriented or technology-oriented, and they can serve multiple DOE programs and other sponsors or a single program. While the whole network is associated with DOE's mission areas, each National Laboratory has a unique set of core competencies, facilities, and focus areas.[6] As a system, they provide complementary capabilities that collectively support DOE mission needs in both the near and long term. Further, through Strategic Partnership Projects (SPPs), the National Laboratories leverage their unique, core capabilities in support of other agencies' missions and those of private partners.

Figure 2-3: Types of DOE National Laboratories



The 17 National Laboratories vary in structure, with each optimized for creating a certain value for the system. Figure 2-3 illustrates the diverse missions and types of DOE National Laboratories, from basic to applied research, and from single-program to multidisciplinary functions.

The Energy mission of the DOE is served in large part by three Energy Laboratories that focus on the different parts of an "all of the above" energy strategy: National Renewable Energy Laboratory (NREL), Idaho National Laboratory (INL), and NETL. As with Science Labs, there are both multipurpose and single-purpose Energy Labs. INL is a multipurpose Energy Lab with primary focus on nuclear power while also advancing other clean energy technologies and critical infrastructure protection. NETL and NREL are single-purpose Energy Labs. NETL is focused on fossil energy, and NREL on renewable energy.

The multipurpose Science Labs are Argonne National Laboratory (ANL), Lawrence Berkeley National Laboratory (LBNL), Brookhaven National Laboratory (BNL), SLAC National Accelerator Laboratory (SLAC; most recently transitioning from being a single-purpose Physics Lab into a multipurpose Science Lab), Pacific Northwest National Laboratory (PNNL), and Oak Ridge National Laboratory (ORNL).These bring together a spectrum of facilities, capabilities, and research programs that is a key part of the DOE toolbox. These six Labs have common features, e.g., programs in materials and chemistry, data science, and nanoscience, which form an infrastructure for doing multidisciplinary, crosscutting science.

[6] See section 4.8 for a description of the organizational alignment of the Labs with DOE's Program Offices and their core capabilities.

But within each of these Labs are unique large-scale facilities for special types of programs that differentiate one Lab from another. For example, ANL has the Advanced Photon Source, a hard x-ray facility, a very large-scale computation effort, and an important focus on energy storage and transportation. ORNL has large instrumentation associated with neutron science, facilities for computing at the largest scale, activities in nuclear fusion in isotopes, and research in applied materials. Although all of the multipurpose Science Labs share a common way of doing business, the functions they execute are distinctive and depend on the particular facilities inside each Laboratory. Importantly, as these facilities are developed over time, each Lab's facilities and programs reinforce one another, and each makes the other stronger.

The four single-purpose Science Labs—Fermi National Accelerator Laboratory (FNAL), Thomas Jefferson National Accelerator Facility (TJNAF), Princeton Plasma Physics Laboratory (PPPL), and Ames Laboratory (Ames)—focus on fundamental discoveries of matter and force in the universe, and how to harness that knowledge for human benefit. FNAL is tasked with investigating forces at the highest energy in elementary particle physics. TJNAF looks at the forces inside nuclei in nuclear physics, PPPL concerns plasma physics and fusion energy, and Ames is dedicated to condensed matter physics and materials science. Each of these Labs provides a core expertise that is available to the other Labs.

In the area of security, the National Nuclear Security Administration (NNSA) manages three Labs dedicated to the science and technology of keeping the Nation safe: Lawrence Livermore National Laboratory (LLNL), Sandia National Laboratories (Sandia), and LANL are involved in nuclear design. The existence of two Laboratories in this important area allows specialization and creates a community for collaboration, as this work is not peer-reviewed in the open literature. Because of the complex and often classified nature of this research space, it is critical to have two entities that can conduct peer reviews to ensure a safe, secure, and reliable program. Other Labs such as ORNL, INL, and PNNL, frequently interact with the NNSA Labs to lend their expertise on security issues. SNL is responsible for the nonnuclear design of the nuclear systems, and the system integration role. And although the three National Security Labs share a general mission space, these Labs, like the multipurpose Laboratories, have complementary facilities, such as the plutonium large-scale facility at LANL, or the National Ignition Facility at LLNL.

Savannah River National Laboratory (SRNL) is a multipurpose Lab dedicated to environmental remediation and to understanding the behavior of elements as they flow through the environment. This specific role lends itself to security aspects such as nuclear detection and gas processing. Several other Labs—ORNL, INL, PNNL, and LANL—also engage in environmental R&D and interact with SRNL to share expertise.

The Labs are constantly evolving and changing in response to technical opportunities and changes in mission needs. For example, SLAC was built for the purpose of discovery science in high energy physics. While their unique linear accelerator enabled many scientific breakthroughs, in the last decade it became clear that this accelerator could be used to create a new type of x-ray laser. This x-ray laser could in turn enable ultrafast studies of materials and chemical science, as well as new approaches to structural biology and fusion science. Thus, a single-purpose Laboratory transitioned into an important mission area where the DOE had a critical need—an area related to structural biology, chemistry, and fusion.

2.2 Operating Specialized R&D Facilities in the Public Interest

One of the primary avenues through which the Labs develop and maintain specific core competencies is through designing, developing, and operating distinctive and specialized R&D facilities that provide world-class capabilities for a broad research community. This suite of facilities—many of which would be impractical to house in a university or industry setting—is one of the primary factors that distinguishes the National Laboratories from the academic and industrial components of the U.S. research enterprise. These facilities are available to both academic and industrial partners and offer capabilities that are sometimes unique in the world. The DOE supports two broad types of facilities that can be accessed by researchers from the S&T

community: designated user facilities and shared R&D facilities.[7] These facilities are accessed by more than 33,000 researchers each year.

Designated user facilities are typically purpose-built and feature an open-access operating mode in order to accelerate advancement of science and technology to meet DOE mission needs. These scientific user facilities provide researchers with the most advanced tools of modern science, including accelerators, colliders, supercomputers, light sources and neutron sources, and facilities for studying the environment, the atmosphere, and materials at the nanoscale. In FY 2016, researchers from all fifty states, the District of Columbia, and other nations used these facilities. To encourage innovation and the exploration of new scientific knowledge, the DOE removes financial barriers to researchers by both fully supporting the design, construction, and operational costs of these facilities and not charging fees for designated user facilities as long as researchers plan to openly publish the results in the scientific and technical literature. Moreover, users from universities, industry, and international partners often fund and install specialized experimental equipment at these facilities, further enhancing their scientific capabilities.

In addition to the user facilities, DOE operates shared R&D facilities that are typically constructed to meet specific program mission needs, but which may be available to users as the Program Office mission needs evolve. Examples of shared R&D facilities include the Biomass Feedstock National User Facility at INL, the Manufacturing Demonstration Facility at ORNL, and the High Performance Computing Innovation Center at LLNL. Access to these facilities is gained through other formal agreements, such as Cooperative R&D Agreements (CRADAs) and SPPs, with the host DOE National Laboratory. In these facilities, operational costs are supported by DOE for mission activities, but operational costs for all external use must be supported through cost recovery mechanisms. Shared R&D facilities are located throughout DOE's National Laboratory Complex and among university partners. Information regarding specific user and R&D facilities aligned to specific DOE mission areas is included in section 3.5.

The primary mission of these specialized R&D facilities is to enable DOE Laboratories and the rest of the Nation's research community and industrial partners to conduct nonproprietary, basic research to advance the DOE's core mission areas. However, the capabilities of these facilities are often of direct interest to other partners across the Federal Government, and as such, they are also used to enable nonproprietary, basic research to advance other Federal agency missions.

In addition, the unique character and capabilities of user and R&D facilities are also used to enable proprietary basic research, applied research, and experimental development by the Nation's industrial base.

2.3 Providing Science and Technology Expertise to the Federal Government, Academia and Private Sector Partners

While much of the focus of the Laboratories is to support the mission of DOE, they also engage in a broad range of partnerships across the entirety of the Nation's R&D landscape, including through partnering with each other, with the rest of the Federal Government, and throughout academia and industry. The DOE SPP program enables other Federal agencies and nonfederal organizations to take advantage of the Laboratories' specialized RD&D capabilities on a full-cost recovery basis. The SPP arrangements are critical to the vitality of the Laboratories as they in turn provide capabilities that can be applied to DOE missions. The Laboratories collaborate with universities in fundamental and applied research, as well as support the training of thousands of future scientists and engineers by supporting postdoctoral students, providing research opportunities to graduate students and offering research internships to undergraduates. The National Laboratories also partner with industry in technology development and deployment to ensure the transfer of their R&D to the marketplace. Finally, the National Laboratories apply their expertise, capabilities and facilities to solve R&D problems for other Federal agencies and for nonfederal sponsors.

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[7] A database of DOE facilities is available at http://energy.gov/technologytransitions/technology-transitions-facilities-database.

Partnerships with other Federal and nonfederal entities extend the impact of DOE investments. They are pivotally important in delivering on our mission to provide leadership in use-inspired science and engineering, to accelerate the transition of scientific discovery to the marketplace, and to deliver beneficial impacts to the Nation. While a majority of SPP activities support other Federal agencies, some of the highest impact partnerships address industry R&D challenges. By engaging with a broader base of customers on diverse problems, Laboratory scientists and engineers are able to work smarter in the core research portfolio, i.e., identify and work on problems of societal relevance, and thereby positively impact the Laboratories' ability to meet the missions of DOE's NNSA. In addition, partnerships with entities that are able to transition technology from an early proof-of-concept stage to a more commercially ready, higher technology readiness level are a primary way of delivering on the commercial impact requirements of our mission.

The drivers for engaging entities beyond DOE include

- reaching subject matter experts and specialized equipment that do not exist within the National Laboratory enterprise but can help achieve DOE's missions;
- assisting Federal agencies and nonfederal entities in accomplishing goals that may be otherwise unattainable, and to avoid the need to duplicate Federal facilities, as illustrated by the following examples:
  - The light and neutron sources are used extensively by NIH-funded researchers in pursuit of an understanding of biological function at the molecular, cellular, and organismal levels;
  - Climate modeling funded by the National Oceanic and Atmospheric Administration (NOAA) relies on the computational and data science capabilities at the National Labs;
- providing access for non-DOE entities to highly specialized or unique Laboratories and facilities, services, or technical expertise when private sector facilities with those capabilities are not available;
- increasing R&D interaction between DOE National Laboratories and industry to transfer technology originating at the National Laboratories to industry for further development or commercialization; and
- maintaining and advancing core capabilities, enhancing the S&T base at DOE National Laboratories, and continuing to accomplish the DOE missions.

This section describes how DOE's National Laboratories both individually and jointly pursue partnerships with each other and non-DOE Federal agencies and industrial and academic partners, as well as the mechanisms they use to formalize those relationships.

2.3.1 Federal Government Missions

While approximately 80 percent of the work conducted by the National Laboratories is funded by DOE, the National Laboratories represent a national resource for the entire Federal Government, and they engage in partnerships to leverage their capabilities and facilities to support the missions of Federal agencies other than DOE. The National Laboratories have played a vital role in ensuring the safety, security, and reliability of the U.S. nuclear arsenal and related nonproliferation activities. The Laboratories, through the effective use of science, technology, and systems solutions, enhance our Nation's capability to protect itself against high-consequence threats. The Labs have well-established R&D support agreements with agencies such as the Department of Homeland Security, the Department of Defense, and the Intelligence Community. The National Laboratories also work with the Department of State and the International Atomic Energy Agency on nonproliferation, civilian nuclear power R&D, nuclear waste recycling, and scientific diplomacy, and the National Laboratories lend their nuclear capabilities and infrastructure support to the deep space missions of NASA.

Supporting NASA's Space Missions

Several of the National Laboratories (INL, LANL, ORNL, SNL) developed a radioisotope power system to enable NASA's missions to Mars, Pluto, and many other destinations over the last 50 years. The use of space nuclear power technologies to power future missions to our solar system and beyond was codified in an updated memorandum of understanding between DOE and NASA in October 2016. These unique power systems are fueled by plutonium-238. Another example is the NASA Space Radiation Laboratory (NSRL) at BNL. Commissioned in 2003, the NSRL is funded by NASA and operated by BNL. The Booster Accelerator, which primarily feeds the Office of Science's Relativistic Heavy Ion Collider (RHIC) with heavy ions and protons for nuclear physics research, serves as the energetic heavy ion source for the NSRL. NASA-funded scientists use the beams of ions at NSRL to simulate cosmic rays and assess the risks of space radiation to human space travelers and equipment.

In FY 2015, the 17 National Laboratories received $2.3 billion in SPPs. Of that, the U.S. Department of Defense (DOD) was the primary partner. Other Federal partners (in funding order) were Health and Human Services (including the NIH), NASA, and the Nuclear Regulatory Commission (NRC).

National Laboratory expertise in developing and operating leading-edge computational resources is being applied to meet the needs of the National Science Foundation, the National Oceanic and Atmospheric Administration, and other agencies. Capabilities developed in support of DOE's missions in bioenergy and environment are applied to the needs of NASA, NIH, EPA, and the Food and Drug Administration (FDA). In each case, the Federal agency leverages the National Laboratories' unique expertise and capabilities rather than duplicating them at great expense.

2.3.2 Academic Partnerships with Laboratories

While this report focuses on the National Laboratory enterprise, much of the Nation's expertise in science and engineering is found throughout academia. Universities have been critical partners with the Laboratories since the earliest days of the Manhattan Project. Today, universities and consortia of universities are integrally involved in the management of DOE National Laboratories. Experts from academia serve on the National Laboratories' boards of directors, advisory committees, and review panels.

The vitality of the DOE National Laboratories very much relies on the vitality of university-based research, which is the core of basic research in the United States and educates the future cadre of researchers to pursue DOE's missions. The National Laboratories support the development of the future science, technology, engineering, and mathematics (STEM) workforce by making their facilities and capabilities available to students and faculty at all levels. In fact, the National Laboratories annually provide programs for

- more than 250,000 K–12 students,
- 22,000 K–12 educators,
- 2,950 undergraduate interns,
- 2,010 graduate students, and
- 2,300 postdoctoral researchers.

These programs range from workshops to semester-long appointments to extended-term employment. Of the 2,700 postdocs employed at FFRDCs in 2015, the National Laboratories employed 2,300 (86 percent). Altogether, the National Laboratories engage more than 450 academic institutions in the United States and Canada.

Productive collaborations between university and National Laboratory researchers take place through personnel exchanges, research collaborations at the individual investigator level, joint research programs established to develop and take advantage of DOE user facilities and unique capabilities, and strategic centers and institutes established to focus on new areas of scientific endeavor. Additionally, there are 1,285 National Laboratory employees serving in joint faculty appointments across the DOE National Laboratory System. National Laboratory employees also serve on thesis committees, advisory committees and review boards at universities.

DOE National Laboratories are encouraged to partner with academic institutions and industry and compete for RD&D awards through open and competitive solicitations. A 2005 report[8] from the National Research Council documented how university collaboration with National Laboratories provided a cost-effective way to conduct R&D requiring large, complex facilities and teams trained in their safe and effective operation; science requiring substantial engineering and instrument development; or science requiring specialized facilities. These collaborations also provide for expansive opportunities for interdisciplinary research, professional development, and training. In FY 2014, U.S. and foreign universities accounted for $97.2 million in direct partner funds-in to the National Laboratories through SPPs and CRADAs.

DOE National Laboratories collaborate with academic institutions by subcontracting work for which focused areas of expertise of researchers at universities can provide for productive outcomes. DOE National Laboratory subcontracts with academic institutions not only provide an additional avenue for education and training, but also represent a substantial flow of DOE resources to the academic research community. The National Laboratories collectively subcontract over $500 million to universities and employ more than 8,500 students, postdocs, and faculty. This subcontracted research is in addition to the more than $900 million that DOE directly funds the universities through academic research grants.

The university research communities are actively engaged in DOE's designated user facilities.[9] In fact, the largest portion of the users of facilities in National Laboratories under the purview of the DOE Office of Science (SC) comes from academic institutions. In targeted areas, universities have also been hosts to major research facilities and capabilities that support the research program mission areas, and in a few instances are the lead institutions for designing, constructing, and operating scientific user facilities. Of the more than 33,000 individuals who used DOE SC designated scientific user facilities in FY 2014, approximately 60 percent came from academic institutions in all 50 U.S. states and Washington, DC, and from academic institutions abroad. The user statistics for the DOE SC designated user facilities are fully searchable on its interactive statistics web page,[10] where one can search for the users by facility, by sponsoring SC Program Office, and by facility host site.

2.3.3 Industry Partnerships with DOE National Laboratories

It is industry, and not the DOE or its National Laboratories, that ultimately manufactures, markets, commercializes, and operates new technologies, making industry support integral to achieving DOE goals. Developing technologies that can effectively be transitioned to the marketplace (e.g., manufacturability, aimed at a market need) typically involves engagement with industry. These partnerships also trace their origins to the Manhattan Project. The cutting-edge experimental and computational capabilities at the National Laboratories provide unique opportunities for partners from the commercial sector to develop and test new technologies.

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8 National Research Council, National Laboratories and Universities: Building New Ways to Work Together (2005), available at https://www.nap.edu/read/11190/chapter/1.

9 Information about the Department's Scientific User Facilities program can be found at http://science.energy.gov/user-facilities/.

10 SC publishes annual statistics on the users of the SC user facilities available at http://science.energy.gov/user-facilities/user-statistics/.

DOE National Laboratories that host and operate designated scientific user facilities work continuously to improve the processes for developing and executing user partnerships. Several user facilities have industrial liaisons on staff who are practiced in discussing the research needs of the prospective partner, introducing them to the technical capabilities available at the facility, and facilitating negotiation of partnership agreements. In the aggregate, these scoping interactions are labor-intensive, as each industrial user approaches the facility with a unique set of problems, goals, and constraints.

Partnerships with Pharmaceutical Companies

DOE designated user facilities enable numerous high-impact, industrial partnerships. Pharmaceutical companies rely on DOE's x-ray light sources to conduct rapid, precise structure measurements of novel biomolecules for drug discovery. The two structural biology beamlines at ANL's Advanced Photon Source, one operated by Lily Research Laboratories and a second by a consortium of Merck, AbbVie, Pfizer, Bristol-Myers Squibb, and Novartis, have pioneered high-throughput automated protein crystallography sample environments. The Lily beamline alone processes over 10,000 individual samples each year, and typically completes measurements on a next-day schedule. Collectively, molecular structure measurements at the light sources have played a significant role in the development of new pharmaceutical therapies for a variety of diseases.

Dedicated National Laboratory staff work to connect prospective users with the knowledge and expertise necessary to illuminate potential technical approaches to the problem. Several user facilities offer a rapid-access mode that allows prospective industrial users an opportunity to gain short-term access quickly on a provisional basis to make preliminary measurements and investigate the viability of a notional project; to gain further access, the industrial user submits a full proposal to the user facility.

Several user facilities offer a variety of standardized partnership agreements to facilitate negotiation of intellectual property rights and the level of collaboration. Many industrial users elect to employ a nonproprietary user agreement or SPP agreement to enable active collaboration with National Laboratory scientists.

The National Laboratories also engage heavily with small businesses to support their operations and to further their missions. In FY 2014, more than $2.1 billion of the National Laboratories' subcontracts were directed to small businesses. A DOE mentor-protégé program, formally established in 2000, fosters long-term business relationships between DOE prime contractors (including management and operating [M&O] contractors at National Laboratories), small businesses, and minority institutions of higher learning. Further details on technology transition activities are included in Chapter 4.

DOE and the Human Genome Project

DOE's involvement in the Human Genome Project (HGP) helped fulfill a Congressional mandate, rooted in the Atomic Energy Act of 1947, to understand the effects of ionizing radiation on human health. An interdisciplinary team culture at the National Laboratories fostered technology development capabilities integrated with advanced computation that were an important foundation for the HGP. Novel instrumentation development, robotic platforms for high-throughput processing, and early research and development on mapping and DNA sequencing technologies all laid the groundwork for DOE's ability to contribute its "share" of what became an internationally coordinated project.

Victor Markowitz (left and Nikos Krypides (right) lead the teams that developed and maintain the Integrated Microbial Genomes (IMG) systems.

National Laboratory technologies enabled the inception of DOE's Human Genome Initiative in 1986, the antecedent of the HGP (1990–2003). These enabling technologies included (1) laser-based cell sorter and computational technologies developed at LLNL and LANL used for purifying human chromosomes, a prerequisite for chromosome mapping; (2) computational capabilities first developed at LANL and subsequently at ORNL for finding genes in long stretches of DNA; and (3) the intellectual underpinnings of the modern day DNA sequence database, GenBank, at LANL. In addition, scientists at ANL and BNL developed novel sequencing and DNA processing methodologies used in applications beyond the HGP.

Headquartered in Walnut Creek, California, the U.S. DOE Joint Genome Institute has over 250 staff devoted to advancing the frontiers of genomics in support of clean energy generation and environmental characterization and cleanup.

The DOE Joint Genome Institute (JGI), established in 1997 and initially comprising staff from three National Labs (LBNL, LANL, and LLNL), further developed and shared their technologies and mapped, sequenced, and published analysis of human chromosomes 5, 16, and 19 as part of the larger HGP effort. In the years since the HGP ended, the DOE JGI became an SC user facility to serve the research community. The JGI continues to innovate and has become a world leader in performing sequencing and functional genomics of nonpathogenic microbes, plants, and microbe-microbe and microbe-plant systems consisting of potentially millions of unique organisms in environments important for DOE missions in energy and environment. In 2016, the JGI generated more than 140 trillion base pairs of DNA sequence, served more than 1,300 researchers, and hosted nearly 800,000 unique computer sessions for those using JGI data and tools. In its 19 years of existence, scientists have completed more than 23,000 sequencing projects at the JGI and produced nearly 1,600 publications, many of them opening up new areas of science.

Partnerships in High Performance Computing

For scientific advances, DOE provides high performance computing systems and leadership computing systems. The National Energy Research Scientific Computing Center (NERSC) at LBNL serves 6,000 scientists worldwide with high performance computing and data analysis. Fundamental to the mission of NERSC is enabling computational science of scale in which large, interdisciplinary teams of scientists attack fundamental problems in science and engineering that require massive calculations and have broad scientific and economic impacts. The Leadership Computing Facilities supercomputers at ANL and ORNL—among the most powerful computing resources in the world for open science—have enabled a variety of advances for both leading scientific and industry users. Industry researchers have used the resources at DOE's Leadership Computing Facilities to conduct both proof-of-concept and validation simulations to advance fundamental understanding in their R&D efforts. These users have praised U.S. Government support for such cutting-edge resources and state that their results have helped them gain a competitive advantage by demonstrating the benefits of high performance computing to their companies. Caterpillar, Boeing, Pratt & Whitney, and Ford, among others, have used the Leadership Computing Facilities to evaluate complex conditions for new engines or turbines, and to shorten design-to-demonstration time. General Motors used the capabilities to accelerate by at least a year the research needed to develop new thermoelectric materials to increase the fuel efficiency of their cars by reducing the waste heat. GE used the resources to design quieter, more efficient wind turbines by simulating the complex behavior of air flow around the blades, and also to simulate ice formation to improve turbine resiliency in cold climates. Industry applications are held to the same peer review and readiness criteria as academic and National Laboratory applications and come from a broad range of industry areas.

2.4 Evolving and Adapting to Serve the Nation's Needs

As the needs of the Nation have changed, the DOE National Laboratories have adapted and innovated to address challenges in new ways. In earlier days, the DOE's National Security Laboratories were focused on weapons design and analysis of nuclear weapons performance. But in the post-testing era of nuclear weapons, the Federal Government needed to be able to understand all of the components of weapons, including how they age, which led to a period of stockpile stewardship when computer simulations and nonnuclear testing became vital and foundational capabilities. More recently, the National Security Laboratories are undergoing more changes as they are called into a broader nuclear security role with applications in a variety of areas that relate to nonproliferation and counterterrorism—issues that have taken on much greater prominence in the last quarter century.

The Science and Energy Laboratories evolved from their initial focus after WWII on developing peaceful uses of nuclear energy including understanding the fundamental science that underlies nuclear power. The oil embargo and energy crises in the 1970s resulted in the formation of DOE and in a broader focus on energy R&D by the Laboratories, while the Cold War sharpened our focus on nuclear weapons design and led to the science-based stockpile stewardship paradigm we rely on today. In the 21st century, the capabilities at the Laboratories have been enhanced to address the challenges of counterterrorism, clean energy, and cybersecurity. The National Laboratories developed powerful tools and explored all areas of physical science. Now, the Laboratories explore a diverse set of energy technologies and scientific research areas. While originally, much of the work was sensitive and controlled, today's Science and Energy Laboratories are focused more on openly published R&D and forging collaborations in support of the Nation's energy and science missions. The National Laboratory System has evolved in response to major world events from their early day to today, as illustrated in detail in Appendix B.

One of the more recent evolutions in the activities of the Labs is their ability to constitute a readily available technical response capability for emergent problems and "technological surprises." The Nation has called upon the National Laboratories to assist during national and international emergencies. For example, National Laboratory scientists and engineers played key roles in responding to Superstorm Sandy in 2012; the terrorist attacks on September 11, 2001; the 2009 Christmas Day airline bomb attempt; the BP Deepwater Horizon oil spill in 2010; and the nuclear accident at Fukushima in 2011. Over the past year, the National Laboratories provided expertise and support for the Joint Comprehensive Plan of Action (Iran nuclear agreement), supporting the Conference of Parties (COP21) agreement in Paris, and addressing and evaluating the impact of the leak at the Aliso Canyon underground natural gas storage facility. In each case, when the U.S. Government needed immediate impartial technical advice, it turned to the DOE National Laboratories. The National Laboratories responded with technical staff on the ground within 24 hours. State and local governments also rely on National Laboratory scientists for technical advice, for example, to inform regulatory policies.

Researcher using the CTD Rosette to collect water samples from the deep-sea oil plume that appeared during the Deepwater Horizon spill. The samples were analyzed by a team of scientists back at LBNL. (Photo Credit: Eric Dubinsky, LBNL)

3 Leading Science and Technology Accomplishments

The DOE National Laboratories are the science and technology powerhouse that supports the Department's efforts in tackling the energy, science, national security, and environmental stewardship challenges that constitute the missions of the DOE. To ensure a secure, affordable, and clean energy future, advances are needed to make fossil-based energy sources cleaner at lower cost, to move from a reliance on fossil-derived fuels to renewable sources, to advance the state of the art in carbon-emissions-free nuclear power, to reduce overall energy usage by minimizing energy needs and losses, and to reduce the waste footprint of energy systems through carbon sequestration and other approaches. Further, continuing efforts to push the boundaries of our science and technology are essential to maintain the security posture for the Nation, ranging from our nuclear security to our efforts in ensuring the nonproliferation of nuclear technology, and continuing the cleanup of the legacy footprint from the Cold War.

3.1 Energy Programs

At present, primary energy sources, namely nuclear energy, fossil energy (coal, oil, and natural gas), and renewable sources (wind, solar, geothermal, and hydropower), are converted to electricity, which flows through power lines and other transmission infrastructure to homes and businesses. Keeping power flowing is critical for everyday life and economic vitality. Maintaining a resilient infrastructure and keeping the electric grid secure from cyber and physical attacks are foundational for our society. The energy industry is the third largest industry in the United States. The National Laboratories provide deep capabilities to this industry to ensure cutting-edge technologies are explored and evaluated.

This section discusses accomplishments of the Laboratories' energy-focused programs.

Energy Technology Advances, Next-Generation Cars and Nuclear Reactors

Printed a classic

Next-generation manufacturing takes on a 50-year-old icon as DOE researchers at ORNL create a laboratory on wheels by 3-D printing a Shelby Cobra.

Put the jolt in the Chevy Volt

The Chevrolet Volt would not be able to cruise on battery power were it not for the advanced cathode technology that emerged from ANL. The same technology is also sparking a revival of America's battery manufacturing industry.

Developed nuclear energy

The National Labs have been instrumental in designing several generations of nuclear reactors used around the world to produce 15 percent of the world's energy without any carbon emissions.

Discovering new energy technologies on many fronts: The National Laboratories play a vital role in developing advanced technologies for the generation, distribution, storage, and use of energy in both stationary and mobile applications.

> *Example: Clean energy.* Through the National Laboratories, energy independence and leadership in clean energy technologies are advanced to ensure the availability of clean, reliable, and affordable energy for our Nation. The National Laboratories perform cutting-edge research and deploy innovative clean energy technologies. For example, they have helped develop the current breed of high-efficiency wind generators and new, high-efficiency solar cells.
>
> *Example: Fracking.* The National Laboratories had a major role in the development of hydro-fracking technology, which has led to the "shale gas revolution," yielding significant increases in oil and gas production. In this regard, scientists at the National Laboratories helped develop 3D seismic imaging, directional drilling techniques, and diamond drill bits, and conducted computer simulation, pore level analysis and modeling, and monitoring and evaluation of fracking.
>
> *Example: Energy efficiency and conservation.* The National Laboratories developed the solid-state ballast for fluorescent lighting, which has been one of the greatest gains in energy efficiency ever. The National Laboratories also have made important advances on construction and design of buildings, as well as the efficiency of the equipment inside of them.

Facilitating safe, clean, and efficient use of existing energy technologies: The National Laboratories have been instrumental in advances in traditional energy sources, such as high-efficiency, combined-cycle natural gas turbines, supercritical coal boilers, and nuclear generating plants. National Laboratory R&D has also led the way in supporting ancillary waste-management activities essential to the continued use of traditional energy sources, including, for example, carbon capture and sequestration and the safe and secure management and permanent disposal of nuclear wastes.

> *Example: Deep geologic disposal of spent nuclear fuel.* Multiple National Laboratories, including LANL, LBNL, LLNL, and SNL, provided fundamental research supporting characterization of the Yucca Mountain site in Nevada beginning in the early 1980s to evaluate its suitability for permanent geologic disposal of spent nuclear fuel and high-level radioactive waste from national defense programs. Additional National Laboratories, including ANL, ORNL, PNNL, INL, and SRNL, contributed to the characterization of spent fuel and high-level wastes that were candidates for disposal at the site. As the project moved into the regulatory licensing process, SNL served as Lead Laboratory for the program, providing leadership and accountability for the scientific basis of the project while drawing on expertise from all participating National Laboratories along with contractors and university experts. All participating National Laboratories contributed under the leadership of SNL to the long-term safety evaluation that formed a key part of the DOE's License Application for the site submitted to the NRC in 2008. Under the direction of the DOE Office of Nuclear Energy (NE), nine National Laboratories are presently engaged in a collaborative R&D campaign that supports the safe and secure storage of those wastes in surface facilities and researches multiple viable options for permanent geologic disposal to ensure that technical solutions are available to support a broad range of national policy decisions.

Performing award-winning research: Scientific innovation is often recognized through R&D 100 awards (known as "the Oscars of Innovation"). The R&D 100 awards are given annually in recognition of exceptional new products or processes that were developed and introduced into the marketplace during the previous year. The awards are selected by an independent panel of judges based on the technical significance, uniqueness, and usefulness of projects and technologies from across industry, government, and academia. Since 1962, when the annual competition began, DOE's National Laboratories have received over 800 R&D 100 awards. In 2015, they won 33 of 100 awards in the competition.[11]

Examples: Three recent R&D 100 Award winners.

- "NanoFab Lab…in a Box!" is a shoebox-sized, mini-laboratory and "printing press" for growing nanowires. The standard technique to make them requires an expensive "clean room," a Laboratory with extensive filters to keep out the hundreds of thousands of particles usually floating in the air. Nanowires are a relatively new technology, but scientists believe that they could have applications in fabricating transistors, in sensors, in solar cells, and as electronic components.
- The Multiphysics Object Oriented Simulation Environment (MOOSE) makes it easier for scientists to predict phenomena ranging from nuclear fuel and reactor performance to groundwater and chemical migration. Such simulations can help speed the pace of scientific discovery but have traditionally required more computing resources than most scientists and engineers could readily access. MOOSE is a key element of the Virtual Environment for Reactor Applications (VERA), the virtual reactor under development by the Consortium for Advanced Simulation of Light Water Reactors (CASL), a DOE Energy Innovation Hub.
- The HP Apollo 8000 System, developed in collaboration with HP, uses component-level warm-water cooling to dissipate heat generated by a supercomputer, thus eliminating the need for expensive and inefficient chillers in the data center. This innovative design allows waste heat from the computer to be captured and used to heat office and Laboratory space, achieving even higher energy efficiency levels.

[11] See section 4.11 for more information on National Laboratory R&D 100 wins.

Strengthening U.S. competitiveness: The United States is home to a thriving energy industry, with globally competitive firms in all technology subsectors, and the National Laboratories have provided much of the foundational knowledge that helped grow this industry rapidly in the past.

The transition of scientific and technical outputs from the DOE's National Laboratories to private sector partners has always been an important driver of national prosperity and an integral part of the National Laboratories' mission. The DOE 2014–2018 Strategic Plan supports this work by leveraging the impact of Federal R&D investment in the Laboratories, accelerating the transfer of technology into the private and government sectors, and responding to opportunities and challenges.

The National Laboratories are innovation powerhouses, featuring world-class user facilities, cutting-edge instruments, and leading scientists and engineers. These outstanding technical and intellectual assets are available to entrepreneurs in the private sector through a variety of means, including access to the DOE user facilities, collaborative research with scientists, and the creation of strategic partnerships. Private sector companies have already formed thousands of active agreements with DOE National Laboratories, making discoveries, solving technical problems, and developing innovations.

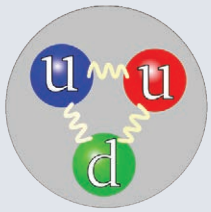
> *Examples: New programs to move innovation to the marketplace.* Working with DOE, the National Laboratories have taken important steps in recent years toward improving engagement and strategic partnerships that help reduce or shift risk with private sector engagements, such as the adoption of the Agreement for Commercializing Technology (ACT) contracting mechanism for industry-sponsored research and Fast Track Cooperative Research and Development Agreements (CRADAs). ACT and the Fast Track CRADAs represent concrete steps taken by the Department and its Laboratories to increase flexibility and reduce the agreement processing timeline.
>
> The Lab-Corps Pilot is another avenue to empower researchers engaged in technology transitions to commercialize National Laboratory technologies. The National Laboratories continue to identify other opportunities for technology transitions training and professional development for researchers across the DOE National Laboratory Complex. Additionally, in FY 2016, a Small Business Vouchers Pilot was initiated to increase the utilization of Lab assets by small businesses.
>
> The Energy Technology Commercialization Fund (ETCF), authorized under the Energy Policy Act of 2005, established a path to provide matching funds with private partners to promote promising energy technologies for commercial purposes. In 2014, over $2.3 billion was made available for applied energy research, development, demonstration, and commercialization.

3.2 Science Programs

Basic science, including the tools needed to facilitate discovery, expands our understanding of the natural world and forms the foundation for future technologies. The DOE National Laboratories are at the forefront in the pursuit of discovery and innovation in basic science. They are unveiling secrets of the basic building blocks of matter, such as quarks, neutrinos, and the Higgs boson. They are also peering deep into space, seeking understanding of the dark matter and dark energy that seem to dominate the universe and yet remain mysterious. They are creating a new generation of materials (including biological and bio-inspired materials) that may underpin the imperative of advances in energy generation, storage, transmission, efficiency, and security. Creating such materials requires a level of understanding of the relationships between structure and function, and across many spatial scales, which is not yet supported by our understanding of the physical world. Basic scientific research fills these knowledge gaps and enables discovery and innovation in everything from the creation of new materials with the characteristics needed for next-generation clean energy technologies to a greater understanding of the universe a fraction of a second after the Big Bang.

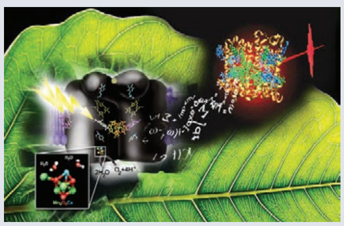
The sections below focus on the basic science conducted by the National Laboratories to develop new energy technologies, provide solutions to environmental problems, and better understand the universe.

Expanding Our Understanding of the Natural World through Basic Science



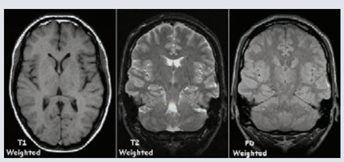
Changed the face of matter

Protons and neutrons were once thought to be indivisible. However, National Lab scientists discovered that protons and neutrons are made of even smaller parts, called quarks. Later experiments identified six kinds of quarks, changing our view of how the material world works.



Explained photosynthesis

Ever wonder how plants turn sunlight into energy? A team of National Lab scientists determined the path of carbon through photosynthesis, a scientific milestone that illuminated one of life's most important processes.



Revolutionized medical diagnostics

From the original scintillation camera that detected gamma rays emitted by radioactive isotopes to today's cancer-detecting, compact nuclear-imaging devices and the magnets in MRI scanners—National Lab discoveries have revolutionized medicine and saved countless lives.

Unmasked a dinosaur killer

Natural history's greatest whodunit was solved in 1980 when a team of National Lab scientists pinned the dinosaurs' abrupt extinction on an asteroid collision with Earth.

3.2.1 Science and Energy

Fundamental science can provide the underpinning knowledge required to formulate new concepts for future energy technologies. National Laboratories provide a rich environment where fundamental and applied science are closely coupled to encourage the development of new technologies that will ensure a secure, economically competitive, and environmentally responsible energy future for the Nation. The examples that follow illustrate the breadth and impact of the work of the National Laboratories as related to energy.

Revolutionizing and diversifying the Nation's energy supply: Transportation is a major consumer of energy in the United States. Production of transportation fuels from sunlight offers a plentiful supply of clean energy, including production of fuels from biomass, generation of hydrogen from water, and even conversion of carbon dioxide into fuels. The National Laboratories are utilizing a range of strategies to increase efficiency and diversify the Nation's fuel supply: applying high performance computing to model combustion, engines, and aerodynamics; developing new materials for catalytic production of fuels; and improving fuels extraction. The National Laboratories have developed novel nanomaterials, ceramics, and even "bio-inspired" molecules that mimic nature's enzymes, all of which can be designed and modeled using DOE's high performance computational resources.

To realize highly efficient, long-lived, passively safe nuclear reactors, wholly new reactor designs are needed. High performance computation is enabling the design of new reactor concepts, allowing them to be studied and optimized in silico, and expediting the design of fuel and reactor technologies in collaboration with industry. National Laboratories are also designing a new generation of radiation-resistant structural materials that could enhance the safety and efficiency of reactors and extend their lifetimes.

Example: Next-generation bioenergy crops. National Laboratory scientists are driving the development of next-generation bioenergy crops by unraveling the biology of plant development, identifying feedstock candidates, and designing enzymes and microbes with novel biomass-degrading capabilities. They are also developing transformational microbe-mediated strategies for advanced biofuels production. Through the three DOE Bioenergy Research Centers (which in total involve 7 National Laboratories, 22 universities, and 6 industrial or foundation partners), breakthroughs are being achieved at each of the steps involved in biofuels production: biomass development, biomass deconstruction, and fuels synthesis.

Researchers at the Joint Bioenergy Institute hold a tray of Arabidopsis Thaliana plants used for research on engineering plant cell walls to make the sugar within more accessible.

Advancing energy conversion for electricity and fuels production: The sun is the ultimate source of free energy, and a new generation of materials is needed to efficiently harness this energy by converting solar radiation into electricity or fuels. This source of energy could be used across all four energy sectors: residential, commercial, industrial, and transportation. The National Laboratories are designing a new generation of nanomaterials that will far exceed today's silicon-based technologies, both in increased efficiencies and in reduced costs.

Example: Solar-to-fuels generation. Through the Joint Center for Artificial Photosynthesis (JCAP), National Laboratory researchers are investigating the design of highly efficient solar-to-fuel generators that utilize water and carbon dioxide to produce energy-dense fuels. The primary goals being pursued are discovery and understanding of highly selective catalytic mechanisms for carbon dioxide reduction and oxygen evolution under mild conditions of temperature and pressure; discovery of new electrocatalytic and photoelectrocatalytic materials and light-absorbing photoelectrodes; and demonstration in test-bed prototypes of artificial photosynthetic carbon dioxide reduction and oxygen evolution rivaling natural photosynthesis.

Developing storage and distribution for a modern grid: Electrical energy storage is critical to realizing the full potential of both electric-powered transportation and renewable electrical energy sources for the grid. Fundamental research is providing breakthroughs in new materials and chemical processes to produce higher capacity, safer, and less expensive batteries for the future and to develop the power electronics necessary to use them. Research at the National Laboratories, coupled with associated DOE user facilities (including x-ray light and neutron sources and nanoscience centers), is providing key information that will allow next-generation batteries and capacitors to be realized.

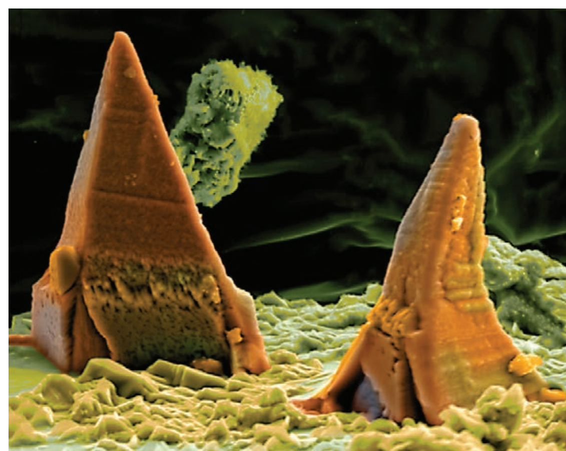
Example: Innovative battery technologies. The Joint Center for Energy Storage Research (JCESR), a DOE Energy Innovation Hub, is pursuing next-generation battery technologies that will transform both the transportation sector and the electric grid. Crosscutting approaches to computer simulation and discovery of battery electrodes and electrolytes are being developed. Team scientists are pursuing novel syntheses of battery materials and using advanced characterization tools, including multinuclear magnetic resonance, electron microscopy, x-ray scattering, and scanning probes.

Discovering tomorrow's energy-efficient technologies: Next-generation materials have the potential to greatly enhance energy efficiency. National Laboratories are developing new thermoelectric materials that can convert waste heat to electricity for use in vehicles, homes, or industry; magneto-caloric materials to provide higher efficiency substitutes for traditional heating and cooling sources; and advanced materials for thermally efficient windows. Working closely with applied programs, materials scientists and engineers are translating these fundamental breakthroughs into new energy technologies that are being licensed by industries in the United States.

Example: Magneto-caloric cooling. Heating and cooling together account for 48 percent of the energy used in a typical U.S. home. The National Laboratories are creating innovative new ways to heat and cool homes based on magnetic materials. One of these new solutions is the magneto-caloric heat pump, which moves heat by manipulating the magnetic structure in magnetic materials. This revolutionary compression-free technology is more efficient than current gas-compression heating and cooling systems, and eliminates the need to use refrigerants that contribute to greenhouse gases and climate change.

Reducing the waste footprint of energy through science: Waste resulting from energy production has enormous environmental impact not to mention added costs, and waste minimization presents an opportunity to increase total efficiency. Understanding the fate of pollutants, such as the biological methylation of mercury, can yield a means to mitigate their impact. Waste treatment technologies are being developed to enable the separation of radioisotopes from waste streams, thereby lowering costs and minimizing disposal requirements. Subsurface carbon storage in geological formations is also being actively pursued by the National Laboratories.

Example: Carbon sequestration. The combustion of fossil fuels accounts for over 80 percent of our current energy supply, and National Laboratory scientists are working hard to understand the science of carbon capture and storage to enable the continued sustainable use of these fuels. Three dimensional (3-D) printed models from National Laboratory Energy Frontier Research Center researchers are being used to understand the movement and reactions of carbon dioxide through pores in sandstone. Simulations and modeling by National Laboratory scientists are being used to understand and predict where carbon will go and what state it will be in after a long period of time underground. This research is ultimately aimed at making carbon storage a viable technology solution.



Scientists at PNNL are using electron microscopes to understand the reaction of CO_2 and minerals found underground. This electron microscope image shows the aftermath of fayalite reacting with gaseous CO_2 to form siderite, thereby capturing the CO_2 in a solid, stable form. Capturing and storing CO_2 and other greenhouse gases deep underground is one of the most promising options for reducing the effects of energy production on the Earth.

3.2.2 Science and the Environment

DOE National Laboratories advance scientific understanding of the impact of humankind's energy production and energy use on the Earth's natural energy budget. The focus is on the total amount of solar energy and radiant heat entering, exiting, and remaining in the Earth system. Since the Earth's energy budget is a major determinant of climate, a deeper understanding of what shapes the energy budget will allow scientists to make more informed and more accurate projections of future conditions.

Understanding the Earth's energy balance: The balance of energy absorbed versus radiated by the Earth is the engine of climate. Better understanding this energy balance is a primary goal for DOE. Researchers at the DOE National Laboratories quantify the interactions among particles in the atmosphere (aerosols), clouds, precipitation, solar radiation, and radiant heat to improve our understanding of climate; gain a deeper understanding of these key elements of the climate system; and advance the goal of creating more accurate global and regional climate simulations and projections.

Example: Measuring and understanding atmospheric processes. National Laboratory scientists are using DOE's advanced tools and facilities to characterize the complex processes that occur in the Earth's atmosphere to enhance climate prediction. For example, the Atmospheric Radiation Measurement (ARM) Climate Research Facility allows scientists to gain detailed and accurate descriptions of the Earth's atmosphere in diverse regions and climatic conditions. The ARM Facility plays a crucial role in data gathering through field measurement campaigns around the world and is demonstrating how molecular-to-field scale measurements continually improve climate models. The field data gathered through the ARM Program is playing a major role in reducing some of the persistent gaps and uncertainties in our understanding of Earth systems that limit the accuracy of climate models and projections. In addition, Laboratory-based molecular level measurements of aerosols improve our understanding of their composition and physical and chemical properties that can then be incorporated into climate models to improve their accuracy.

Example: Measuring and understanding climate at the molecular scale. DOE's Environmental Molecular Sciences Laboratory (EMSL) complements the work of the ARM program and contributes to our understanding of climate by studying chemical and physical processes at the molecular scale. For example, studying the complex chemical changes that aerosol particles undergo over time in the atmosphere as they interact with solar energy and other molecules allows scientists to incorporate their knowledge of these processes into climate models.

SNL technician examines a solar tracker that follows the sun. The tracker shown is part of SNL's Atmospheric Radiation and Cloud Station (ARCS) outdoor sensor array. This is part of DOE's ARM program, which is seeking to find how sunlight and infra-red radiation interact with clouds and, in particular, whether varying levels of atmospheric moisture could influence Earth's radioactive energy to the point of causing long-term global climate changes.

Climate modeling: Models developed by DOE National Laboratories advance our understanding of climate and our ability to predict future climatic conditions.

Example: Accelerated Climate Model for Energy (ACME). DOE sponsors the National Laboratories to develop, test, and evaluate a cutting-edge Earth system model—the Accelerated Climate Model for Energy—built around best-in-class science. ACME incorporates insights from previous models and expands upon them, offering decision makers the ability to explore climate change impacts, responses, and climate-human system feedbacks under a variety of conditions. ACME and other DOE models combine field observations with experimental research findings to shed light on the roles and interactions among Earth system components that contribute to climate variability and change. The observational programs and models focus on understanding and representing processes at various geographical scales to facilitate sound decision-making at local, regional, and global levels. ACME represents a new generation of climate and Earth system models and is distinguished from other models in its very high geographic resolution (15–25 km), coupling of climate with energy systems, and focus on a near-term "hindcast" (1970–2015) for model validation and a near-term projection (2015–2050) most relevant to societal planning.

3.2.3 Science and the Universe

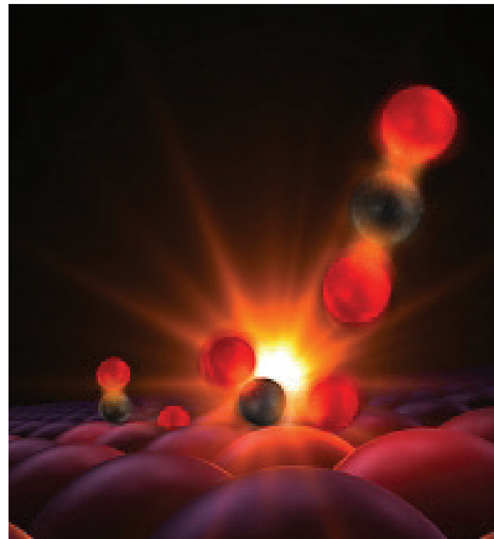
The universe around us retains the imprint of the fundamental processes governing its evolution from the Big Bang to the present. The fundamental particles and forces of nature can be examined in Laboratory experiments today by recreating the conditions of the early universe. They also govern the atomic-scale properties of atoms and materials, and eventually the macroscopic behavior of complex systems. Pursuing the science of the universe challenges the imaginations of new generations of scientists, and delivers the scientific discoveries that transform our understanding of nature.

Understanding the subatomic building blocks and forces of the universe: Subatomic physics explores the fundamental constituents of matter and energy. It reveals the profound connections underlying everything we see, including the smallest and the largest structures in the universe. The field has been highly successful. Investments have been rewarded recently with discoveries of the heaviest elementary particle (the top quark), the tiny masses of neutrinos, the accelerated expansion of the universe, and the Higgs boson. From the hot dense soup of quarks and gluons in the first microseconds after the Big Bang, through the formation of protons and neutrons beginning the evolution of the chemical elements, to the awesome power of nuclear fission, the physics of nuclei is fundamental to our understanding of the universe and, at the same time, intertwined in the fabric of our lives. Nuclear physicists and chemists are creating totally new elements in the Laboratory and producing isotopes of elements that, hitherto, have only existed in stellar explosions or in the mergers of neutron stars. Current opportunities will exploit these and other discoveries to push the frontiers of science into new territory at the highest energies and earliest times imaginable.

> *Example: Discovery of the Higgs boson.* The massive particle detectors at the Large Hadron Collider (LHC) were constructed to explore the frontiers of particle physics at high energies and to discover the Higgs boson, a key particle in understanding the origin of the universe. The LHC program is a model for successful international science projects, with the U.S. contingent consisting of some 1,200–1,400 scientists, from approximately 90 universities and five DOE National Laboratories. With the identification of the Higgs boson, a new window for discovery has now been opened. What principles determine the effect of the Higgs on other particles? How does it interact with neutrinos or with dark matter? Is there one Higgs particle or many? Is the new particle really fundamental, or is it composed of others? The Higgs boson offers a unique portal into the laws of nature, and it connects several areas of particle physics. Any small deviation in its expected properties would be a major breakthrough. The full discovery potential of the Higgs will be unleashed by percent-level precision studies of the Higgs properties at the upgrade of the LHC planned for around 2020.

Revolutionizing our understanding of nature at the atomic scale: The 20th century witnessed revolutionary advances in the synthesis and properties of materials. There are high-temperature superconductors that conduct electricity with no energy loss, carbon nanotubes that have a strength-to-weight ratio more than two orders of magnitude greater than steel, and a host of other technological developments. These extraordinary properties arise from the particular arrangement of the atoms in the material, defects in the materials, the way individual domains or components in the material interact with one another, or the characteristics of interfaces between two dissimilar materials across different length scales. Expanding our scientific knowledge from the relative simplicity of perfectly ordered systems to the real-world heterogeneities, interfaces, and disorder should enable us to realize enormous benefits in the materials and chemical sciences that will translate to the energy sciences—including solar and nuclear power, hydraulic fracturing, power conversion, airframes, and batteries.

Example: Watching the formation of a chemical bond. Scientists have been developing theories for many years to predict how atoms and chemical species react to form new molecules. Experiments have observed chemical bonds associated with these molecules before and after the event, but not while they occur. A video animation, based on data collected from DOE's free electron laser facility, will show how carbon monoxide combines with oxygen in the presence of a catalyst to form carbon dioxide, the first time ever this event—the core of all chemistry—has been caught in the act.



This illustration shows carbon monoxide and oxygen forming a tentative bond, a moment captured for the first time in experiments with an x-ray laser at SLAC National Accelerator Laboratory. When the reactants, which are attached to a ruthenium catalyst, are hit with an optical laser pulse, a transitional bond is formed, and the resulting carbon dioxide molecule detaches and floats away (upper right).

Understanding the connection between atoms and complex systems: National Laboratory scientists study matter at three general length scales: nano, meso, and macro. A big challenge in many areas of science is to understand how nanoscale phenomena translate to physical properties at the mesoscale and beyond. Because these materials are heterogeneous and need to be studied over many length scales, often under real-world operating conditions, DOE's x-ray light and neutron sources have proven to be ideal tools. Neutron and x-ray diffraction, for instance, can provide atomic structure information and can be used to understand the emergent properties of macroscopic systems.

In materials science, the organizing principles governing emergent phenomena at the mesoscale, where classical properties first begin to emerge out of the quantum world, are only now being revealed. As systems grow in size from the nanoscale to the mesoscale, defects, interfaces, and fluctuations emerge that could be manipulated to program the various desired functionalities of materials, including specific thermal, electronic, magnetic, and mechanical properties at the bulk level.

Example: New cathode materials. Researchers from academia and German and U.S. National Laboratories teamed up and used a powerful x-ray imaging technique called "coherent x-ray imaging," combined with new data analysis algorithms, to gain insights—at the nanoscale level—on the mechanical properties of a cathode material called an "LNMO spinel" (composed of lithium, nickel, manganese, and oxygen atoms) and gained insight into how these properties might affect battery performance on the macroscale. The study reveals how the cathode material behaves while the battery charges and offers a possible explanation for why this particular cathode material works well at high voltage levels. It was found that this particular cathode material handles strain during charging by moving the defects around within the nanocrystal. More broadly, this study also points to the exciting possibility of "defect engineering" for battery materials that could help battery developers design rechargeable lithium-ion batteries that operate at higher voltages.

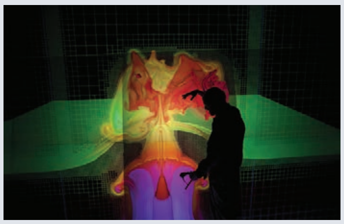
3.3 National Security Programs

The nuclear security programs span a broad range of missions in the national interest:

- maintaining and enhancing the safety, security, and effectiveness of the U.S. nuclear weapons stockpile;
- conducting energy security research to address key challenges facing the Nation and the world;
- informing and implementing comprehensive risk-based systems solutions to reduce the global danger from weapons of mass destruction;
- developing and deploying new capabilities to our defense and national security communities;
- understanding and preparing the Nation for the national security implications of climate change;

- securing the Nation's critical energy and communications infrastructures;
- lowering the risk posed by nuclear and biological proliferation, terrorism, and catastrophic incidents;
- combining cybersecurity expertise with cutting-edge technology to keep critical systems safe and foil attacks;
- conducting biosecurity detection, characterization, and mitigation; and
- responding to nuclear and radiological emergencies in the United States and abroad.

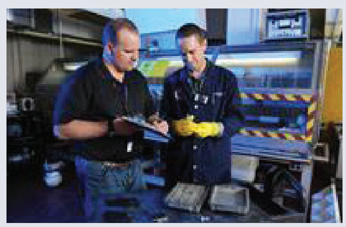
Ensuring National Security and Nuclear Safety




Ensured the safety, security, and reliability of the nuclear stockpile without testing

Many threats to national security require deep understanding of science and technology. For more than 20 years, National Lab scientists have advanced the safety, security, and reliability of the Nation's nuclear stockpile without full-scale testing by using models and supercomputer simulations, gathering data from subcritical experiments and other nonnuclear experiments, and analyzing past nuclear test data.





Kept nuclear material out of terrorist hands

National Lab expertise is enabling the country to recover radioactive material and reduce use of highly enriched uranium in nuclear reactors. Since 1999, National Labs have recovered more than 1 million curies of radioactive sources. They are also applying their expertise to converting reactors to use low enriched uranium. These efforts protect our Nation and the world from material that could be used in "dirty bombs" by terrorists.

The National Laboratories constitute a unique resource for addressing the national security missions of DOE. In addition to their central role in nuclear security, the National Laboratories bring cutting-edge science, technology, and engineering (ST&E) to bear on the challenge of physical and cybersecurity threats to the U.S. energy infrastructure. The National Laboratories also partner with other Federal departments and agencies to provide innovative solutions in the broader areas of defense, homeland security, cybersecurity, and intelligence. The role of the National Laboratories in national security is a unique responsibility stemming from the Nation's decision for civilian management of nuclear weapons R&D.

National Laboratories often serve roles that cannot be executed by universities or the private sector. This is particularly true in national security programs. Beyond direct DOE mission support, these capabilities deliver solutions for broader national security challenges. In doing so, the National Laboratories add depth, breadth, and strength to their scientific and technical base and the expertise of the workforce, which is important to the long-term health of the Stockpile Stewardship Program (SSP).

The deep scientific expertise resident in the DOE National Laboratory System serves the U.S. enduring goals of security and prosperity. The national security strategy outlines many complex challenges to the security of the Nation, including natural and manmade hazards, proliferation of weapons of mass destruction, threats to human health, impacts of climate change, and threats to the access of electronic and space domains. Energy security constitutes an important goal in ensuring future prosperity.

> *Example: Improving the nation's cybersecurity.* Cybersecurity efforts at the National Laboratories demonstrate the broad impact of the national security work. These efforts focus on developing real-time situational awareness, advancing predictive and scalable simulations, and creating analytic methodologies and data management and fusion tools that are needed to protect the National Laboratories and other national assets both in the defense and civilian sectors.

> *Example: Addressing future uncertainties related to National security.* Beyond execution of important national security mission objectives, the National Laboratory System provides an important resource to address future national security uncertainties. Importantly, the National Laboratories provide technical options for leaders to execute the national security strategy. Through engagement in cutting-edge R&D, the National Laboratories provide a resource to guard against technological surprise threatening national security and provide solutions to ensure U.S. leadership in an uncertain world. The value of this excellence serves an important role in U.S. relationships with international partners, for whom the National Laboratories' capabilities are a key element of assurance and extended deterrence. For example, capabilities developed in the stockpile stewardship mission are being applied to addressing the threat of homemade explosives, from understanding the threat to developing methods of detecting and countering the threat.

Improving national security related to nuclear weapons: The NNSA draws its mission and authorities from the Atomic Energy Act and the subsequent NNSA Act and is now charged with programmatic missions in maintaining a safe, reliable, and effective nuclear deterrent, powering the nuclear navy, ensuring nuclear nonproliferation and nuclear safety, and reducing the global threat from weapons of mass destruction. In addition, NNSA is directed to support U.S. leadership in science and technology. These organizations sustain an integrated nuclear security enterprise by stewarding the National Laboratories and their capabilities, while also executing vital programmatic missions.

The National Laboratories and associated production plants and sites are the principal facilities for execution of the DOE's national security missions. The genesis of this relationship can be traced to the Manhattan Project, when Laboratories and other facilities were established to coordinate research, development, and production of the first nuclear weapons. While most of the National Laboratories participate in national security programs, three of the largest National Laboratories (LANL, LLNL, and SNL) are managed under the aegis of DOE/NNSA as part of the DOE nuclear security enterprise. These three National Laboratories ensure that the essential and innovative ST&E capabilities required to serve the long-term DOE missions in management of the nuclear stockpile are sustained.

> *Example: Up-to-date assessments of the weapons stockpile.* The DOE/NNSA National Laboratories work with plants and sites in exercising their unique responsibility to conduct an annual assessment of the nuclear weapons stockpile. In the process, a report is prepared by each of the directors of the three DOE/NNSA National Laboratories, detailing their assessment of the safety, reliability, and performance of each warhead type in the nuclear stockpile. The Secretaries of Defense and Energy submit these reports to the President, along with the conclusions the Secretaries have reached as to the safety, reliability,

performance, and military effectiveness of the U.S. nuclear deterrent. These annual assessments and the nuclear weapons life-extension programs rely on the enormous advances the National Laboratories are making in understanding the underlying science of nuclear weapons performance through the SSP.

Example: Advances in high performance computing. The National Laboratories, partnering with the U.S. computer industry, have driven the state of the art in high performance computing and helped enable a global leadership role for U.S. industry. DOE has largely led this effort—initially for NNSA weapons development, and today enabling stockpile stewardship responsibilities. This process has driven remarkable advances in the state of the art of high-end computing, and in establishing U.S. leadership in the area.

Initiating nuclear threat reduction: The science and engineering base of the National Laboratories is also applied to the second of NNSA's mission pillars: nuclear threat reduction. The National Laboratories provide staffing and expertise to engage with interagency and international partners and advance technical capabilities to prevent, counter, and respond to nuclear and radiological proliferation and terrorism threats and incidents worldwide.

Examples: Nonproliferation. National Labs provide unique scientific, technical, engineering, and manufacturing capabilities essential to countering global nuclear proliferation. National Laboratories' expertise supports U.S. programs that prevent the proliferation of weapons-useable nuclear materials. Lab capabilities are required to assist countries around the world in converting reactors to low-enriched uranium fuel and repatriating the highly enriched uranium fuel. Labs develop and build advanced systems essential to monitor, detect, assess, and respond to the potential spread of nuclear materials and nuclear weapons or nuclear weapons capabilities.

Working with others on national security: The National Laboratories work in partnership across the U.S. Government, academia, and industry to be better prepared for future technological surprises that might threaten national security. To that end, the DOD, Department of Homeland Security (DHS), and the Intelligence Community are able to leverage a deep and broad base of capabilities and specialized facilities. These strategic partnerships enable other Federal agencies to perform work not otherwise possible; in return, these relationships enrich the national security enterprise by helping to sustain science and technology capabilities that are important to meet future national defense requirements. In particular, the 2002 Homeland Security Act gave DHS direct access to the DOE National Laboratories' unique expertise, knowledge base, and experimental and computational facilities to help with needed science and technology for homeland security.

In the context of applying innovation from the NNSA Laboratories to the broader marketplace, the role of strategic partnerships (and in particular nonfederal partnerships) takes on special significance in national security programs. Increasingly, innovation comes from all segments of the U.S. economy. Engagement with broader technical communities serves to enhance the capabilities of the National Laboratories to serve core missions in national security and enhance the creative environment that will attract the next-generation workforce.

Many examples exist of synergistic innovation in which technologies and codes originating in the National Laboratories are refined and adapted by nonfederal entities in ways that later serve to improve mission capabilities. For many elements of national security missions, partnerships with the private sector are vital to ensure efficient and cost-effective delivery of solutions at scale; technology partnerships between unique sectors of the ST&E community (not restricted to technology transfer) improve mission delivery.

Benefiting areas beyond national security: Capabilities essential for national security missions are also leveraged to advance DOE's energy and climate science objectives, especially in the areas of understanding the subsurface; developing, testing, and predicting the performance of advanced materials; and applying high performance computing, modeling, and simulation in optimizing the Nation's energy infrastructure and predicting the impacts of natural and manmade disruptions.

The National Laboratories are also regularly engaged to address emerging challenges and opportunities that crosscut the Federal Government in such disparate areas as the Materials Genome Initiative, National Strategic Computing Initiative, Precision Medicine, Cancer Moonshot, and the National Network for Manufacturing Innovation. The Laboratories remain a resource for the United States for ST&E innovation in addressing national-level challenges.

3.4 Environmental Stewardship Programs

The DOE Office of Environmental Management (EM) has the mission to complete the safe cleanup of the environmental legacy brought about from the development and production of nuclear weapons and the government-sponsored nuclear energy program. This mission spans the DOE complex and includes 16 sites that remain the focus of ongoing cleanup efforts. Key to the timely and cost-effective accomplishment of that mission is the central role that National Laboratories have in providing innovative solutions to resolve the complex and high hazard challenges that are endemic to environmental remediation; dispose of high-level waste and excess nuclear materials; and achieve facility decontamination and decommissioning.

The environmental challenges fall into three interrelated areas: managing legacy wastes, including high-level liquid waste currently in storage tanks, decontaminating and decommissioning legacy facilities, and cleaning up environmental contamination of soil, groundwater, streams, and ecosystems. Basic science environment-related accomplishments can be found in section 3.2.2.

Management of DOE legacy waste: As part of the environmental stewardship enterprise, the SRNL provides strategic technical leadership for the EM programs across the DOE complex, as well as the program leadership of critical R&D programs essential to the completion of the overall EM cleanup mission. SRNL works in concert with other National Laboratories to ensure that the full suite of capabilities of the DOE National Laboratory System is brought to bear on resolving the complex and high hazard challenges associated with the DOE-EM cleanup mission.

At present, DOE has approximately 88 million gallons of liquid waste stored in underground tanks and approximately 4,000 cubic meters of solid waste derived from processing the liquids. The current DOE estimated cost for retrieval, treatment, and disposal of this waste exceeds $50 billion, to be spent over several decades. The highly radioactive portion of this waste, located at the Hanford Site, INL, and Savannah River Site (SRS), must be treated, immobilized, and prepared for ultimate disposal. The National Laboratories are improving pretreatment processes to reduce the amount of waste to be disposed, developing waste retrieval technologies, advancing vitrification performance for waste storage, and inventing breakthrough waste immobilization technologies. Current projects focus on a number of efforts:

- In-tank sludge washing at the Hanford Site
- Enhanced waste processing at the INL, Hanford Site, and SRS
- Disposition of salt waste at SRS
- Low- and medium-Curie waste pretreatment at the Hanford Site
- Improved in situ characterization/monitoring methods at the Hanford Site, INL, and SRS
- Sludge heel retrieval at SRS
- Advanced melter technology at SRS and the Hanford Site

*Example: Defense Waste Processing Facility (DWPF).*The DWPF converts the high-level liquid nuclear waste currently stored at SRS into a solid glass form suitable for long-term storage and disposal. As a result of National Laboratory research, waste loading of the glass high-level waste form for the DWPF was increased by approximately 25 percent through employment of a tailored approach to frit composition. The improvement in waste loading has reduced the number of canisters needed to contain vitrified high-level waste by about 25 percent. Continuing this trend will result in a total reduction of approximately 1,400 canisters at a savings of $1 million each.

Example: Solid Waste Processing Facility (SWPF). Radioactive cesium is a significant contaminant in high-level waste. Recently, DOE-EM started operations of a new process to perform the challenging task of removing radioactive cesium from salty high-level waste tank liquids. The Caustic-Side Solvent Extraction (CSSX) process removes cesium selectively in the presence of many other salts—allowing the treated water to be mixed with grout for safe and cost-effective disposal in the form of saltstone. The next generation solvent (NGS) that has been used n the SRS Modular CSSX Unit will be deployed in the planned SWPF. Implementation of NGS in the SWPF will improve throughput by 30 percent, enabling completion of the SWPF mission in nine years. The resulting 2.7-year operation reduction at a cost of about $500 million per year will total approximately $1,350 million in savings.

The National Research Council and the Nuclear Regulatory Commission have made recommendations regarding the focus of the next set of strategic investments in developing deployable technologies. These recommendations include developing options for chemical cleaning of tanks; emerging technologies to assist tank-waste removal, including robotic enhancements to current waste retrieval technologies; and near- and long-term performance and monitoring of tank fill materials as they interact with the environment. In all these areas, the National Laboratories possess significant expertise and capabilities.

Deactivation and Decommissioning (D&D): Because of residual radioactivity, hazardous constituents, and other facility hazards, DOE faces unique technological challenges in the D&D activities necessary to complete the cleanup of facilities across the DOE Complex. To meet these challenges, the National Laboratories are focusing on developing new D&D tools and timely insertion of these new tools with existing technologies, processes, and hardware to address D&D risks and challenges. The National Laboratory support has led to full scale "in situ decommissioning" of reactors (closure in place), increased productivity and personnel safety of D&D operations, enhanced verification and long-term monitoring of facility end-state performance, and improved public acceptance of cost-effective D&D technologies.

E*xample: The in situ decommission of nuclear reactors.* The scientific basis for decommissioning excess large nuclear facilities using in situ decommissioning strategies in compliance with regulatory requirements and authorities was developed and used in the decommissioning of the P- and R-Reactor complexes at SRS. The actual cost for each of the reactor in situ decommissioning projects was under $75 million, significantly less than the estimated cost of about $250 million for full demolition of the above-grade structures along with reactor vessel removal and below-grade decontamination of each reactor complex.

Cleanup of environmental contamination: DOE manages one of the largest groundwater and soil remediation efforts in the world. The inventory at the DOE sites includes 6.5 trillion liters of contaminated groundwater, an amount equal to about four times the daily U.S. water consumption, and 40 million cubic meters of soil and debris contaminated with radionuclides, metals, and organics. The National Laboratories network is providing transformational technologies and applying these technologies at some of DOE's most difficult and challenging contaminated areas. This research emphasizes deployment at real "test bed" locations, including Hanford, SRS, and Oak Ridge. The National Laboratories have provided new capabilities for simulation through the Advanced Simulation Capability in the Environmental Management initiative. The resulting technologies have been used across the DOE complex, accelerating and improving the cleanup actions and reducing costs.

Example: Mercury treatment. The Clean Water Act identifies acceptable pollution levels in water for many pollutants, including mercury. National Laboratory research has demonstrated/deployed an innovative and cost-effective means to treat mercury, such that air stripper discharges would meet new stringent surface water discharge standards. Deployment in 2007 of M-1 Air Stripper Stannous Chloride to treat mercury resulted in a $10 million capital cost avoidance and $1 million cost savings per year for 30 years for operations, totaling $40 million in cost savings.

Example: Groundwater monitoring. National Laboratory research has proposed a more effective and less costly approach to long-term groundwater monitoring, reducing less effective point-source measurements. Implementation of this proposal has the potential (based upon SRS demonstration) to save $150 thousand per year for three large site groundwater plumes over 30 years for a total savings of ~$15 million.

Working with others: The National Laboratories provide a unique role in the development of technical solutions needed to meet the environmental challenges of DOE, NNSA, other Federal agencies, and industry. This role involves bridging the technical discovery of academia to the deployable needs of the customer. The National Laboratory System has a depth, breadth, and strength that cannot be matched by any single institution or entity. The following paragraphs provide a few examples representing the benefits that the National Laboratories, working with others, have provided to DOE-EM and to the Nation.

Example: High-level waste at Hanford. For the past three years scientists from the National Laboratories have been working within an integrated team of Bechtel National Incorporated, Atkins, and the DOE Office of River Protection to bring a new and novel mixing system to fruition. The resulting pulse jet mixers will be used in thirty-eight mixing tanks at Hanford and will be a key to processing high-level waste containing elevated concentrations of solids. The mixing tanks reside in "black cells" that provide no access for the maintenance typically needed by conventional mixing equipment with moving mechanical parts. Answering the call of the Secretary of Energy, the National Laboratory team accepted the challenge of helping finalize the mixing design, resolve technical challenges, and demonstrate the effectiveness of the technology for this unique mission. Following full-scale testing in 2017, DOE will team with industry to build and install the tanks in the black cells.

Example: Extraction of radioactive elements from high-level waste. The CSSX technology discussed above was developed through collaboration of the National Laboratories. It is a key part of a larger waste processing facility that also removes other radionuclides, including transuranics. The facility is the culmination of decades of collaborative technology development and commercialization. This industrial achievement is directly traceable to fundamental chemistry and basic science advancements in the National Laboratories. The CSSX and associated waste treatment processes are lynchpins in the sustainability of converting SRS high-level waste into safe and stable waste forms such as glass and saltstone.

Example: Groundwater cleanup. The standard practice for remediating metals and long-lived radionuclides in groundwater is to install extraction wells, pump contaminated water to the surface, and treat that water to remove contaminants. The process incurs risk of exposure to workers and generates a secondary waste stream that must be managed. This system is expensive to operate, and time and labor intensive. The standard practice works, but it is not efficient enough to meet environmental goals in a cost-effective manner. Through National Laboratory and DOE contractor collaboration and innovative thinking, a new "enhanced attenuation" approach was developed to treat the contamination underground, without the expense or exposure risk associated with bringing it to the surface. The first application of the concept (1) successfully transitioned from active pump-and-treat remediation to enhanced attenuation-based remedies, (2) achieved regulatory goals for release of metals and long-lived radionuclides, (3) pioneered safe, low-cost technology that has the potential for worldwide use to remediate groundwater, (4) saved energy by replacing a 24/7 active pumping and treating operation that was scheduled to run for decades, with a one-time per year injection system that stabilized contaminants in place, and (5) saved over $350 million in remediation costs.

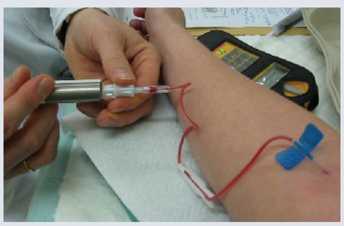
Example: Permanent disposal of defense-related transuranic waste at the Waste Isolation Pilot Plant. Working closely with DOE-EM and management and operating contractors, National Laboratories led by SNL played a central role in the development and certification of the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico. The WIPP began disposal operations as the world's first deep geologic repository for radioactive waste in 1999, emplacing transuranic waste from multiple DOE sites in a mined facility in bedded salt at a depth of 650 meters. Before disposal operations were halted in February

2014 following an underground fire and radiological release, WIPP had disposed of more than 90,000 cubic meters of transuranic waste from 12 DOE-managed sites, accounting for more than 60 percent of the total projected volume of transuranic waste requiring geologic disposal. LANL and SNL are working with DOE-EM and the present management and operating contractor, Nuclear Waste Partnership LLC, to plan and implement recovery operations that will allow the facility to return to full operations and complete its mission supporting cleanup of the DOE complex.

Moving forward in environmental stewardship: The National Laboratories have a strong history in the successful deployment of technologies that tackled some of the most hazardous of DOE-EM environmental stewardship challenges. As DOE-EM moves forward with its cleanup mission, daunting challenges remain, including the construction and operation of treatment facilities for high-level waste and the D&D of complex and highly radioactive facilities. Through successful partnering and leveraging of capabilities, the National Laboratories are positioned to provide DOE-EM with the innovative technical solutions needed to succeed in this cleanup mission in a timely and cost-effective manner. This expertise in solving difficult environmental issues is recognized internationally as the National Laboratories have been engaged with efforts to resolve environmental issues at Chernobyl and Fukushima.

3.5 Unique Facilities

New Isotopes, Dust-Free Rooms, and Satellites



Harnessed the depth of the periodic table

The discovery, development, and production of new radioactive isotopes have revolutionized medicine, industry, and research. Technicium-99m from molybdenum-99 generators developed at the National Labs saves lives through more than 50 different diagnostic tests.

Kept the dust out

The development of the laminar flow clean room by the National Labs enabled the development of the modern microelectronics industry. The dust-free environment is key to the manufacture of the chips in smart phones and supercomputers.

Put eyes in the sky

Vela satellites, first launched in 1963 to detect potential nuclear detonations, transformed the nascent U.S. space program. The satellites featured optical sensors and data processing, logic and power subsystems designed and built by National Labs.

3.5.1 Energy Programs

The DOE National Laboratories operate both designated user facilities and specialized R&D facilities focused on the energy missions. Earlier sections discussed recent accomplishments of the Laboratories' energy-focused programs. Select examples of the unique facilities that bring these accomplishments to bear are highlighted here.

Energy sector research facilities: DOE facilities support broad energy sector research by providing integrated test environments and comprehensive resources.

Example: Wind energy. The National Wind Technology Center (NWTC) is the Nation's premier wind energy technology research facility. The NWTC advances the development of innovative land-based and offshore wind energy technologies through its research and testing facilities. Researchers draw on years of experience and their wealth of expertise in fluid dynamics and structural testing to also advance marine and hydrokinetic water power technologies. At the NWTC, researchers work side-by-side with industry partners to develop new technologies that can compete in the global market and to increase system reliability and reduce costs. The Center's test sites experience diverse and robust wind patterns that are ideal for the development of advanced wind energy technologies. The NWTC's 305-acre site comprises field test sites, test laboratories, industrial high-bay work areas, machine shops, electronics and instrumentation laboratories, and office areas. The Center is the first facility in the United States that has fault simulation capabilities and allows manufacturers and system operators to conduct the tests required for certification in a controlled laboratory environment. It is the only system in the world that is fully integrated with two dynamometers and has the capacity to extend that integration to turbines in the field and to a matrix of electronic and mechanical storage devices, all of which are located within close proximity on the same site.

Turbines at the NWTC with the Flatirons in the background. NWTC, the Nation's premier facility for wind turbine R&D, is a center for research and a magnet for new industry. The site, at the foot of the Rockies, is ideal due to its variable winds and reliable winter storms.

Example: Nuclear energy. The Nuclear Science User Facilities (NSUF), which are distributed across five National Laboratories, six universities, and one industry partner, provide the Nation's nuclear energy researchers with access to a wide variety of facilities and instruments for nuclear energy science and technology in the United States. For example, the behavior of fuels and materials subjected to irradiation in a nuclear reactor is extremely complex and provides a rich field for scientific investigation. NSUF offers access to world-class capabilities, facilities, expertise, and materials to help researchers understand the complex behaviors of these fuels and materials, providing the knowledge needed to develop new systems and processes that will increase the availability and enhance the safety of nuclear power.

Example: Electrical grid. The Energy Systems Integration Facility is a one-of-a-kind user facility, which features a 1 MW distribution grid for "plug and play" testing of whole system experiments, hardware-in-the-loop testing, and integration with high performance computing capabilities for grid modeling and simulations.

Infrastructure research facilities: From transportation to buildings, DOE facilities advance the research necessary for an energy efficient future.

Example: Transportation. The National Transportation Research Center offers industry, academia, and other agencies the opportunity to access state-of-the-art technologies, equipment and instrumentation, and computational resources to advance transportation technologies. These resources are critical for improving fuel economy, reducing emissions, and addressing transportation system issues, such as traffic congestion, evacuation planning, and highway safety.

Researcher demonstrates an electric vehicle being wirelessly charged using ORNL technology at the National Transportation Research Center.

Example: Energy efficient buildings. The FLEXLAB is the most flexible, comprehensive, and advanced building efficiency simulator in the world, and it is unleashing the full potential of energy efficiency in buildings. FLEXLAB lets users test energy-efficient building systems individually or as part of an integrated system, under real-world conditions. FLEXLAB test beds can test HVAC, lighting, windows, building envelope, control systems, and plug loads, in any combination. Users can test alternatives, perform cost-benefit analyses, and ensure a building will be as efficient as possible—before construction or retrofitting even begins.

Energy and the environment: Investigating the intersection between environmental stewardship and energy production.

Example: Molecular sciences. The Environmental Molecular Sciences Laboratory is funded to ensure that the research community can investigate innovative solutions to the Nation's environmental and energy production challenges in areas such as atmospheric aerosols, feedstocks, global carbon cycling, biogeochemistry, subsurface science, and energy materials.

Energy technologies: Understanding of the fundamental scientific basis for energy technologies is vital for continued energy innovation.

Example: Critical materials. The Critical Materials Institute focuses on technologies that make better use of materials and eliminate the need for materials that are subject to supply disruptions. Many materials deemed critical by DOE are used in modern clean energy technologies, including wind turbines, solar panels, electric vehicles, and energy-efficient lighting. The DOE's 2011 Critical Materials Strategy reported that supply challenges for five rare earth metals may affect deployment of clean energy technology in the coming years. The Critical Materials Institute focuses on these five "critical" rare earths (dysprosium, terbium, europium, neodymium and yttrium) and two "near-critical" materials (lithium and tellurium).

Example: Combustion. For more than 30 years, the Combustion Research Facility (CRF) has worked to satisfy the need for a thorough and basic understating of combustion and combustion-related processes. CRF research ranges from studying chemical reactions in a flame to developing an instrument for the remote detection of gas leaks. Users and partners have access to state-of-the-art facilities and an expert staff that brings with them enhanced knowledge and new approaches to combustion and combustion-related research.

Example: Batteries and fuel cells. The Electrochemical Analysis and Diagnostics Laboratory (EADL) provides battery and fuel cell developers with reliable, independent, and unbiased performance evaluations of their cells, modules, and battery packs. The EADL is an extensive facility designed to test both small and large batteries and fuel cells. It is now the only known facility with capabilities to conduct

120 concurrent advanced battery studies under operating conditions that simulate electric-vehicle, hybrid electric vehicle, utility load-leveling, and standby/uninterruptible power source applications. Each battery is independently defined, controlled, and monitored to impose charging regimes and discharge load profiles that simulate the types of dynamic operating conditions found during actual use.

The EADL consists of two parts: battery testing and post-test analysis. Here, an ANL scientist analyzes results in the Battery Post-Test Facility. The facility allows the Laboratory's researchers to dissect, harvest and analyze battery materials from used and previously tested battery cells in order to identify for developers and manufacturers the exact mechanisms that limit the life of their battery cells.

Example: Turbine combustion. The High-Pressure Combustion Facility provides the test capabilities needed to evaluate new combustion concepts for high-pressure, high-temperature hydrogen and natural gas turbines. These concepts will be critical for the next generation of ultraclean, ultraefficient power systems.

Example: Understanding new photovoltaic materials. Organic (polymer) photovoltaics represent a very promising low-cost approach for flexible and versatile solar energy conversion. These films can be "printed" using slot-die printer technology, very similar to ink-jet printers, on a variety of surfaces. However, the efficiency of these materials depends critically on the molecular level structure, and this structure, in turn, is a very sensitive function of the deposition and curing process of the films. Direct measurement of this microstructure, during the deposition process, is a key to optimization of these films. For this purpose, a compact "printer" has been incorporated directly in a synchrotron beamline to enable direct x-ray studies of the microstructure as it develops. Moreover, data from these studies are piped directly to DOE supercomputer facilities for real-time processing, analysis, and feedback to allow experimenters to directly test the effect of different deposition conditions and chemical compositions on the formation of the microstructure.

Computing to improve economy and competitiveness: DOE computing facilities are increasingly providing computational expertise and systems to industry partners. As opposed to many cloud services, the DOE computing center staff have expertise in solving problems in fields such as computational fluid dynamics and molecular dynamics, which can be applied to problems being addressed by industry. The results of these partnerships are improving the fuel efficiency of automobiles, cargo trucks, aircraft, and power systems. They also improve manufacturing processes.

3.5.2 Basic Science Programs

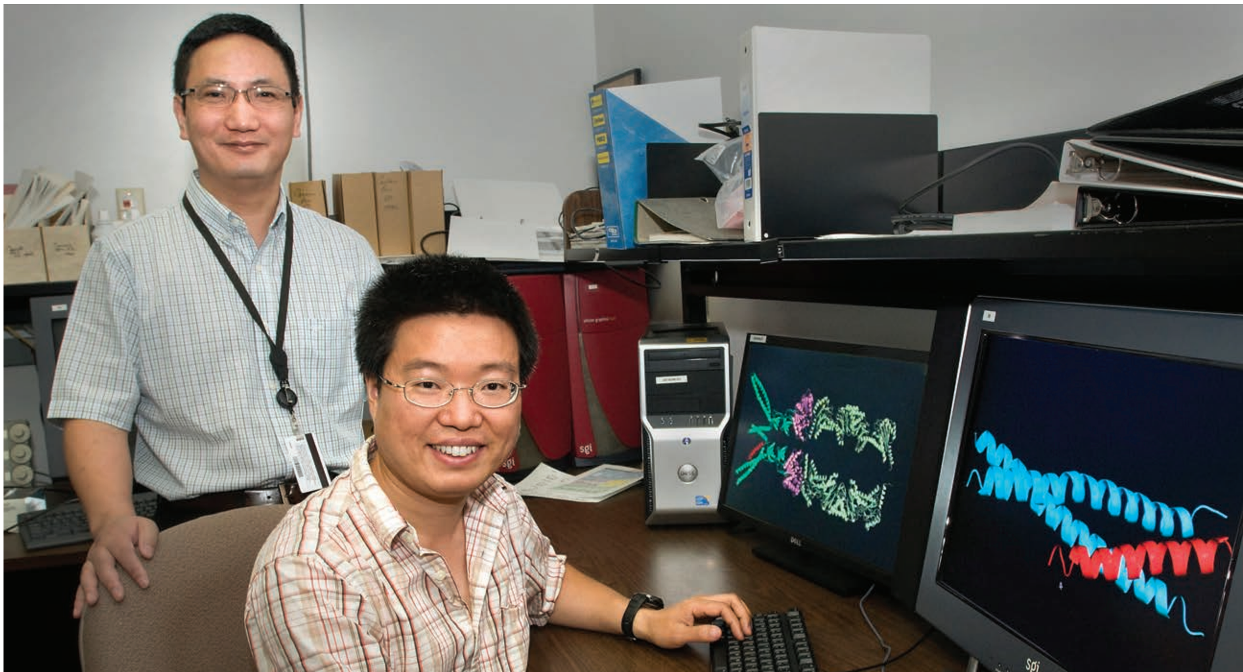
Investment in basic science research is expanding our understanding of how structure leads to function in natural systems—from the atomic- and nanoscale to the mesoscale and beyond—and is enabling a transformation from observation to control and design of new systems with properties tailored to meet the requirements of the next generation of energy technologies. At the core of this effort is a suite of experimental and computational tools and facilities that enable researchers to probe and manipulate matter at unprecedented resolution. The planning and development of these tools and facilities is rooted in basic science, but they are critically important for technology development, enabling discoveries that can lead to broad implementation.

Each year, thousands of users take advantage of the capabilities and staff expertise at the DOE user facilities for basic research, while the facilities leverage user expertise toward maintenance, development, and application of the tools in support of the broader community of users. The multidisciplinary and multi-institutional research centers supported by DOE are designed to integrate basic science and applied research to accelerate development of new and transformative energy technologies, as illustrated below.

Revealing the atomic world through x-ray and neutron facilities: X-ray light and neutron sources provide unprecedented access to the structure and dynamics of materials and the molecular-scale basis of chemical reactions. These tools, combined with novel nanoscale synthesis and fabrication techniques, are being used to launch a new era of control science at the mesoscale that will lead to new materials for energy applications, including batteries, photovoltaics, and catalysts.

Robust and efficient energy storage and conversion are central to the energy problem. The fundamental science challenge is to understand the materials chemistry occurring at electrodes and the interface between the electrode materials and electrolyte. Because these materials are heterogeneous and need to be studied over many length scales, often under real-world operating conditions, DOE's x-ray light and neutron sources provide the ideal tools to do that. The penetrating power of x-rays follows the dynamics inside operating batteries, ion distributions, and structural changes in electrode materials, while x-ray spectroscopy reveals the charge states involved. Neutron and x-ray diffraction can provide atomic structure information, while imaging techniques can be used for larger length scales.

> *Example: Determining protein structures.* Synchrotron light sources are crucial in the study of protein structures because they provide the highest quality crystallographic data that can be currently obtained. Using synchrotron radiation, National Laboratory scientists obtain atomic-resolution structures of drugs bound to their target proteins and invaluable information related to the ways these compounds physically interact with their targets. The determination of the structure of proteins at the atomic level through crystallography has provided important clues to the biological function of the proteins in the body, which can, in turn, lead to insight about the fundamental processes by which the human body functions. Such studies have resulted in several Nobel Prizes in Chemistry during the last decade, the most recent being in 2012 when Robert Lefkowitz and Brian Kobilka were awarded the Nobel Prize in Chemistry for studies of the G-protein-coupled receptors (GPCRs)—most of the structural studies of which were done at DOE light sources. GPCRs are the largest family of cellular G-protein-coupled receptors in humans and other animals. About half of all modern pharmaceuticals target these receptors, either to boost or block their activities. Such studies require protein crystals a few tens of microns in size, but these are often difficult or impossible to produce. With the advent of x-ray free electron lasers, National Laboratory researchers will be able to solve structures with nanometer size crystals or perhaps without crystalizing the proteins at all.

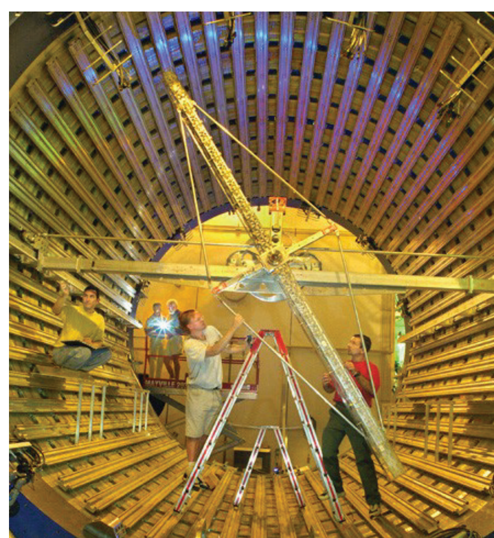


Researchers at BNL used beams of high-intensity x-rays at the Lab's National Synchrotron Light Source to determine atomic-level structures in order to elucidate the interactions of the "kiss of death" marker (red on screen image) with components of the tuberculosis bacterium's protein-degrading machinery.

Understanding the origin of matter in the early universe with unique accelerator facilities: The universe retains the imprint of a huge variety of fundamental processes that have governed its evolution from the Big Bang until today. Understanding problems such as the asymmetry of matter over antimatter and the role of neutrinos, the formation of visible matter and the origin of chemical elements, the properties of the quark-gluon plasma, and searches for new forces and particles require world-class facilities with high-power beams and massive detectors. Fundamental science can address today's technology bottlenecks by providing the underpinning knowledge required to formulate new concepts for future technologies.

Example: Recreating the early universe. Powerful particle collisions at DOE's Relativistic Heavy Ion Collider (RHIC) recreate matter as it existed just a fraction of a second after the Big Bang. This four-trillion-degree quark-gluon plasma is a free flowing "perfect" liquid made of matter's most fundamental building blocks. The quark-gluon plasma produced at RHIC has revealed intricate details of nature's strongest force and the transition of this primordial soup to ordinary matter that makes up our universe today.

Example: Subatomic forces and particles. DOE's newly upgraded Continuous Electron Beam Accelerator Facility (CEBAF) will enable pioneering explorations of the forces within the atomic nucleus, enabling the search for elusive exotic mesons and the first exploration of the three-dimensional structure of protons and neutrons. CEBAF will also facilitate unique studies contributing to astrophysics, precision tests of the standard model explaining how the building blocks of matter interact, and searches for new physics.



The Star Detector, one of four at Brookhaven's RHIC, tracks and analyzes the thousands of particles that may be produced by each gold ion collision inside the detector, contributing to the further understanding of the fundamental nature of matter.

Connecting the biological world to energy: The Bioenergy Research Centers accelerate transformational breakthroughs in the basic science needed to develop the cost-effective, sustainable technologies necessary to make cellulosic biofuels viable on a commercial scale. The three Centers are multi-institutional, multidisciplinary, and collaborative efforts engaging the universities, DOE National Laboratories, the private sector, and nonprofits. They research on the entire pathway from bioenergy crops to biofuels production. Their focus is on basic research, pursuing a range of high-risk, high-return approaches to cost effectively produce biofuels and bio-products from renewable biomass. Additionally, the Centers track the development of intellectual property to facilitate the transfer of basic science discoveries from the Laboratory to the private sector, thereby enabling the translation of their fundamental research advances into the market place. Research at the Centers, and in the biofuels community at large, is supported and accelerated by continuing development of novel enabling technologies; notably, high-throughput genomic and metabolic screening, synthetic biology, and computational modeling for predicting the effects of genetic manipulation.

Nanoscale science for materials by design: Nanoscience—assembling atoms, clusters of atoms, and molecular ensembles into new nanoscale architectures and materials with unique properties—relies on a set of five Nanoscale Science Research Centers to integrate theory, synthesis, fabrication, and characterization in their research activities.

> *Example: Smart-window technology.* In the United States, about 25 percent of our total energy production is used for lighting, heating, and cooling buildings. Molecular Foundry scientists have designed a new coating based on nanocrystals that can be manipulated electrically to provide selective control over the transmission of visible light and heat-generating near-infrared light. This enables windows to maximize both energy savings and occupant comfort, while exploiting natural lighting indoors in a wide range of climates.

LBNL researchers have unveiled a semiconductor nanocrystal coating material capable of controlling heat from the sun while remaining transparent. Heat passes through the film on the window without affecting its visible transmittance, which could add a critical energy-saving dimension to "smart window" coatings.

> *Example: Light emitting diodes (LEDs) from giant quantum dots.* Current LEDs use rare earth (RE) phosphors, now produced almost exclusively in mainland Asia. The United States is trying to lessen its dependence on RE phosphors, and therefore must create LEDs without REs. National Laboratory scientists have created giant quantum dots (gQDs), which are semiconducting nanocrystals (typically CdSe), coated with a shell that creates a nonblinking light. They are working with a major lighting company to achieve high-efficiency lighting paired with lifetime reliability and application as direct replacements for red phosphors in the full range of LED architectures, including plastic and direct-on-chip architectures, from low/medium power LEDs to newer ultrahigh power (5 W/mm2) LEDs.

Entering new regimes for fusion energy: Fusion offers the promise of an energy system that would produce no greenhouse gases, have no long-term radioactive byproducts, and be a practically inexhaustible source of energy, requiring only water and lithium as fuel. As the worldwide fusion community prepares for next-generation fusion devices including the ITER, it is important to determine and test the plasma configurations that will be used in it, and to validate and test the codes used to predict plasma behavior. Developing the understanding and novel solutions to produce burning plasmas is an important task for the DOE National Laboratories.

In addition to the user facilities described above, the Laboratories also feature computing facilities that have wide-ranging application. Modeling, simulation, and data analysis using high performance computers offer researchers the opportunity to simulate complex real-world phenomena, interrogate and interpret large data sets, and accelerate development of new technology. The next generation of hardware, software, and algorithms offers the opportunity to computationally design complex systems for energy and environmental applications. DOE is a world leader in using supercomputers to tackle the most challenging problems in science and technology, giving us a better understanding of ourselves, our world, and our universe. Four of the top ten supercomputers in the world are found at DOE National Laboratories, as are 10 of the top 100 supercomputers, all linked by ESnet, DOE's high-speed network. While the examples below support basic science applications, the sections on energy and national security facilities also feature advanced computational support.

Science discovery through high performance computing facilities: Simulating complex, real-world phenomena, interrogating and interpreting large data sets, and accelerating the development of new technologies rely on advanced modeling, simulation, and data analytics using high performance computing (HPC). Increasingly, DOE computing centers work in close collaboration with other DOE research facilities to help drive discovery, often using simulations to predict results and then comparing observed data with simulations to improve accuracy.

Example: Mapping the universe. Now under construction in Chile, the Large Synoptic Survey Telescope (LSST) will survey the universe, remapping the entire sky every few nights for 10 years. Each night, the LSST will capture 15 terabytes of data, which supercomputers will analyze immediately to identify objects ranging from distant supernovae to nearby asteroids. The LSST will map tens of billions of stars and galaxies, helping scientists explore the structure of the Milky Way, investigate dark energy and dark matter, and make new discoveries.


A rendering mix of the exterior of the LSST building showing the dome open.

A **coming revolution in science enabled by next-generation exascale computing:** The convergence of increasingly large datasets from experimentation, observation, and simulation is driving a higher level of discovery in areas ranging from cosmology to climate and new materials to clean energy. But keeping up with the flow of data and analyzing and understanding the information is starting to outpace our computing capabilities. Exascale computing systems (a billion billion calculations per second) now being developed by DOE National Laboratories and industry will provide the powerful tools needed to continue advancing scientific computing.

Example: Modeling complex materials. Understanding and controlling the properties of materials is important in applications ranging from large structures to nanotechnology. Current computational capabilities provide accurate results for simple, idealized systems, but exascale computing would allow scientists to investigate more complex materials with defects and impurities at realistic operating temperatures, producing results that can be used in manufacturing, energy storage, and national security.

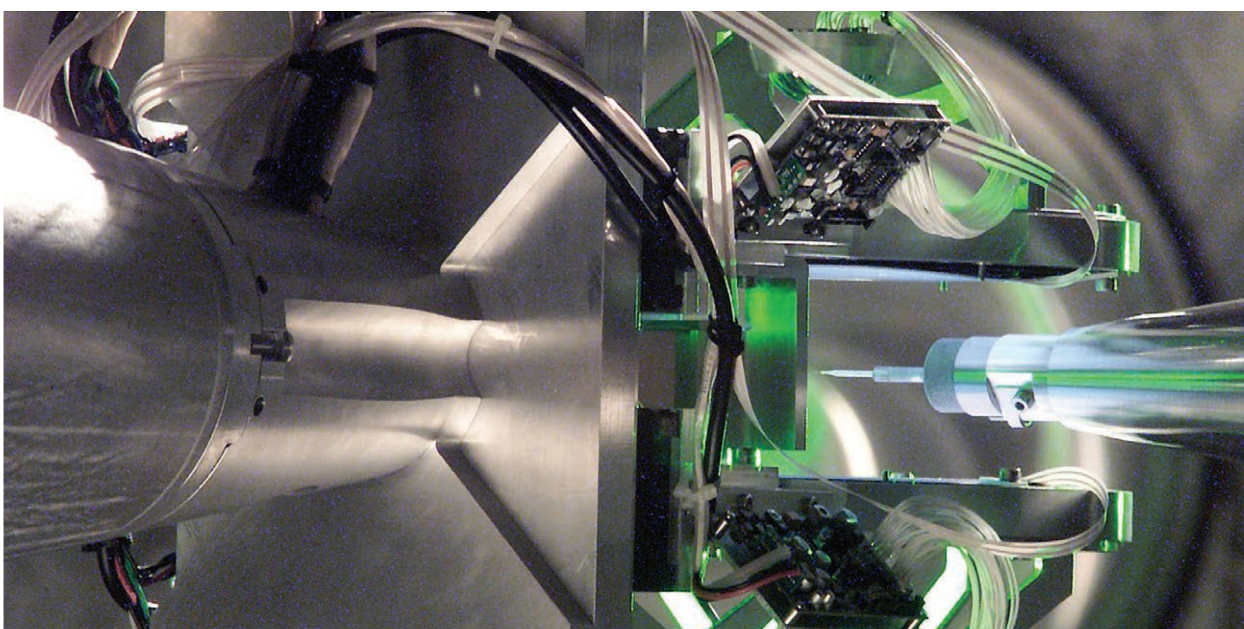
3.5.3 National Security Programs

Maintaining a safe, secure, and effective strategic deterrent in the absence of nuclear explosive testing requires innovative science and engineering. Through state-of-the-art experimentation, advanced simulation, and challenging evaluation of engineered systems, the current status of the stockpile is assessed, and confidence is sustained in its performance.

These efforts require specialized R&D and production facilities, supporting research with materials and in environments required for national security missions, including energetic materials research, development, testing, and evaluation, actinide science, and research in dynamic materials performance. Operation of specialized programmatic facilities related to national security often involves management of secure environments (for management of classified information, communication, and/or items) or higher hazard environments. Programmatic facilities include those for handling of special materials (including operation of nuclear facilities), test facilities, and major experimental facilities enabling state-of-the-art science in support of national security missions.

Experimental facilities probing science in extreme conditions: Experimental facilities are required that characterize the behavior of weapons materials and systems in extremes of temperature and pressure, as well as in radiation environments. With these facilities, scientists can explore matter at extremely high energy densities, study the properties of shocked materials, and understand neutron and charged particle reaction rates relevant to fission and fusion.

> *Example: Extreme states of matter.* The National Ignition Facility (NIF) is the world's largest and most energetic laser facility ever built. By focusing NIF's laser beams onto a variety of targets, scientists create extreme states of matter (conditions relevant to a nuclear explosion), including temperatures of more than 100 million degrees Celsius (180 million degrees Fahrenheit) and pressures that exceed 100 billion times Earth's atmosphere. NIF users and collaborators include researchers from DOE National Laboratories, universities, and other U.S. and foreign research centers.



The target positioner and target alignment system at the NIF precisely locate a target in the target chamber. The target is positioned with an accuracy of less than the thickness of a human hair.

Example: Pulsed neutrons. The Los Alamos Neutron Science Center (LANSCE) is an accelerator-based, multidisciplinary research facility providing the scientific community with intense proton and neutron sources for both civilian and national security research. Studies in nuclear and materials science (from fundamental understanding of nuclear structure and reactions to the characterization of materials under extreme environments) are carried out with intense beams of unmoderated pulsed neutrons, moderated pulsed neutrons, and protons.

Micro-systems development and testing: Engineered weapons systems rely on the performance of electronic circuits that need to operate reliably under a wide range of conditions. Microsystems incorporate radiation-hardened microelectronics, and other advanced components such as micro-machines, optoelectronics, and photonic systems. The critical nature of these systems requires facilities and equipment to design, develop, manufacture, integrate, and qualify microsystems for national security needs that cannot or should not be made in industry—either because the low volumes required for these applications are not profitable for the private sector, or because of stringent security requirements for high-consequence systems.

Example: Microsystems. The Microsystems & Engineering Sciences Applications (MESA) Complex represents the essential facilities and equipment to design, develop, manufacture, integrate, and qualify microsystems for national security needs. It supports the development of leading edge trusted microsystems technologies to enable new and increasingly powerful macrosystem capability and functionality for critical national security platforms. It provides capabilities in areas such as material growth and process development for silicon and binary compounds (e.g., GaN), device and product design, advanced packaging technologies for 3-D integration, reliability, and failure analysis.

Hydrodynamic testing and radiography: Nonnuclear dynamic experiments are used to gain information on the behavior of weapons systems during explosions. Codes are validated through integral (system-scale) dynamic experiments in which high explosives are set off to study the hydrodynamic behavior of mockups of primaries. These experiments are diagnosed with radiographic imaging systems; the data sets from these implosions are compared to simulations derived from computer codes.

Example: Radiography. The Dual Axis Radiographic Hydrotest Facility (DARHT) is a unique facility that allows scientists to measure the many complex, dynamic aspects of a nuclear weapon during initiation. The facility consists of two large x-ray machines that produce freeze-frame radiographs (high-powered x-ray images) of materials that implode at speeds greater than 10,000 miles per hour. DARHT can take four sequential radiographs on one axis and one radiograph along a perpendicular axis, providing the first-ever simultaneous views of an implosion from two directions. The exposure time of such radiographs—60 billionths of a second—freezes the action of an imploding mockup to much less than a millimeter.

At LANL, the DARHT facility uses x-rays to simulate the events that trigger a nuclear detonation.

Production facilities: Ensuring the capacity to produce all necessary materials and components (nuclear and nonnuclear) for weapons systems requires a set of production capabilities and associated facilities, currently resident at both Laboratories and production sites. These include specialized facilities for production, storage, and assembly/disassembly of components involving special nuclear material (plutonium and uranium), as well as other specialized materials such as tritium.

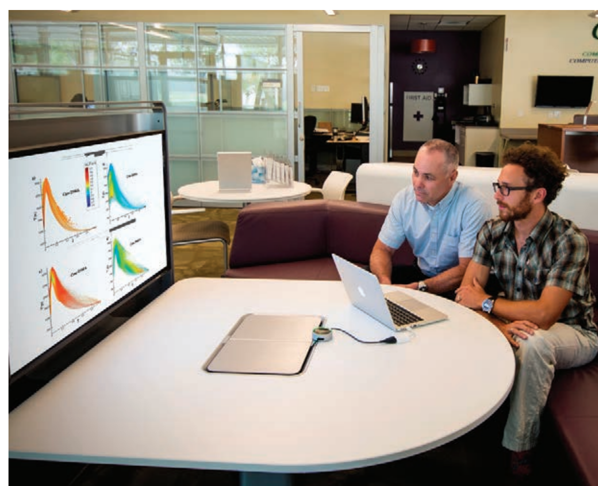
Example: Key commodities. The management of production capability and capacity for key commodities (uranium, plutonium, and tritium) is important to mission success, and modernizing the supporting programmatic infrastructure is a high priority. Y-12 manufactures uranium components for nuclear weapons, cases, and other nuclear weapons components and evaluates and tests these components for surveillance purposes. LANL provides the only fully functioning plutonium facility used for R&D and the only pit manufacturing capability within the nuclear security enterprise. The SRS recycles, extracts, and purifies gases for tritium production, and helps to maintain the U.S. nuclear stockpile by replenishing gas transfer systems.

Simulation and modeling to advance national security: From developing better gear to protect our troops in combat to ensuring the safety, security, and reliability of the Nation's nuclear deterrent, the NNSA National Laboratories rely on HPC to analyze the performance of materials under extreme conditions and over time scales ranging from years to decades. This research has led to technologies that have been adapted for use in manufacturing, health, energy, and other areas.

Additionally, while numerous studies and reports document the value of national security work to basic and applied science, the reciprocal result is well evidenced in the work conducted by DOE's Science and Energy programs and Labs. This foundational, applied, and use-inspired work contributes directly and indirectly to U.S. national security.

Example: Adaptive optics for telescopes. Laser Guide Star is a science program for land-based telescopes that has led to a breakthrough in using laser ranging in the upper atmosphere to correct for optical distortions in real time. This is now used for all large land-based telescopic systems. It also is used for precision in finding, managing, and destroying aerial platforms for friendly and unfriendly units.

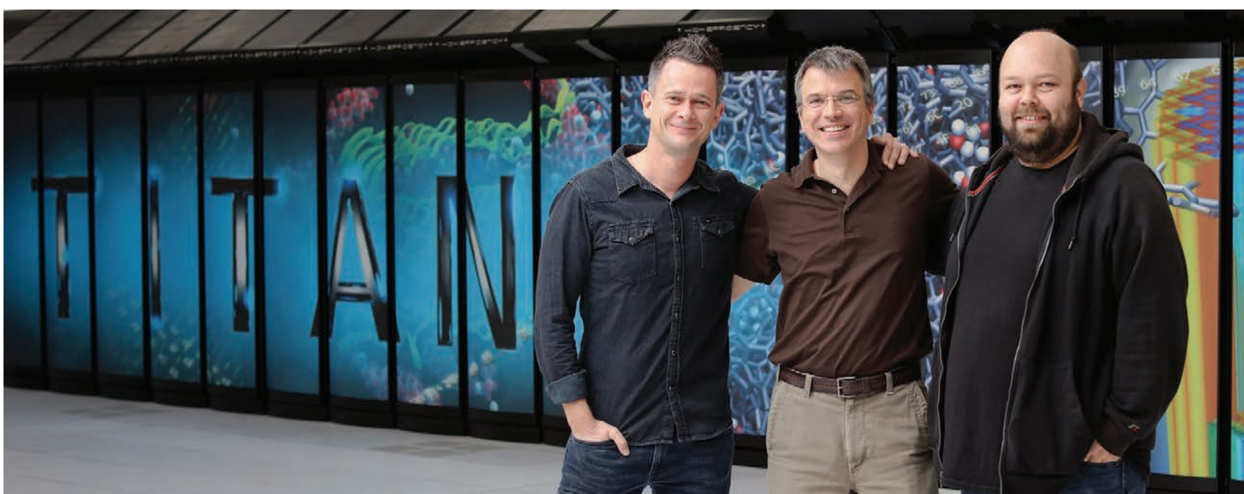
Example: Advanced combustion research. The Sandia Combustion Research Facility has sustained basic combustion R&D for decades. This unique facility, funded by SC as well as other offices and from industry, exists to answer basic questions about how fuels burn and the nature of combustion. It has empowered radical rethinking of the auto industry (and its associated military support), including high efficiency and low emissions engines. It has also directly led to dramatic improvements in the design and function of rocket propulsion systems and military jet applications, as well as modern land-based mobile military platforms.



Researchers at the Sandia Combustion Research Facility discuss their work on scramjet engine simulations. Their detailed analysis of combustion regimes in a scramjet, an engine that operates at super- to hypersonic speed, will be used in the future for military, point-to-point transport and access-to-space applications.

Example: Compound semiconductor III-V devices. DOE support of novel semiconductors includes both basic science work on the physics and chemistry of these materials, as well as efforts to improve the performance of solar photovoltaic materials. Years of work at universities and National Laboratories (notably SNL and NREL) played a key role in developing compound semiconductor III-V devices, which rests on a foundation of state-of-the-art III-V semiconductor crystal growth and regrowth using metal-organic chemical vapor deposition and post-growth quantum-well band-gap modification. These devices have important technological uses in military hardware, as well as many domestic security and civilian applications. These include vertical cavity surface-emitting lasers, which can achieve the lowest power consumption of any electrically driven lasers, highly attractive for low-power optical microsystems that include lasers, lenses and other optical elements, photodiodes, and standard integrated circuits for laser driving and photodiode sensing. They also include photonic integrated circuit design and fabrication capabilities.

Example: Advanced supercomputing. Much has been written on how the need to simulate nuclear weapons without testing has produced dramatic gains in computer power. It is also true that major investments in algorithm development, novel architectures, high-throughput computing, etc., have produced major gains and capabilities in national security. Funding from NNSA helped finance, operate, and maintain the machines and facilities, which in turn have transformed and provided the foundation for U.S. leadership in hardware and software development. However, basic science research on these machines has produced radical scientific and technical breakthroughs, which themselves have impacted national security. These breakthroughs include the ability to simulate structural mechanics (used in automobile crash testing, soldier helmet design, and aerospace design), hydrodynamic and aerodynamic flow (used in wind turbine design and weapons testing), and materials design and discovery (including drugs, catalysts, and explosives). These codes and capabilities, initially used in weapons designs, are the computational core to global climate models, which themselves have led to important national security actions and planning. The impact on U.S. economics and security is immense.



Researchers used the Titan supercomputer at the Oak Ridge Leadership Computing Facility to calculate the structure of the rare isotope nickel-78 and found that it is "doubly-magic"—protons and neutrons are present in its nucleus in certain "magic" numbers that make the nucleus more strongly bound.

Example: Quantum computing. The ability to compute beyond binary (1 or 0) remains a basic research enterprise, but with the potential to dramatically improve computing density and performance with tremendous energy use and cost reductions. One of the leading candidates for a solid-state quantum bit is the spin of a single donor electron in silicon (SNL)—its long spin lifetime is promising for quantum computing applications. Efforts in this technology as well as others leverage and help to enhance materials and fabrication capabilities directly relevant to national security. In addition to pursuing specific success in quantum computing, the exploration of "Beyond CMOS" (complementary metal–oxide–semiconductor) computing technologies serves to enhance computer science capability focused on the coupling between advanced algorithms and unconventional architectures, which is a key element of codesign. Work continues at ORNL, LANL, and other Laboratories and universities through DOE support.

Example: Treaty monitoring and verification geophysics. The stringent requirements of treaty monitoring have resulted in a very sophisticated capability in geophysics. Detecting the source strength and location of a clandestine subsurface detonation, amidst the noise of natural and other anthropogenic processes, requires detailed signature analysis, often considering multiple lines of evidence, simultaneously. Such capabilities are synergistic with those required in assessing production, sustainability, and hazard components in subsurface fossil and geothermal energy development. Recent advances sponsored by the Office of Fossil Energy (FE) and the Office of Energy Efficiency and Renewable Energy (EERE) have led to novel methods for locating very small seismic events caused by energy extraction in the crust. These methods have directly improved the capabilities and precision of treaty monitoring, which in turn has improved the capabilities and precision of test-ban monitoring, currently used to monitor Iran and North Korea, as well as the core algorithms in the ShotSpotter sniper detection system. Using joint inversion of multiple geophysical observations also permits evaluation of subsurface stress beyond boreholes in exploration, helping manage risks such as induced seismicity from water disposal from shale gas production.

4 Maintaining Excellence and Impact

The DOE maintains the system of National Laboratories as high performance organizations through leadership structures that build community and foster collaboration. In addition, the Laboratories demonstrate scientific excellence through the process of continued peer reviewed publication.

Just as significantly as its efforts to maintain the Labs' excellence, the DOE ensures the Laboratories' impact by leveraging each one's distinctive capabilities to shape them collectively into networks of programs and facilities. This expertise and experience is brought to bear on problems of national scale, and society benefits from the intellectual capital created at the Labs through transitioning technology to the marketplace. Partnerships and collaborations—among the Labs and with external partners—enable the Laboratories to leverage resources and ensure maximum efficacy in mission execution. And similarly, key Departmental initiatives—such as the Big Ideas Summit and crosscutting initiatives—facilitate collaboration between the Department's programs and the Laboratory System.

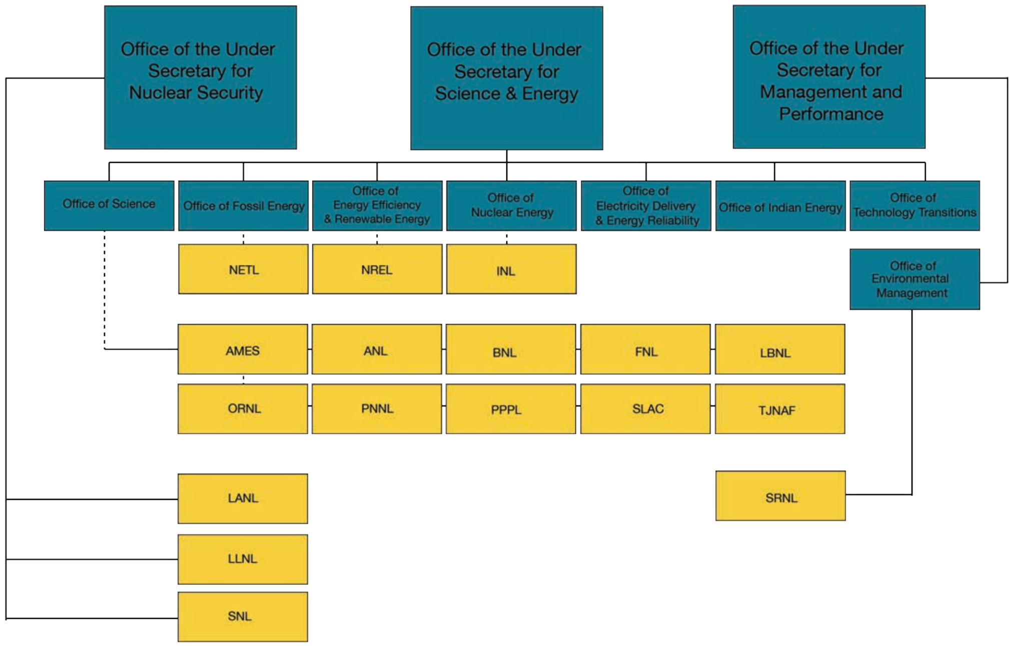
Finally, the National Labs provide foundational expertise in science and engineering disciplines. An essential part of the Department's stewardship role is to ensure this expertise is nurtured and sustained. The DOE's program of Laboratory Directed Research and Development (LDRD) enables the Labs to maintain their vitality and to stay on the cutting edge of scientific research. And the Department works closely with the Laboratories to develop a future workforce equipped with the expertise needed to meet tomorrow's energy and science challenges.

4.1 Organizing for Success: Increasing Organizational Alignment and Coordination

The leadership of DOE is responsible for the overall stewardship of the National Laboratory network. As depicted in Figure 4-1, stewardship for the 17 Laboratories is divided among DOE's three Under Secretaries according to their primary areas of specialty: the Under Secretary for Management and Performance (US/MP), the Under Secretary for Science and Energy (US/SE), and the Under Secretary for Nuclear Security (US/NS), who serves as the Administration for the National Nuclear Security Administration (NNSA).

The three DOE Under Secretaries oversee a variety of Program Offices that are each directed to engage in the DOE's mission areas. Programs under the direction of the US/SE that steward DOE Science and Energy Laboratories include SC, which has ten National Laboratories, and EERE, NE, and FE, which each have one National Laboratory. In addition, the NNSA stewards three National Laboratories, and EM stewards one National Laboratory. Although each National Laboratory has a stewarding Office, the National Laboratories are funded to do work by offices across DOE and the rest of the Federal Government.

Figure 4-1: DOE National Laboratories Stewarded by Offices of Under Secretaries



The Office of the US/MP is the Department's primary management organization, coordinating project management and the mission support functions of the DOE and overseeing the cleanup of the legacy waste from the Cold War.

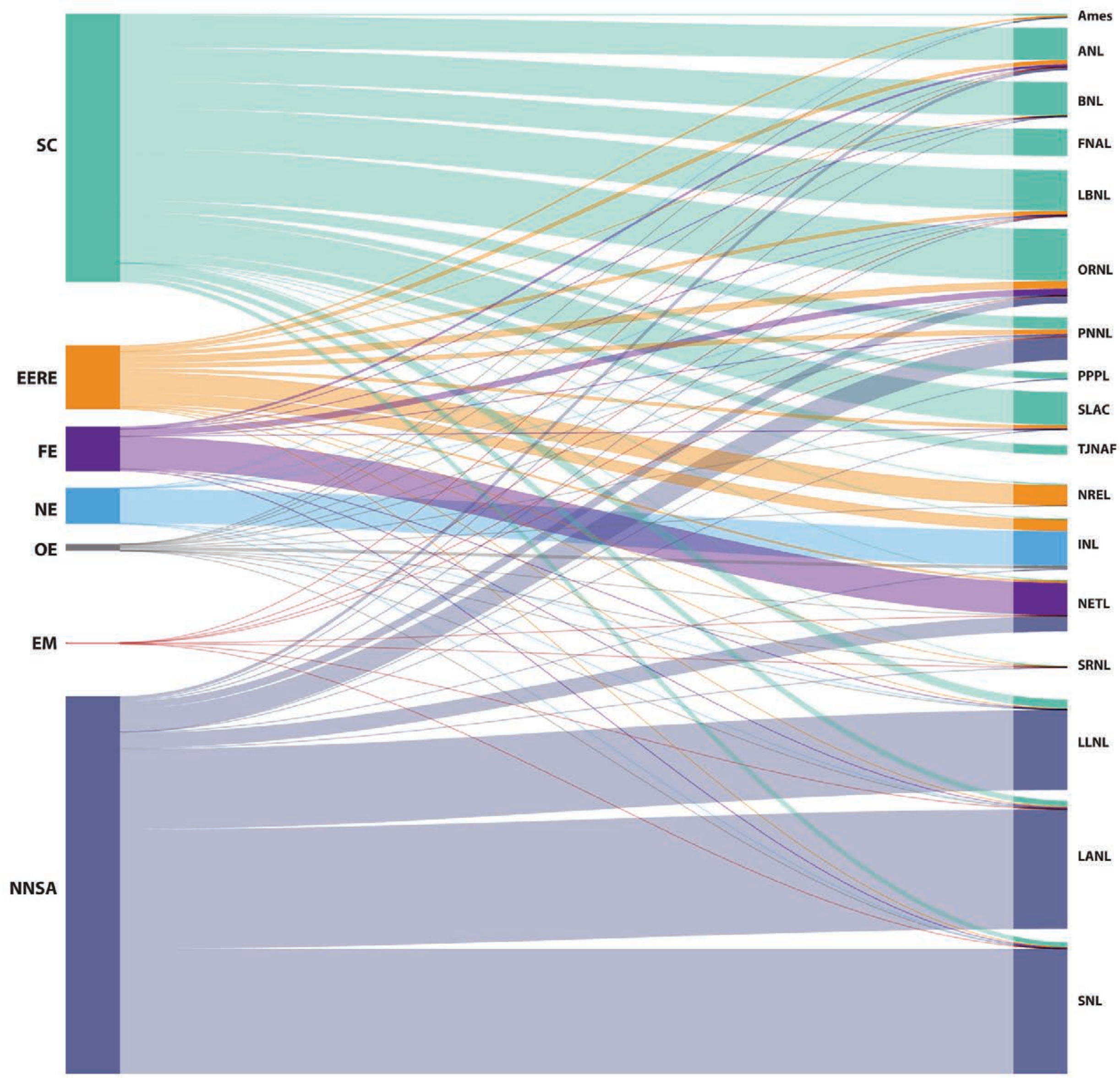
Key program areas that reside within the US/MP include EM and the Office of Legacy Management (LM). EM's mission is to complete the safe cleanup of the environmental legacy resulting from over five decades of nuclear weapons development and government-sponsored nuclear energy research. EM is the steward for SRNL.

In 2013, with the vision of accelerating science and energy technology discoveries through the innovation chain, Secretary Moniz combined DOE's Under Secretary for Science and Under Secretary for Energy into a single Under Secretary for Science and Energy (US/SE). The new Office of the US/SE manages and oversees the Science and Energy Program Offices and their National Laboratories to enhance mission performance in support of the Department's strategic Science and Energy goal and its objectives. The establishment of the US/SE was an important first step to create opportunities for close coordination among the many DOE entities involved in basic science, applied research, and technology demonstration and deployment, as well as enhanced involvement of the associated Science and Energy National Laboratories. The organizational structure for the US/SE is depicted in Figure 4-1.

The mission of the US/SE is to drive transformative science, technology, and engineering solutions through coordinated planning and management oversight of the Department's Science and Energy programs. Its vision is to deliver to the Nation groundbreaking scientific advancement, technical understanding, and viable clean energy solutions in partnership with industry, researchers, and civil society. Achieving this mission requires an aggressive, organized plan for how DOE's Science and Energy Enterprise will work together toward our Nation's economic and energy security while ensuring that America maintains its leadership in a broad range of scientific activities, including basic research in the physical sciences, developing the next generation of computational technology, and developing and maintaining world-class scientific user facilities.

The US/SE provides oversight to the management of the Nation's unparalleled system of Science and Energy National Laboratories, which are signature assets of DOE. The US/SE engages in the oversight and management of the National Laboratories in several ways. The US/SE oversees the annual planning process of the National Laboratories that is executed by the Science and Energy Program Offices, working to ensure that Laboratories are stewarded in a consistent and effective manner. Specifically, the US/SE has purview over four Program Offices with responsibility for National Laboratories (SC, EERE, NE, and FE) as well as the Office of Indian Energy Policy and Programs, the Office of Electricity Delivery and Energy Reliability (OE), and the Office of Technology Transitions (OTT). The US/SE also works to engage the Laboratories in a strategic manner through avenues such as the National Laboratory Big Ideas Summit. To maximize Laboratory subject-matter expertise to inform strategies and planning, the US/SE incorporates relevant information and outcomes from the Department's boards, councils, and program workshops and reviews. US/SE staff also coordinate with the Science and Energy program managers, the field operations and chief operations officers, as well as elements of the Administrative Department, to accomplish these activities.

Figure 4-2: Flow of Funds from DOE Program Offices to DOE National Laboratories



The US/NS is the leader of the NNSA, a semiautonomous agency within DOE responsible for enhancing national security through the military application of nuclear science. NNSA maintains and enhances the safety, security, and reliability of the U.S. nuclear weapons stockpile without nuclear explosive testing; works to reduce the global danger from weapons of mass destruction; provides the U.S. Navy with safe and effective nuclear propulsion; and responds to nuclear and radiological emergencies in the United States and abroad. NNSA oversees three Laboratories: LANL, SNL, and LLNL.

Independent of the stewarding organization, the Program Offices fund the Laboratories that provide the needed capabilities. Figure 4-2 illustrates the flow of funding to each of 17 DOE National Laboratories from US/SE Program Offices, NNSA, and EM.

4.2 Building Community: National Laboratory Directors' Council

Made up of the 17 Laboratory Directors, the National Laboratory Directors' Council (NLDC) is a community of leaders who gather to discuss how best to meet the collective national missions through the National Lab System. The NLDC has a working group structure, and these provide an interface to DOE organizations on issues and concerns of common interest, both strategic and operational. For example, the Chief Research Officers advise on scientific and crosscutting programmatic issues, and the Chief Information Officers on computing, information processing, and cyber security issues.

The NLDC also functions as a forum for information exchange, consensus building, and coordination of matters that affect all of the National Laboratories. The NLDC furthermore serves as a feedback mechanism to provide continual improvements throughout the enterprise and ensure alignment with the Secretary's vision. The Secretary regularly meets with the Executive Committee (four Laboratory Directors selected by their peers who serve on the Laboratory Policy Council [LPC]), and typically twice per year with the whole NLDC.

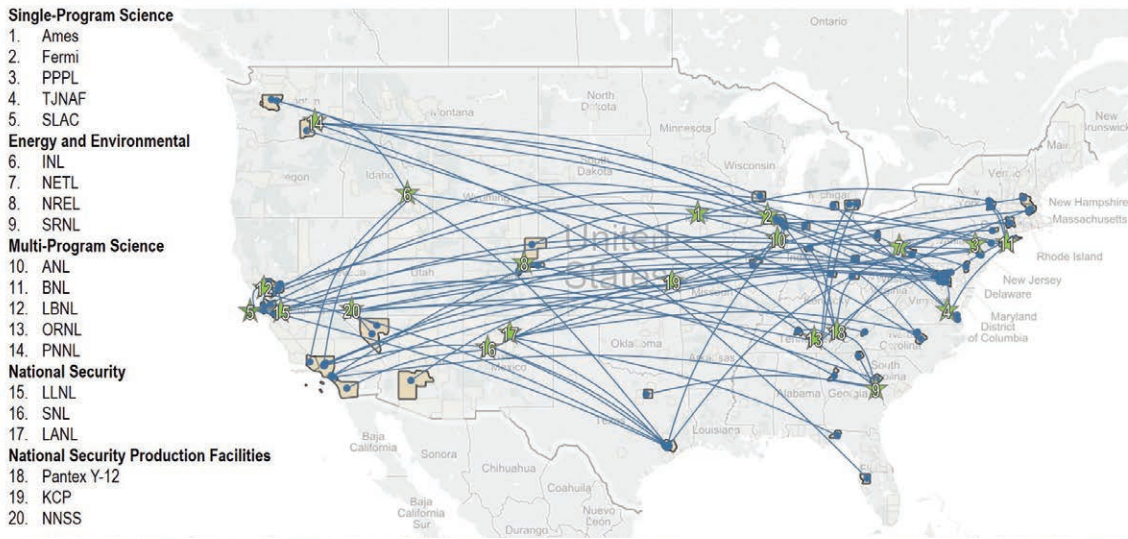
4.3 Leveraging Resources: Laboratory Partnerships and System Collaborations

Since 2013 the Department has initiated a systematic and comprehensive effort to more strategically engage the National Laboratory System in focusing on large-scale, impactful initiatives. Because of their unique role in the energy innovation ecosystem in addressing complex, multidisciplinary problems with long time horizons—a role supported by the unique DOE facilities housed within the National Laboratory Complex—National Laboratories serve as critical hubs connecting the efforts of universities, industry, and Federal research partners. In general terms, the locus of excellence for universities resides in early discovery; for industry, in near-term solutions responsive to market needs and competitive pressures; and for the National Laboratories, in the space in between that deals with complex problems requiring sustained, long-term focus. The National Laboratories thus serve as key nodes within a network of energy innovation, enabling and facilitating developments throughout the R&D spectrum.

This role can be seen in at least two important ways—collaborations involving the Laboratories and external partners, such as states, industry, and universities; and collaborations among the Laboratories, leveraging their various strengths into a cohesive system that flexibly responds to major challenges.

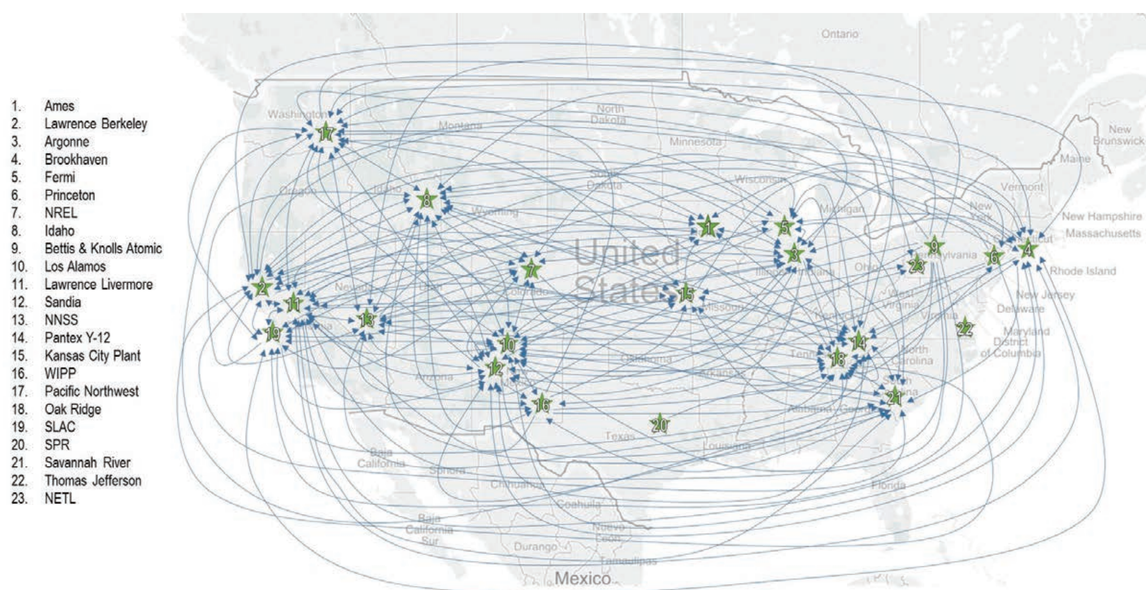
Figure 4-3 depicts collaborations between the Laboratories and NNSA production facilities and nonfederal external partners. For each of the 20 Laboratories and NNSA facilities, the diagram shows the top five nonfederal partner collaborations via technology transfer agreements active in FY 2015—i.e., ACTs, CRADAs, and SPPs. While representing only a sliver of the approximately 3,000 active agreements in FY 2015 between Laboratories and nonfederal partners, the diagram illustrates the sheer breadth of engagement of the National Laboratories with external partners on technology transfer. It also underscores the crucial role that National Laboratories play in bridging the gap between fundamental discovery science and the large-scale commercial deployment of energy technologies.

Figure 4-3: DOE National Laboratory and Production Facility Collaborations with Nonfederal External Partners



Another clear indication of the extent to which the National Laboratories work together as a cohesive system can be found in the Inter Entity Work Order (IEWO) process. Figure 4-4, below, depicts active Integrated Contractor Agreements through August 2016 for the National Laboratories and NNSA plants. The IEWO process is used for a wide array of collaborations including research and development, software development, materials testing and characterization, engineering analysis and design, and project management reviews. In the map, lines with an arrow on one end indicate funds moving from one integrated contractor to another through one or more work authorizations. Lines with arrows on both ends indicate funds moving in both directions through one or more work authorizations. The visualization unambiguously reveals a network of National Laboratories operating to complement and support one another.

Figure 4-4: Inter Entity Work Orders between DOE Laboratories and Facilities



4.4 Maintaining Adaptability: Innovation through Flexible Partnership Tools

Innovations from the National Laboratories are a vital element in the Nation's innovation ecosystem. They partner with others, especially industry, to integrate fundamental and applied precompetitive research for the broad benefit of the economy. They contribute materially to U.S. economic prosperity by making key scientific discoveries, demonstrating the utility of these discoveries in early proofs of concepts, and working with industry to move these technologies into the marketplace.

Facilitating this innovation ecosystem are flexible R&D partnership tools used by the Department to support the Laboratories in addressing a wide array of R&D challenges. Ranging from single investigator awards that focus on relatively specific scientific or technical research questions to research structures that enable dozens of scientists and engineers spanning multiple disciplines and institutions to cooperatively address major research challenges, these modalities encompass the full R&D spectrum—from discovery science to large-scale demonstrations (Figure 4-5). In recent years, these mechanisms have included the following:

- Single investigators and small groups of investigators conduct discovery science with the goal of understanding the world around us. Activities are typically reviewed every 3 years, and there is no sunset provision.
- Energy Frontier Research Centers (EFRCs) are composed of a set of self-assembled investigators, often spanning several science and engineering disciplines and multiple organizations, who 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 CO2 sequestration. DOE's SC currently supports 32 EFRCs, representing some 530 senior investigators and 1,250 students, postdoctoral fellows, and a technical staff at 100 institutions across the Nation. Of the 32 EFRCs, 8 are led by National Laboratories, and 29 have National Laboratory participants.
- Energy Innovation Hubs focus the attention of a large set of investigators spanning many science, engineering, and public policy/economics disciplines on a critical national need. 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 currently sponsors four hubs:
    - The Joint Center for Artificial Photosynthesis (JCAP), with the California Institute of Technology and LBNL as lead partners, and with contributions from SLAC and UC San Diego. JCAP is supported by DOE's SC.
    - The Consortium for Advanced Simulation of Light Water Reactors (CASL), with ORNL, INL, LANL, and SNL as lead Lab partners; Michigan, MIT, and North Carolina State as university partners; and EPRI, TVA and Westinghouse as industry partners. CASL is supported by DOE's NE.
    - The Joint Center for Energy Storage Research (JCESR), led by ANL, with participation from LBNL, PNNL, SNL, and SLAC, as well as research universities and materials and battery companies. JCESR is supported by DOE's SC.
    - The Critical Materials Institute (CMI), led by Ames, INL, ORNL, LLNL, seven research universities, and eight companies as partners. CMI is supported by DOE's EERE.
- Manufacturing Innovation Institutes (MIIs) are established through partnerships between DOE and several other Federal agencies, including Commerce, Defense, and Agriculture, as part of the National Network for Manufacturing Innovation (NNMI). NNMI brings together industry, academia, DOE Labs, and state and local economic and workforce development stakeholders to revitalize America's manufacturing industry. This network of local "ecosystems" (1) combines public and private resources

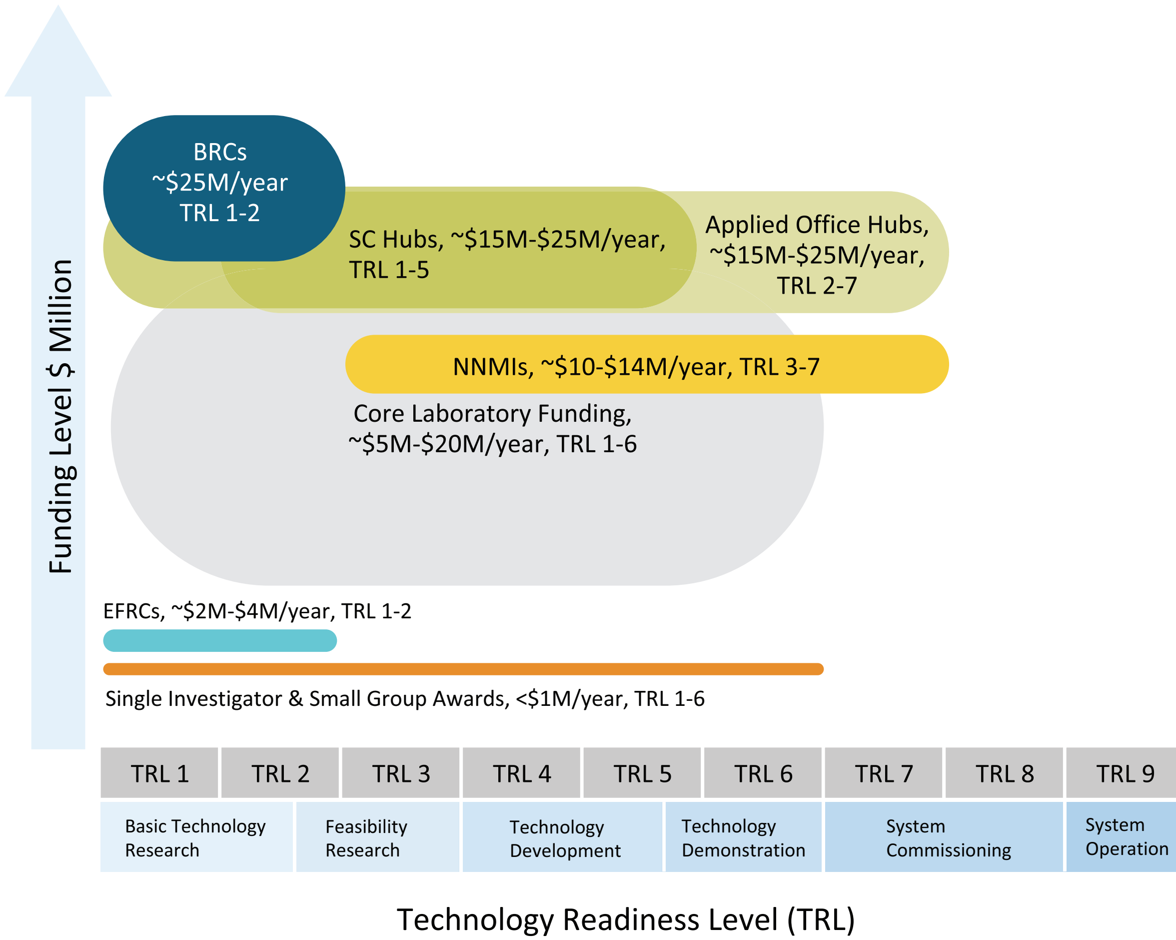
to develop advanced technologies that help U.S. manufacturers achieve a competitive advantage in global markets, (2) makes it attractive for private industry to site future manufacturing facilities in the United States, and (3) creates a talent pipeline needed to support the growth of manufacturing in the United States. Every MII includes a business plan to enable the institute to sustain its operation with private, state, and local funding after the initial five-year period of Federal funding. DOE is sponsoring three MIIs:

  - The Institute for Advanced Composites Manufacturing Innovation, with ORNL and NREL as key partners
  - PowerAmerica, with ANL and NREL as key partners
  - Clean Energy Smart Manufacturing Innovation Institute, for which PNNL will lead a regional hub with INL, LLNL, ORNL, NETL, NREL, and SRNL as research partners

- Bioenergy Research Centers (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 programs on microbes and plants in an effort to develop innovative biotechnology solutions for energy production. The three current BRCs are
  - Joint BioEnergy Institute (JBEI), led by LBNL,
  - Great Lakes Bioenergy Research Center (GLBRC), led by the University of Wisconsin-Madison, and
  - BioEnergy Science Center (BESC), led by ORNL.
- Annual Operating Plans & Laboratory Calls provide additional partnership tools. The Applied Energy Technology Offices use their annual operating plans (AOPs) to directly fund core and enabling S&T capabilities that have long-term value in advancing strategic and programmatic objectives. Any funding opportunity announcement (FOA) awards should be supplementary, meaning the funds are not necessary to sustain core or enabling capabilities. Program Offices may conduct inter-Lab competitions or Lab calls; these may be appropriate for new or emerging capabilities and for determining capabilities that may exist at National Laboratories but are not currently recognized. Lab calls may also be a good tool to encourage inter-Lab collaboration and bigger consortia-like projects where Labs synergistically combine enabling capabilities to accomplish a challenging multiyear goal in one project.

In addition to pursuing R&D at the early and middle stages of a technology's innovation path, the National Laboratories are also charged with a technology transfer mission to ensure that the Nation's R&D investment is exploited to the fullest extent. Details about the Department's and Laboratories' technology transfer activities are provided in section 4.2.

Figure 4-5: Select DOE R&D Partnership Tools



4.5 Fostering Collaboration: National Laboratories Big Ideas Summit

In addition to building community across the Laboratory System leadership, the DOE also fosters collaboration among the Labs. A key mechanism used by the Office of the US/SE to engage the Laboratories in strategic technical planning is the National Laboratory Big Ideas Summit (BIS). The Summit presents an opportunity for the senior leadership at DOE headquarters and the Laboratories to work in partnership to address the Nation's most important clean energy challenges.

The BIS challenges the National Laboratories to develop early-stage, potentially large-scale solutions to national energy issues. The process facilitates collaborative, cross-Laboratory, multidisciplinary teams and provides a unique outlet for National Laboratory-generated ideas. The NLDC's Chief Research Officer (NLCRO) committee coordinates preparations for the BIS, requesting ideas in advance of each summit, and down-selecting the best ideas to bring forward. The selected ideas must cross multiple program areas, involve diverse research at multiple Laboratories, and have transformational aspirations (Table 4-1).

Ideas from the BIS have resulted in major DOE initiatives and have been incorporated into the DOE Presidential Budget Request. They have also informed the DOE's planning in other ways, e.g., influencing the direction of activities going forward and facilitating focus on emerging ideas. In addition, BIS ideas are frequently reflected in the DOE's crosscut initiatives and Technology Teams.

Table 4-1: Ideas from the First Three Years of the BIS

BIS-1, March 2014	BIS-2, April 2015	BIS-3, April 2016
• Creating an adaptive and resilient U.S. electric grid • Systems integration: accelerating the clean energy future • Adaptive control of sub-surface fractures and fluid flow • Sustainable and secure water management • Accelerating materials to manufacture • Climate change science and adaptation • Nuclear energy: enabling rapid commercialization • Accelerating sustainable transportation	• Energy-water nexus • Accelerating the path to economic and sustainable fuels and vehicles • DOD/DOE coordinated energy research program • Urban systems science and engineering • Bridging nano to macro: enabling advanced materials scale-up for industrial manufacture • Chemical conversions for sustainable energy	• Enhancing the global carbon sink • Greenhouse gas - emissions reporting and analysis system (GHG-ERAS) • H2@ Scale: Deeply decarbonizing our energy system • Solving big problems with small accelerators • Transportation as a system • Solving the information technology energy challenge beyond Moore's law • Advancing biomanufacturing: The SynBio foundry • Energy Everywhere: Clean energy through modular chemical conversions • Metropolitan energy initiative

4.6 Bridging Gaps: Programmatic Crosscutting Initiatives

In 2013 the Department began a set of crosscutting initiatives—many of which build upon and incorporate ideas originally presented at the National Laboratory Big Ideas Summit (see section 4.5). While the Science and Energy Program Offices work to achieve their own missions and goals, science and technology research opportunities often overlap Program Office boundaries. Fundamental science advances can create potential technology applications, and technology advances can illuminate opportunities for better understanding of fundamental physics, chemistry, and transport phenomena to advance applications. To address these complementarities, the Office of the US/SE oversees "crosscutting initiatives" that span multiple Program Offices and Laboratories to accelerate progress on high priority challenges. These activities are not solely focused on science and energy challenges; in fact, several of the DOE's crosscutting initiatives explicitly include interests associated with national security programs, such as exascale computing, cybersecurity, advanced materials, and manufacturing. The NNSA National Laboratories are also engaged as partners in other crosscuts.

Of the crosscutting activities underway, the Grid Modernization Laboratory Consortium (GMLC) perhaps best exemplifies how engagement between the Program Offices and the Laboratory network has evolved.

Following its ideation at the 2014 Big Ideas Summit, the GMLC was formally established in Fall 2014 to better align the activities of EERE, OE, and the Office of Energy Policy and Systems Analysis (EPSA), and the Laboratories to pursue advances in the grid-related areas of technology and policy. Directed by a four-person leadership team featuring Federal employees from EERE and OE, and Laboratory employees from NREL and PNNL, the GMLC leadership team established an operating structure that consists of an executive committee representing senior DOE leadership, and a core consortium team with senior representatives from DOE and the Laboratories, and six R&D technical teams led by Laboratory employees. In total, 13 of the 17 National Laboratories are participating in the GMLC.

While the GMLC initially focused on aligning the multitude of ongoing grid-related efforts through the DOE enterprise, it also initiated and completed a strategic multiyear program plan (MYPP) that establishes the direction of DOE's grid R&D for the next five years. Pursuant to that plan's guidance, the GMLC competitively awarded $220 million in funding for the Laboratory participants in Spring 2016. These types of activities are demonstrating early returns on the close collaboration among the enterprise's most senior grid-focused managers, scientists, and researchers.

As the Nation's grid undergoes a period of massive public and private sector investment, DOE's engagement in advancing grid technologies and policies is especially important. Since 2009, investment in the modernization of America's electricity infrastructure has increased dramatically, in large part due to the nearly $8 billion in 99 public-private Smart Grid Investment Grant (SGIG) projects involving more than 200 electric utilities. These projects have helped push the deployment of smart meters to approximately 37 percent of the country's electricity consumers. In addition to public-private programs like the SGIG, America's shareholder-owned utilities spent approximately $55 billion on transmission infrastructure from 2012 to 2015, a 32 percent increase over the previous four-year period. Overall grid modernization investments are projected to achieve $130 billion in annual benefits for the U.S. economy by 2019.

4.7 Fostering Innovation: Laboratory Directed Research and Development

Among the most important mechanisms for innovation and for maintaining the vitality of the National Laboratories is the LDRD program, the main source of discretionary funding for investments in R&D. In 1991, the DOE formally established the LDRD program to give Laboratory Directors the ability to allocate funding to support employee-initiated proposals that explore forefront areas of S&T. The LDRD program's objectives are to (1) maintain the scientific and technical vitality of the National Laboratories; (2) enhance the Labs' ability to address current and future DOE/NNSA missions; (3) foster creativity and stimulate exploration of forefront S&T; (4) serve as a proving ground for new concepts in R&D; and (5) support high-risk, potentially high-value R&D.

The LDRD program is used by the Laboratories to maintain critical core competencies, recruit and retain the next generation of scientists and engineers by providing postdocs with challenging and important research, target emerging research areas where there is potential high return-on-investment for resolving sponsor problems, and address evolving customer needs. The LDRD program is particularly important at the three National Security Laboratories, as a significant fraction of the R&D workforce is recruited through the postdoctoral program, and LDRD provides a high percentage of support for postdoctoral researchers in those areas that can be published. For the DOE National Laboratories as a whole, 28 percent of the postdoctoral researchers at National Laboratories received at least partial funding from an LDRD project in FY 2015. Further, LDRD-supported research produced over 2,000 publications per year in FY 2012, FY 2013, and FY 2014. Finally, in FY 2014, LDRD-supported research led to 376 invention disclosures and 160 patents, numbers that support the premise that LDRD is an important mechanism for innovation.

Each DOE National Laboratory establishes the strategic direction and priorities for their LDRD programs, bearing in mind their sponsor's and other national needs. Laboratory researchers submit proposals that are aligned with the LDRD call; these are competitively selected based on technical merit and applicability to the criteria.

The current limit on LDRD funds at a Laboratory (consistent with section 309 of the Consolidated Appropriations Act of 2014) is six percent of a Laboratory's total operating and capital equipment budget. The actual funding levels vary across the DOE National Laboratories and are approved each year by the DOE Program Office responsible for the Laboratory. Each year, a Laboratory submits an LDRD Program Plan to request the funds and provide the strategic areas of LDRD investment for the coming year. For the DOE National Laboratories as a whole, 4.15 percent of the total operating and capital equipment budget was used to fund 1,662 projects in FY 2014, and 4.15 percent of the funding was used to fund 1,741 projects in FY 2015. The DOE Chief Financial Officer (CFO) submits an annual report to Congress on LDRD expenditures, and the reports are available on the CFO portion of the DOE website (http://energy.gov/cfo/reports/laboratory-directed-research-and-development-annual-reports).

4.8 Ensuring Excellence: Stewardship of Core Capabilities

The DOE exercises its overall stewardship of the National Laboratories through setting goals via the annual Performance Evaluation and Measurement Program (PEMP) and allocating appropriate resources; through holding the Labs accountable for delivering results (though endeavors to not interfere with how the work is done); and through administering competitions for funding to pursue grand challenges. It also reviews annual Lab plans for the SC and Applied Energy Labs.

The contractual mechanisms for the National Laboratories—called an M&O contract—are discussed in detail in Appendix A. The four fundamental features of the M&O model—stewardship, accountability, competition, and partnership—ensure that the National Laboratories are always evolving to meet national needs, are intellectually competitive, and are working in partnership with the national research community.

With its collection of unique scientific expertise and facilities, the National Laboratories play a vital role in helping the United States maintain the science and technology leadership needed to sustain economic superiority in a highly dynamic and innovative global economy. But beyond the economic aspects of what the Laboratories contribute to the Nation, they also offer foundational expertise in scientific and engineering disciplines that undergird the Nation's research community and national security. A key aspect of DOE's stewardship of the Laboratories is to ensure that these foundational areas of expertise, or core capabilities, are nurtured and appropriately sustained.

Perhaps the clearest example of such a core capability is the development, design, and certification of the Nation's nuclear stockpile. Each year, the Secretaries of Energy and Defense certify that the stockpile remains safe, secure, and effective without the need for underground nuclear explosive testing. The scientists, engineers, and technicians at the three National Security Laboratories, the four nuclear weapons production plants, and the national security site are primarily responsible for ensuring such a certification is possible. The ability to provide the information required to support such a certification requires deep expertise in weapons physics, component aging, and material properties. This expertise is sustained and strengthened each year through the NNSA's research, development, test, and evaluation programs and research facilities.

Specific to National Laboratories stewarded by the US/SE, DOE maintains a list of the core competencies for each of the Laboratories. The National Laboratories are highly valued for the technical core competencies they provide via (1) their scientific infrastructure (e.g., large and small user facilities, modern laboratories, computing facilities, and one-of-a-kind research tools); (2) the depth and breadth of knowledge and know-how of their staff scientists and engineers; and (3) the technologies that they create. Capabilities include areas such as accelerator science and technology, high performance computing, and nuclear fuels and reactors. The National Laboratories are the stewards for design and construction of large-scale accelerators, for example, and maintaining such capabilities is important for the future of scientific research, and the U.S.'s leadership in S&T fields critical to maintaining our Nation's economic well-being.

During annual Laboratory reviews, specific attention is given by DOE leadership to ensure that the Laboratory System's core capabilities are being appropriately and strategically supported. The 24 capabilities currently evaluated across the Science and Energy Laboratories are listed below.

Categories of Core Capabilities

- Accelerator Science and Technology
- 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
- Particle Physics
- Plasma and Fusion Energy Science
- Power Systems and Electrical Engineering
- Systems Engineering and Integration

4.9 Maximizing Impact: National Labs as Core, Dynamic, and Rapid Response Networks

In addition to fostering collaboration and competition among the National Laboratories, the DOE maximizes the impact of its investment by leveraging each Lab's set of unique scientific tools, facilities and intellectual environments, not to mention each Lab's integrated scientific engineering and project management expertise. These capabilities set the National Labs apart from both industry and the universities, and give the Labs their distinctive role in the Nation's S&T ecosystem.

The DOE's missions are complex, multiyear problems, and no single institution can completely cover these mission areas. To ensure that it has maximum impact, the DOE organizes the Labs into core, dynamic, and rapid networks. These provide the diversity and flexibility of expertise to respond to urgent and complex challenges. They also provide the depth of expertise in many disciplines so that whole new fields of research can be created in response to changing national needs.

> Core: The National Labs in this network tackle challenges of such long duration, scope, and depth that the goals are reflected in a key area of the DOE mission. These projects typically require large-scale infrastructure—in today's terms, billion-dollar facilities—built over a long period of time and used for decades. Networks of core Labs take on the most advanced and largest scale projects.
>
> Dynamic: Periodically, the DOE needs to address a problem of current national need on a 5- to 10-year time frame. A network of Labs can be brought together to solve these more dynamic problems.
>
> Rapid Response: Faced with an exigent need, the DOE calls on Laboratories with the relevant depth of expertise to respond quickly and with authority.

The particular Laboratory network assembled to work on a problem will depend on the nature of the challenge, but the following examples illustrate in general how the Labs are deployed by the Department.

Examples of Core Lab Networks

One of the most fundamental Laboratory networks concerns physics and the universe. This includes the four single-purpose Physics Labs, as well as other Labs that have significant expertise in this area (i.e., ANL, LBNL, BNL, ORNL, and SLAC). These Labs are focused on questions such as "What is dark energy, dark matter, the quark structure of nuclei, plasma physics and fusion energy, and the properties of quark gluon plasma?" These are hard, deep questions in physics, and when scientists come together in teams to work on these problems, they create specialized facilities and unique measurement capabilities. Accelerator science—the ability to accelerate charged particles to extremely high energies—is at the core of many of the parts of the Laboratories' physics discovery science. Accelerator science was part of the core of the initial formation of the National Laboratories, and today, the technology of creating accelerators is an intriguing area of science with very important technological and scientific impacts. Laboratories specialize in various aspects of creating future accelerators, such as making superconducting radio frequency for different applications (FNAL), producing accelerators for neutron beams (ORNL) or heavy ion beams (TJNAF), or accelerators that operate on different principles than the ones we know today (LBNL), or accelerators related to x-ray lasers (SLAC). Each of these Labs is distinctive, but they collaborate closely in the creation of future accelerators.

The Laboratories' accelerators have had an enormous impact on science and the U.S. economy. In the past 30 years, the creation of new accelerators and the DOE network of synchrotron accelerators have made it possible to observe matter with x-rays. Four Laboratories form a core network of foundational measurement capabilities in the area of x-ray science and are anchor facilities at multipurpose National Laboratories. These four synchrotrons differ in the energy of the x-rays they create, which in turn shapes the science performed at each facility. For example, one synchrotron is optimized for looking at surface chemistry and electronic structure (LBNL); another for looking at bulk matter and investigating materials at depth (ANL). The four facilities are a spin-off from the accelerator science core networks, and have made contributions to science ranging from the discovery of new kinds of drugs to new types of energy technologies. In terms of the scientific community, 11,000 users run experiments at these synchrotrons every year. Many science agencies benefit enormously from this DOE core network.

Examples of Dynamic Lab Networks

Dynamic networks respond to an emergent need that has perhaps a 10-year horizon. One example is the Global Threat Reduction Initiative, initiated after the end of the Cold War. The United States had complex governance and stewardship issues at sites where nuclear material was handled. In response, the DOE created an extensive Laboratory network with ANL, INL, LANL, LLNL, PNNL, SNL, and ORNL. These Labs worked together on the conversion and removal of nuclear material, and also completed physical security enhancements at buildings around the world.

Dynamic Lab networks are also important in the energy space because the world of energy changes on a time scale of about 10 years. Therefore, the Department needs to constantly bring Labs into coalitions that will last on the order of a decade to work on specific problems. For example, the DOE formed a dynamic Lab network to work on the problem of meeting clean energy goals with nuclear power. The DOE tasked LANL, INL, PNNL, and ORNL with developing advanced fuel with improved safety performance; ORNL, INL, and PNNL with exploring how to support life extension for the current fleet of reactors; ANL, LANL, ORNL, INL, and PNNL with advancing the modeling and simulation of nuclear reactors (this network also involves many universities); and INL, NREL, ANL, and ORNL with finding ways to incorporate nuclear power into a modern grid.

Examples of Rapid Response Lab Networks

Rapid response Lab networks bring National Laboratory resources together to address an evolving event. Environmental crises provide the most acute examples, including the 2010 Deepwater Horizon oil spill. The Labs came together very quickly and provided mechanisms for visualizing what was going on underwater. The most quantitative and accurate measurements for determining the flux rate of that spill came from the National

Security Labs (SNL, LLNL, and LANL), who came together to form this rapid response network. Critical measurement capabilities that are needed for the security missions of these Laboratories were rapidly deployed for the purpose of imaging the effects of the oil spill.

Other critical contributions from the Laboratories included advancing the understanding of the spill's effect on the Gulf's ecosystem. For example, today we know the Gulf supports bacteria that eat oil from naturally occurring seeps. When the Deepwater Horizon spill happened, that bacterial population swelled and increased the level of oil biodegradation. Previous and ongoing work at several of the Laboratories led to a greater understanding of the biodegradation process.

Today the network of National Laboratories is a vital part of the innovation ecosystem in the United States and is constantly evolving in response to the needs of the Nation. While each of the 17 National Labs has its own distinctive capabilities, together the Labs serve as the science and technology engine for DOE missions. The DOE leverages networks of Labs that address core missions, dynamic programs, and rapid response needs, with major continuing impact.

4.10 Maintaining Scientific Excellence: Publications

Collaborations among Laboratories constitute another critical aspect of the energy innovation ecosystem. Each National Laboratory has a set of unique scientific tools, facilities, and intellectual environments. By working with one another to leverage these unique assets, the Laboratories expand the frontiers of energy research. Figure 4-6 depicts the consistent and growing degree of collaboration among the National Laboratories, as evidenced in coauthored journal articles. The graph shows the number of total articles published by the National Laboratories since 2000 in dark blue, the percentage of those involving an academic collaboration (as measured by the author's institution) in light blue, and the Lab-to-Lab collaborations in orange (two National Labs involved) and red (three or more National Laboratories involved). For the period 2000 to 2015, inter-Lab collaborations on published journal articles increased from 6.9 percent to 11.3 percent. And while this measure over-weights the research that is published, it shows a clear trend consistent with the anecdotal evidence of increasing collaborations over the past 15 years.

For this same period, National Laboratory collaborations with academic partners increased from 78.6 percent to 81.6 percent. The trend can be attributed to several factors and initiatives. In part, the period of time has seen a large growth in the number of users at the designated user facilities and the expanded use of high performance computing in conducting science. As noted previously, the unique facilities including the computational power are a major driver for collaborations with the National Labs.

If additional types of jointly authored research outputs are considered, the trend toward an increasing degree of collaboration between the National Laboratories becomes more pronounced. Figure 4-7 depicts Laboratory collaborations for journal articles, technical reports, conference proceedings, and patents. The trend line shows a steady increase in collaboration since 2000—a roughly 175 percent increase throughout the time frame.

Research conducted at the National Laboratories spans the full breadth of science- and technology-related disciplines, from physics and chemistry to metallurgy and microbiology. National Laboratory collaborations within specific disciplines have also steadily increased over time. Figure 4-8 depicts the discipline-specific increase for physics collaborations, showing absolute numbers of articles for each year (in blue), alongside the subsets of these articles where two (orange bar) or more Labs (red bar) collaborated in the underlying research. As the total number of articles has increased, so too has the rate of Laboratory collaboration, moving from 6–8 percent in the early 1990s to 16–19 percent in the current decade.

Figure 4-6: Trends in Journal Article Collaboration involving National Laboratory Researchers

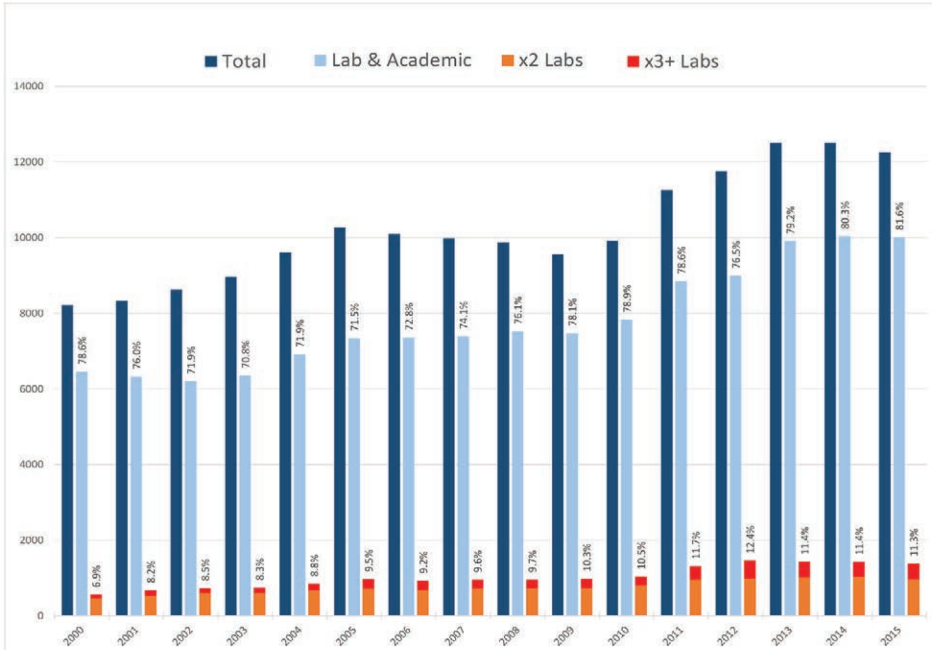
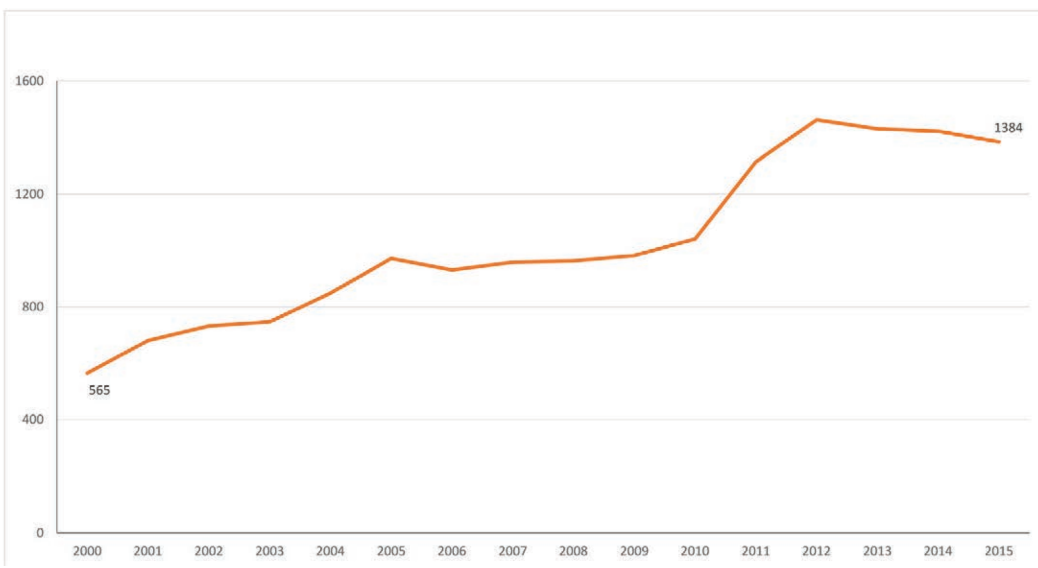


Figure 4-7: Aggregated Trends in Collaborations among DOE Labs



Similarly, Figure 4-9 demonstrates the discipline-specific increase for astronomy and astrophysics collaborations, with the rate of Laboratory collaboration moving from 6 percent in 1990 to 25 percent in 2015.

Figure 4-8: National Laboratory Journal Article Collaborations in Physics

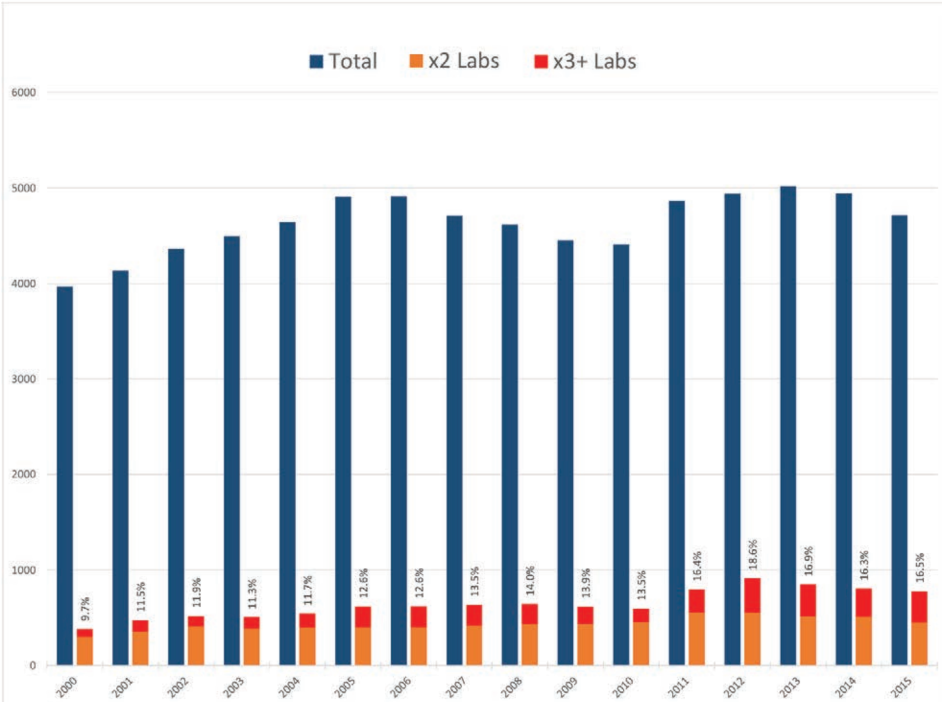
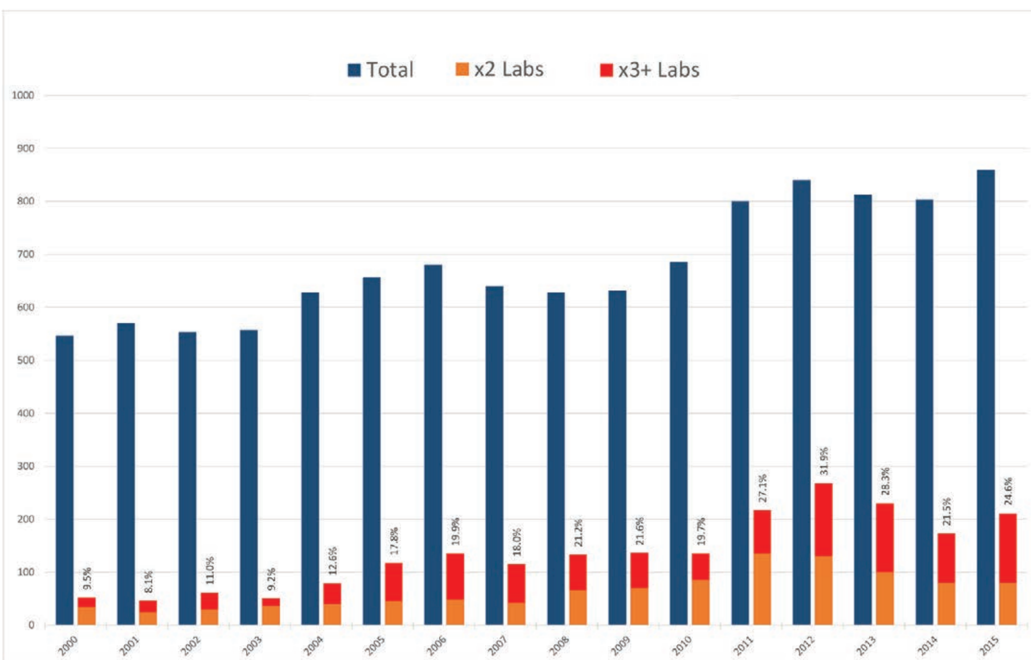


Figure 4-9: National Laboratory Journal Article Collaborations in Astronomy and Astrophysics



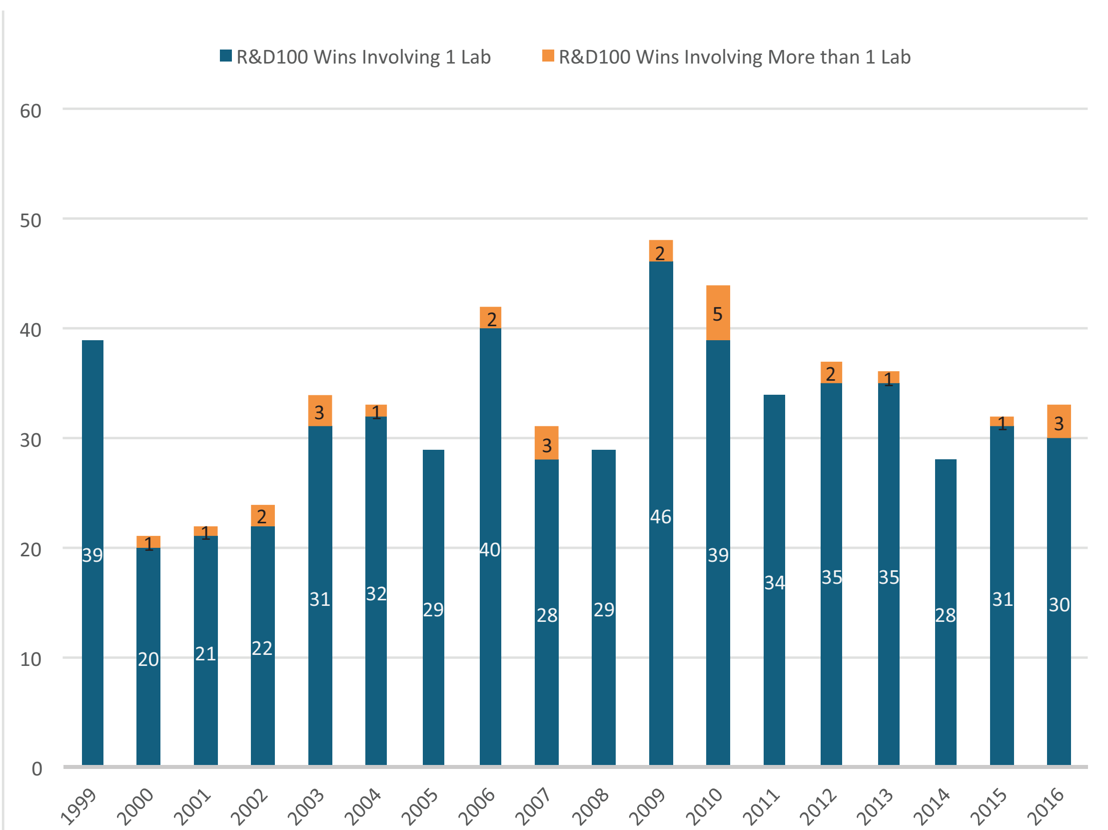
4.11 Achieving Innovation: National Laboratory R&D 100 Wins

An important metric of the success of DOE's technology commercialization activities is the quality and impact of the technologies that reach the commercial sector. It often requires many years, or even decades, to realize the full impact after an initial discovery. In tracking outcomes, the number of "handovers" of technology from the Labs to the commercial sector can serve as a useful metric; indirect assessments are needed to follow any subsequent impacts.

Widely recognized in industry, government, and academia as a mark of excellence for the most innovative ideas of the year, the R&D 100 Awards are the only industry-wide competition rewarding the practical applications of science. The R&D 100 Awards are given annually by R&D Magazine 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 working and marketable condition—no proof of concept prototypes are allowed—and had to be first available for purchase or licensing during the year prior to the award. The awards are selected by an independent panel of judges based on the technical significance, uniqueness, and usefulness from across industry, government, and academia.

The number of R&D 100 Awards illustrates the success and visibility of the National Laboratories' commercialization activities. Figure 4-10 depicts the number of R&D 100 Awards won by National Laboratories—often in collaboration with university and industry partners—from 1999 to 2016. The blue bar depicts R&D 100 wins in which a single Lab was on the winning team; and the orange bar depicts wins involving more than one Lab. National Lab researchers won 33 of the 100 awards in 2016, 32 awards in 2015, and 28 in 2014. From 1996 to 2016, the National Laboratories won an average of 33 percent of the R&D 100 Awards presented each year.

Figure 4-10: R&D 100 Awards Won by the National Laboratories from 1999 to 2016



4.12 Benefits to Society: Technology Transitions

Technology transfer has been an aim of United States Federal Government policy since the passage of the Bayh-Dole Act[12] and the Stevenson-Wydler Act[13] during the 1980s. In 1989, the National Competitiveness Technology Transfer Act[14] affirmed this goal by establishing technology transfer as a mission of Federal R&D agencies, including DOE. However, it was not until the Energy Policy Act of 2005 (EPAct 2005) that a DOE technology transfer function was officially established within the Department. EPAct 2005 instructs the Secretary of Energy to appoint a Technology Transfer Coordinator (TTC) to serve as the "principal advisor to the Secretary on all matters relating to technology transfer and commercialization."[15]

In February 2015, the Secretary of Energy created the OTT and recast the Technology Transfer Coordinator as the Director of OTT to coordinate and optimize how the Department transitions early-stage R&D to applied energy technologies through technology transfer, commercialization, and deployment activities. OTT is responsible for developing the Department's strategic policy and vision for expanding the commercial impact of DOE's RD&D portfolio. The OTT oversees technology transitions at the Laboratories in accordance with EPAct 2005, Title X, Sec. 1001(d), which establishes the DOE Technology Transfer Working Group (TTWG), consisting of representatives from headquarter Program Offices, DOE's site offices, and each of the Laboratories and single-purpose research facilities.

DOE's strategic policy and vision for technology transitions at the Laboratories is described in the Technology Transfer Execution Plan (TTEP)[16] in accordance with EPAct 2005, Title X, Sec. 1001(g). The TTEP provides direction to DOE and to the Laboratories as they work to transition technologies to the market. It guides coordination and optimization of technology transition activities across the Department, thereby securing the greatest public benefit from the work being performed in all of DOE's RD&D efforts, especially at the Laboratories.

DOE and the 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. Technology-transfer–related activities are just one category of activities needed to bridge early stage research to commercial impact. That is why the DOE has defined two overarching goals to guide its technology transitions efforts, both of which are already being pursued by a variety of proven efforts at the Laboratories.

Goal 1 is focused on increasing the commercial impact of DOE investments through the transition of National Laboratory-developed technologies into the private sector, generally considered traditional "technology transfer." DOE's support of National Laboratory research results in the invention and development of new products, novel technologies, and a variety of forms of intellectual property. Even with the hundreds of new patents granted every year, and the thousands of licenses maintained by DOE's National Laboratories, there remains a large reservoir of Laboratory-developed intellectual property that has not successfully transitioned to industry. Objectives and associated activities designed to support Goal 1 aim to increase the number and rate of technology transitions of Laboratory-developed innovations to the private sector to advance both energy and non-energy applications.

Goal 2 is focused on increasing the commercial impact of DOE investments through private sector utilization of National Laboratory facilities and expertise, which was specifically highlighted in the Secretary of Energy Advisory Board (SEAB) Lab Task Force Report. These outstanding facilities are available to entrepreneurs

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12 P.L. 96-517, as amended by P.L. 98-620

13 P.L. 96-480

14 P.L. 99-502

15 Title X, Section 1001(a-c), EPAct2005

16 See DOE, Technology Transfer Execution Plan 2016–2018: Report to Congress (October 2016), available at http://energy.gov/sites/prod/files/2016/10/f33/TTEP%20Final.pdf.

in the private sector through a variety of means including access to user facilities and shared R&D facilities, collaborative research with scientists, and the creation of strategic partnerships. Private sector companies have already formed thousands of active agreements with DOE facilities, making discoveries, solving technical problems, and developing innovations. Objectives and associated activities designed to support Goal 2 seek to further promote private sector utilization to encourage U.S. industry to make use of these world-class facilities and assets, which will keep U.S. industry and DOE at the forefront of scientific and technological advancements

The Department and the Laboratories advance these two overarching goals through a mix of centralized and decentralized strategies. Centralized activities are designed to ensure both Administrative direction and taxpayer accountability. They enable DOE leadership to set priorities and coordinate the complementary strengths of DOE's National Laboratories, while ensuring that DOE acts as one enterprise focused on making its work more transparent to external partners. Decentralizing activities, in contrast, enables individual DOE National Laboratories to be more responsive to their full constituent base within the terms of their contracts. Giving DOE's National Laboratories more flexibility to interact with local, state, and regional innovation ecosystems helps leverage Federally stewarded capabilities for innovation-based economic growth.

To achieve these goals, DOE has encouraged its National Laboratories and production facilities to enter into technology partnering activities with nonfederal entities, as appropriate, using a variety of mechanisms. The DOE allows several different contractual mechanisms for the National Laboratories to interact with industry. These include CRADAs, SPPs, Technology Licensing Agreements, Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) awards, and others. The full set of contractual mechanisms is described in Appendix C.

FLC Excellence in Technology Transfer Awards

The Laboratories participate in the Federal Laboratory Consortium for Technology Transfer (FLC), which was organized in 1974 and formally chartered by the Federal Technology Transfer Act of 1986 to promote and strengthen technology transfer nationwide. Its membership draws from about 250 Federal Laboratories, including DOE's 17 National Laboratories and five production facilities. FLC is supported by a contract between National Institute of Standards and Technology and the Universal Technical Resource Services, Inc., of Cherry Hill, New Jersey. [17]

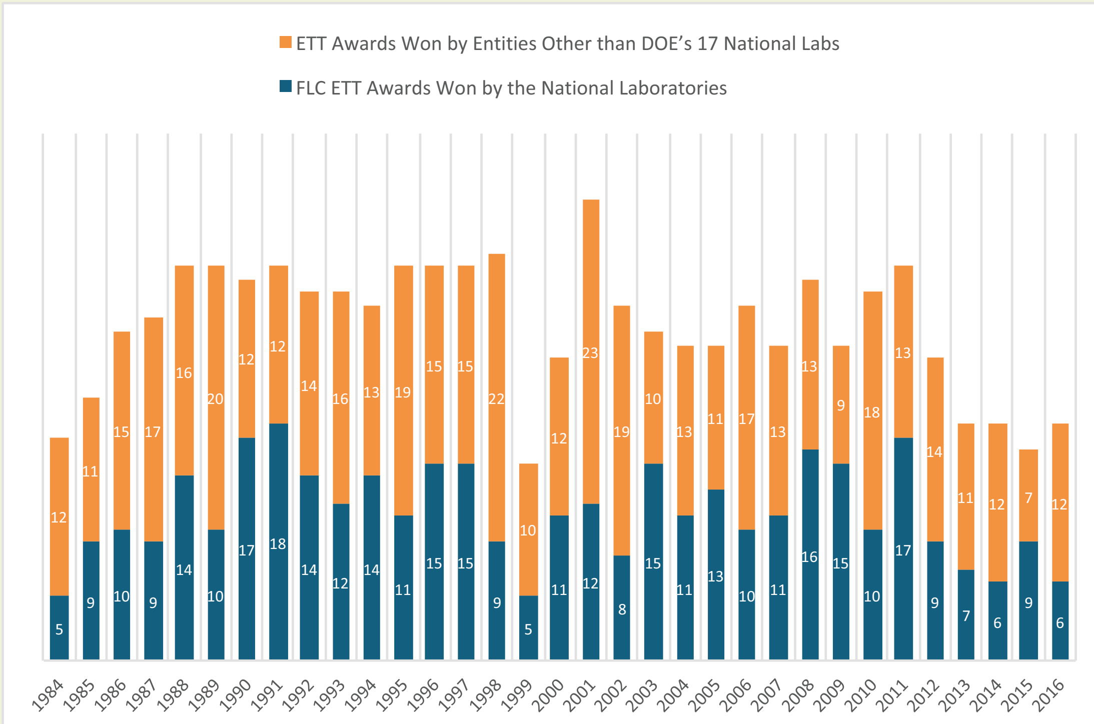
The National Laboratories, and the universities and companies that partner with them, have long been the conduits for technology transfer, collaborating to develop and commercialize energy products and processes for commercial use. One of the most prestigious awards in technology transfer is presented each year by the FLC. Since the government-wide FLC Excellence in Technology Transfer Award program began in 1984, employees at DOE's National Labs have been recognized every year for outstanding work in the process of transferring Federally developed technology to the marketplace. In the first 32 years of the FLC program (1984-2016), researchers at DOE National Laboratories received 373 of the 839 FLC Excellence in Technology Transfer Awards presented (Figure 4-11).

continued on page 72

[17] 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, and staff support.

continued from page 71

Figure 4-11: FLC Excellence in Technology Transfer Awards Won by the National Laboratories



Pursuant to the above policy guidance, the mission to transition technologies has evolved to become a prime area of focus for the DOE Laboratory network. In fact, in FY 2015, DOE and its Laboratories and facilities managed and executed 17,084 technology transfer-related transactions. Not including activities under the national security programs, these transactions include but are not limited to 734 CRADAs; 2,395 SPPs (formerly called Work-for-Others Agreements) involving nonfederal entities (NFEs); 74 ACTs; 6,310 active licenses of intellectual property; and 7,571 user projects. In addition, DOE National Laboratories and facilities disclosed 1,645 inventions; filed 949 patent applications (856 U.S. and 93 foreign); were issued 755 patents (632 U.S. and 123 foreign); and commercialized 577 technologies. Associated with these activities, DOE's Laboratories and facilities reported approximately $249.0 million in SPP nonfederal sponsor "funds-in," $64.8 million in nonfederal sponsor "funds-in" for CRADAs, $30.3 million in nonfederal sponsor "funds-in" for ACTs, $33.1 million in licensing income, and nearly $21.2 million in earned royalties.

In recent years, DOE's programs and Laboratories have also explored several new avenues through which to increase the impact of the Laboratories. In addition to the modalities discussed in section 4.4, DOE has explored the following mechanisms among many others:

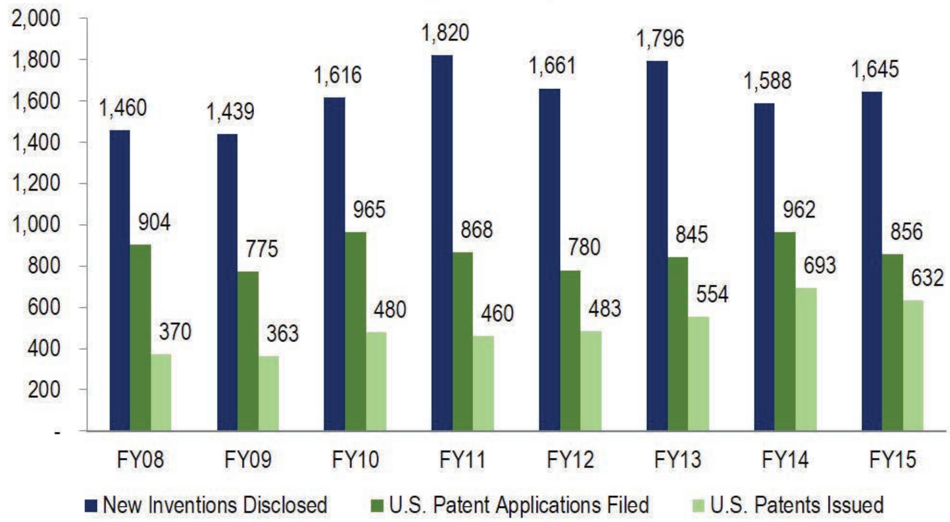
- Agreements for Commercializing Technology (ACT): The ACT program was designed to provide an additional agreement mechanism with unique flexibilities to address barriers that have hindered nonfederal access to National Laboratory capabilities. Barriers included client advance payments, contract terms and conditions required by the government, and Laboratory contractors' inability to provide performance guarantees. While the pilot mechanism was not intended solely to further the development or commercialization of Laboratory-developed technologies, DOE recognized that the mechanism could support commercialization by providing additional flexibility to structure effective agreements with nonfederal partners. The ACT program is being developed under a pilot program that will run until October 31, 2017.

- Lab-Corps: Based on the National Science Foundation's successful Innovation Corps (I-Corps) program, but tailored to the needs of DOE Laboratories, this EERE-developed, $2.3 million pilot program trains top Lab researchers on how to move high-impact National Laboratory-invented clean energy technologies into the market. Lab-Corps trains participants in the identification and pursuit of market applications through direct engagement with industry, entrepreneurs, and investors as well as in entrepreneurship. Six Laboratories are participating in this pilot stage.
- Small Business Venture (SBV) Pilot: The SBV pilot, launched this fiscal year, aims to improve small businesses' awareness of and affordable access to DOE Laboratories' intellectual and physical assets to advance DOE's clean energy mission. These partnerships between clean energy small businesses and National Laboratories help promote economic development and American innovation by pairing DOE's Laboratory resources and expertise with small business drive and creativity. In March of 2015, DOE issued a $20 million SBV Laboratory Call for Proposals ("Lab call"). The selection of five pilot lead Labs was announced in July 2015.
- Technologist in Residence (TIR) Pilot: As a part of the Clean Energy Manufacturing Initiative, EERE will execute a TIR pilot to build deep relationships between clean energy manufacturing companies and DOE National Laboratories that could result in collaborative research and development. If successful, the TIR will develop a streamlined process for any clean energy company to establish such relationships with National Laboratories beyond the pilot period. On September 15, 2015, DOE announced the selection of seven pairs of technologists from Laboratory and industry organizations at the American Energy and Manufacturing Competitiveness (AEMC) Summit who will work together for a period of up to two years to (1) identify the technical priorities and challenges of the participating company or companies and the resources and capabilities in DOE's National Laboratories that may address them; (2) propose collaborative R&D efforts to develop science-based solutions to the company's most strategic scientific, technological, and business issues; and (3) develop an agreement and specific scope of work for the proposed collaborative R&D efforts.
- Technology Commercialization Fund: The Technology Commercialization Fund (TCF) originally authorized in the Energy Policy Act of 2005 Sec. 1001(e) is a fund bridging a financial gap to facilitate promising energy technologies developed from the DOE investment in S&T at the National Laboratories. In FY 2016 the TCF was nearly $20 million. This first Department-wide round of funding through the TCF supported 54 projects at 12 National Labs and involving 58 private-sector partners. The TCF supported technology maturation projects, which focus on maturing unlicensed Lab-developed technologies identified as having commercial potential and needing additional maturation to attract a private partner, as well as cooperative development projects, which focus on a Lab-developed technology in collaboration with a private partner for its commercial application. There are two issues that may inhibit the TCF: the constraint on how the funding can be used based on the control point of appropriated funding, and the 1:1 cost share requirement that limits the ability to attract private entities and small businesses. Both of these issues inhibit the use of these funds for the most promising technologies and partners, and the funding constraints further prevent crosscutting projects and substantially increase the difficulty of TCF implementation and the administrative cost and burden of TCF implementation by adding tracking efforts in order to use the correct funding source. In the FY 2017 Congressional Justification, the Administration recommended language changes to address these issues.
- Further information and data detailing the Laboratory network's technology transitions activities can be found in the FY 2014 Report on Technology Transfer, issued by DOE's OTT.

4.12.1 Moving Innovation to the Marketplace: Inventions Disclosures and Patenting

In FY 2015, DOE's National Labs and associated research facilities[18] disclosed 1,645 new inventions, filed 856 U.S. patent applications, and received 632 U.S. patents (Figure 4-12). For the time span of FY 2008 – FY 2015, the average number of new inventions disclosed was 1,628; patent applications filed was 869; and patents received was 504.

Figure 4-12: Invention Disclosures and Patents: FY 2008–FY 2015



This data indicates that patents are being issued to the National Labs and associated research facilities at a higher rate than any time in the past eight years. In FY 2015, one U.S. patent was issued for every 1.4 U.S. patent applications filed—up from one patent per 2.4 applications in FY 2008. For invention disclosures, multiprogram Labs had the most disclosures (626) in FY 2015, followed by National Security Labs and Energy & Environmental Labs (561 and 268 respectively). From FY 2014 to FY 2015, Energy & Environmental Labs had the largest increase in invention disclosures (27.6 percent).

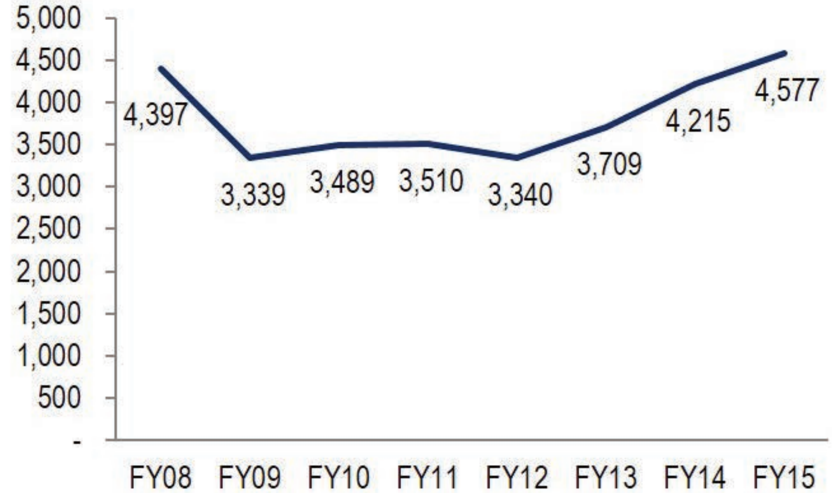
Active licenses originating from DOE's National Labs and associated research facilities have also grown relative to recent years. In FY 2015, 6,310 active licenses—including 648 newly executed licenses—originated from the research undertaken by these entities. From FY 2008 to FY 2015, the average number of such licenses was 5,744. The number of active licenses increased for every Lab grouping, with the highest increase seen for single-program Science Labs (141 percent).

In FY 2015, 1,366 total active invention licenses—including 155 newly executed invention licenses—originated from work undertaken by the DOE Labs and associated research entities. From FY 2008 to FY 2015, the average number of such invention licenses was 1,433.

[18] In addition to the 17 DOE National Labs, the data for the figures in this section include the Bettis and Knolls Atomic Power Labs and the following four production facilities closely related to the DOE's national security mission: Consolidated Nuclear Security facility (Y-12); the Kansas City National Security Campus; Nevada National Security Site; and Pantex Plant.

The number of income-bearing licenses has been stable or increasing since FY 2008 (Figure 4-13). FY 2015 saw a new 8-year high with nearly 4,600 income-bearing licenses.

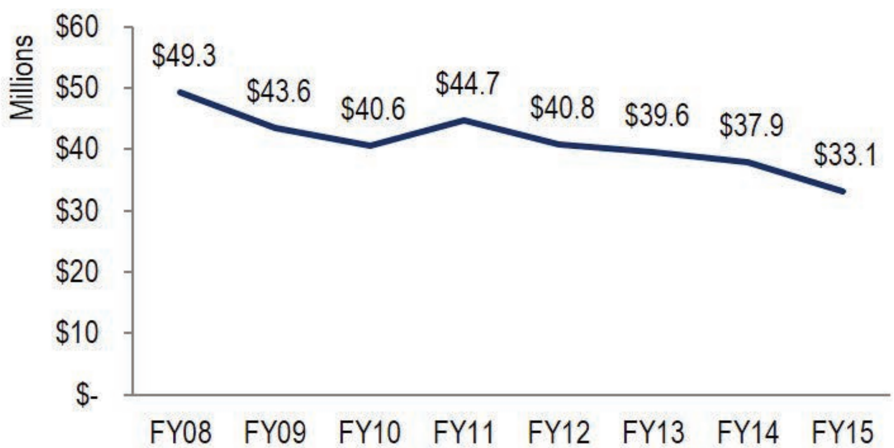
Figure 4-13: Number of active income-bearing licenses: FY 2008–FY 2015



Despite the increase in income-bearing licenses, total income from licenses has steadily declined since FY 2011 (Figure 4-14). In FY 2015, 4,577 income-bearing licenses yielded approximately $33.1 million in revenue—including $29 million from invention licenses and $4 million from copyright and other intellectual property (IP) licenses—compared to $37.9 million in FY 2014.

The number of exclusive income-bearing licenses has also declined since FY 2010 (Figure 4-15). FY 2015 saw a new 8-year low with 98 exclusive income-bearing licenses.

Figure 4-14: Total income from all active licenses: FY 2008–FY 2015



Earned royalty income (ERI) generated over $21 million in FY 2015, with the largest portion coming from National Security Labs ($11.4 million). As shown in Figure 4-16, ERI continued a downward trend from $23.4 million in FY 2014 and is down approximately 33% compared to FY 2008 ($31.7 million).

Figure 4-15: Number of Exclusive Income-bearing Licenses: FY 2008–FY 2015

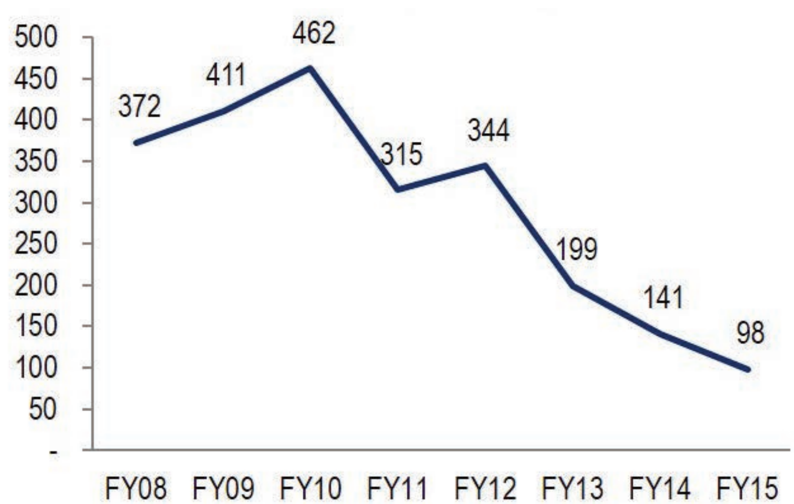
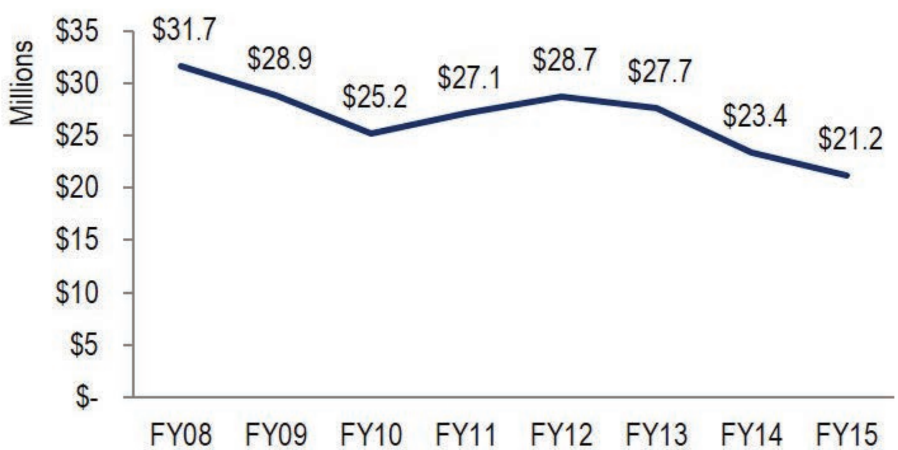


Figure 4-16: Total Earned Royalty Income: FY 2008–FY 2015



4.12.2 Moving Innovation to the Marketplace: CRADAs, SPPs, and ACTs

Technology transfer agreements help to make the resources of the National Labs and facilities available to entities throughout the public and private sector and nurture the Nation's innovation ecosystem. In FY 2015, DOE and its Laboratories and facilities managed and executed 734 CRADAs; 2,395 SPPs involving NFEs; and 74 ACTs.

Shown in Table 4-2, both nonfederal SPP and CRADA numbers have been relatively stable over the last five years, and the ACT pilot program has shown impressive growth. Nonfederal SPPs are a much larger component of industrial interactions than CRADAs, with more than 2,300 SPP agreements[19] active per year vs 700 CRADAs. Additionally, partners contributed nearly $250 million in FY 2015 through nonfederal SPPs, $65 million through CRADAs, and $30 million through ACTs to work with the National Labs and facilities in FY 2015.

Table 4-2: CRADAs and nonfederal SPP technology transfer agreements

	FY10	FY11	FY12	FY13	FY14	FY15
CRADAs, total active* in the FY	**697**	**720**	**742**	**742**	**704**	**734**
Number with small businesses	264	264	265	237	245	257
New, executed in the FY	176	208	184	142	180	184
CRADA funds in (thousands)	$62,332	$68,178	$64,221	$61,818	$70,080	$64,848
Nonfederal SPP, total active in the FY**	**2,222**	**2,273**	**2,519**	**2,733**	**2,021**	**2,395**
Number with small businesses	382	409	429	439	390	420
New, executed in the FY	668	688	749	992	800	775
Nonfederal SPP funds in (thousands)	$287,370	$264,343	$285,113	$283,462	$239,765	$249,024
ACTs*, total active in the FY**	**nr**	**nr**	**2**	**54**	**67**	**74**
ACT funds in (thousands)	nr	nr	$280	$14,510	$29,030	$30,340

* Active means legally in force at any time during the FY
** SPP – Strategic Partnership Projects
***ACT lab-limited pilot program launched in February 2012; extended in 2015 to 2017
nr – not recorded

4.13 Preparing for the Future: Training the Next Generation of Scientists and Engineers

The evolving DOE mission areas, coupled with the dynamic nature of R&D, mean that it is critical that the pipeline to develop the future workforce is informed of the challenges and potential solutions, and that new talent is encouraged to enter the field. As a result, the National Laboratories have placed a high priority on STEM education and have developed education initiatives unique to DOE's mission, needs, and resources. The National Laboratories participate in DOE programs, including the Science Undergraduate Laboratory Internship (SULI), Community College Internship (CCI), the Visiting Faculty Program (VFP), and Office of Science Graduate Student Research (SCGSR) programs.

Several National Laboratories have developed postdoctoral fellowship programs to attract talented early-career researchers. For example, the aim of the Glenn T. Seaborg Institute Postdoctoral Fellows Program at LANL is to advance nuclear science in a comprehensive project that ties targeted research with the Laboratory's mission imperatives, while the goal of ORNL's Clifford G. Shull Fellowship Program is to attract new scientific talent to that Laboratory's neutron science programs. PNNL's Linus Pauling Fellowship Program supports research that is expected to lead to advances in basic science, energy, the environment, or national security.

National Laboratories are also broadening their engagement with graduate students. The NNSA Graduate Fellowship Program, administered by PNNL, supports graduate students interested in a career in nuclear

[19] SPP Agreements were formerly called Work-for-Others Agreements (WFO).

security. Several Labs offer graduate research appointments that support students in their thesis research. In one example, ORNL has partnered with the University of Tennessee to establish an energy-related energy science and engineering Ph.D. program.

In addition, National Laboratories have developed precollege STEM programs that fit within their specific Laboratory mission and address Federal STEM goals. Examples include STEM instruction-teacher programs; youth and public engagement in STEM-K-12 student programs and competitions; Girls in Science, serving groups historically underrepresented in STEM fields; and designing graduate education for tomorrow's STEM workforce. National Labs are also supporting underserved populations, including tribes and rural communities, to expose students, teachers, and parents to career pathways that could lead to future employment opportunities at a material Lab.

For the national security missions, the issue of maintaining a highly capable workforce with specialized skills in a broad array of technical fields is particularly acute, as outlined in the NNSA Enterprise Strategic Vision. In addition to the need to ensure a high quality and innovative workforce, successful mission execution is closely tied to multidisciplinary teams, often including specialized skills or knowledge that can be learned only in the environment of the relevant program. In nuclear weapons and security activities, the specialized skills and knowledge are not acquired through university education. It is the responsibility of the National Laboratories to ensure a robust workforce through a system of planning, recruitment, development, and retention of their workforce, along with effective knowledge transfer.

The current workforce in much of the nuclear security enterprise is not demographically balanced, presenting the likelihood that retirement or other voluntary departures will lead to significant staffing needs over the next five years. In response, some National Laboratories have lengthened their horizon for strategic staffing planning. This approach represents a challenge but also an opportunity to shape the future national security workforce within the DOE National Laboratories, with deliberate attention given to all dimensions of the staff, from mix of technical disciplines to diversity of the workforce in all job families and levels.

An important pathway for bringing new talent to the National Laboratories is hiring at an early career stage. National Labs' student and postdoctoral programs are very important to attracting and retaining new staff in both technical and operational roles, and the NNSA Laboratories maintain significant numbers of postdocs. As discussed previously, LDRD becomes an important tool in this pipeline.

The National Laboratories have found it valuable to engage in efforts designed to cultivate a pipeline of students at the graduate and undergraduate level with tailored curricula and engagement through internships and other practical experiences at the National Laboratories. NNSA is home to some of these efforts; in addition, the Labs have hosted students trained in the Next Generation Safeguards Initiative and have collaborated with universities through the components of the Stockpile Stewardship Academic Alliance. The Labs have also developed student engagement mechanisms in strategic capability areas specific to their own workforce needs, carried out through strategic centers or institutes designed for this purpose. The National Laboratories are involved in other DOE university partnership and workforce development efforts and have participated in other agencies' workforce development efforts for specialized skills areas (such as DHS's Domestic Nuclear Detection Office (DNDO) National Nuclear Forensics Expertise Development Program).

Beyond direct recruiting, partnerships with universities have become an important part of the Labs' intellectual environment. Over the long term, such strategic relationships can result in researchers coming to work at the National Laboratories. Such relationships can involve the use of unique experimental capabilities or particularly strong disciplinary communities at universities, and can involve the exchange of personnel (e.g., hosting faculty and students). Engagement with universities has become an important tool for National Laboratory staff enrichment as well as collaboratively creating new directions in R&D or allowing for direct engagement with the academic communities.

5 Managing for Efficiency and Effectiveness

The DOE National Laboratory System is an asset of extraordinary value to the Nation as well as to DOE itself. The System's collective S&T capabilities have taken decades to develop and are unmatched anywhere in the world. Building, operating, and enhancing these capabilities requires a unique, diverse, and complicated array of resources—spanning human talent and expertise, singular scientific facilities and instrumentation, specialized and innovative processes and techniques, exceptional leadership and management, and significant financial resources.

As illustrated in the "National Laboratories—By the Numbers" summary below, the 17 National Laboratories are arrayed across the United States and comprise over 57,000 highly talented and skilled scientific, technical, and operations staff; thousands of collaborations and partnerships with DOE and other sponsors and research organizations; more than 53 million gross square feet of owned and leased facilities located on more than 800,000 acres of land, and an annual budget of approximately $14 billion dollars.

Effectively stewarding this complex enterprise presents great opportunities and difficult challenges that call for excellence in leadership and management. DOE and the Laboratories accomplish these stewardship responsibilities by partnering closely to

- provide **Strategic Leadership and Planning**,
- work within **Robust and Innovative Contact Models**,
- ensure **Effective Resource Management**, and
- exercise **Strong Mission Execution Capabilities**.

One of the Secretary's major priorities has been to reset the relationship between the DOE and its National Laboratories. A cornerstone of this effort is a focus on ensuring that the National Laboratories are operated with a close, strategic relationship with DOE while still operating effectively within the construct of the M&O contract model. DOE and the National Laboratories share the responsibility of mission readiness, which includes human resources to recruit, retain, and support the right people; financial management to ensure the funding flows to the mission work in the most efficient way; core infrastructure that provides the backbone for running the Laboratories and accomplishing the mission work; and risk management to identify and manage all risks—including but not limited to safety, security, financial, legal, and public affairs—to mitigate the probability of occurrence and resulting consequences.

5.1 Strategic Leadership and Planning

In addition to performing the research, development, demonstration, and deployment activities for much of DOE's portfolio, the Laboratories are also key partners in determining the technological and policy areas of strategic interest to DOE. As the steward/owner of the Laboratories, DOE has the inherently governmental responsibility for their missions, while the National Laboratories have the detailed understanding of the state

National Laboratories—By the Numbers

The DOE National Laboratory System conducts transformative research, development, and engineering on some of the most important science and technology challenges within the missions of the DOE using unique cutting-edge facilities and world-leading capabilities. The Laboratories provide ongoing foundational contributions that benefit the Nation's energy economy, science and technology base, nuclear security, and legacy environmental restoration.

The Laboratories provide employment or research opportunities for over sixty thousand scientists, engineers, technicians, and other professionals in numerous locations around the Nation and the world.

The Laboratories manage and operate in multiple states and have a significant favorable impact on the national economy.

The Laboratories draw more than forty thousand facility users and visiting scientists from around the world to use facilities and participate in Laboratory-hosted science programs each year. The Laboratories operate 46 world-leading user facilities and 141 shared facilities at their sites.

The Laboratories produce 11,000 peer-reviewed publications annually in roughly 1,500 different journals and periodicals.

The Laboratories collaborate with more than 450 academic institutions in the United States and Canada providing over $500M in funding to support students, postdocs, and faculty. This sponsored research is in addition to the more than $900M that DOE directly funds the universities through academic research grants.

The Laboratories provide support to numerous other Federal agencies and industrial partners: 2,395 SPPs involving NFEs; 734 CRADAs; 577 commercialized technologies; and 6,310 active licenses. More than $2B of the National Laboratories' subcontracts are provided to small business annually.

The Laboratories have contributed to 115 Nobel Prizes for work carried out within the National Lab System.

The Laboratories have earned over 800 R&D 100 Awards since 1962 when the competition began. In 2016, the DOE's National Laboratories won 33 of the 100 awards.

Physical Assets:

- 813,000 acres
- 53M GSF in 4,740 buildings
- Replacement plant value: $53B
- 1.5M GSF in 193 excess facilities
- 5M GSF in leased facilities

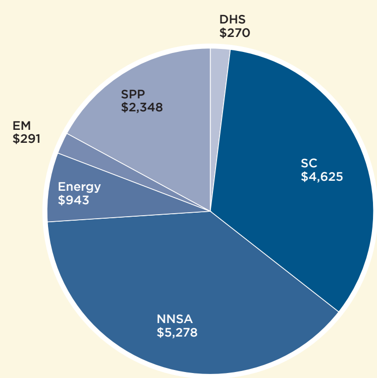
Human Capital:

- 57,600 full-time equivalent employees (FTEs)
- 1,285 joint faculty
- 2,300 postdoctoral researchers
- 2,950 undergraduate students
- 2,010 graduate students
- 33,000 facility users
- 10,600 visiting scientists

FY 2015 Costs by Funding Source:

(Cost Data in $M):

Labs funding profile $13.8B



FY 2015 Lab operating costs: $13.8B

FY 2015 DOE/NNSA costs: $11.6B

FY 2015 SPP (Non-DOE) costs: $2.6B

FY 2015 SPP (Non-DOE) as % total Lab operating costs: 18%

Note: Certain numbers rounded

of the field and actions needed for investments to meet the near-, mid-, and long-term missions. Together, DOE and the National Laboratories can produce the most coherent plans for accomplishing the missions and conducting world-class R&D.

5.1.1 Quadrennial Technology Review and Quadrennial Energy Review

The Quadrennial Technology Review (QTR) is a foundational planning driver for DOE. The QTR explores the current state of technologies in key energy sectors and R&D opportunities present in the mid-term. It is intended to frame a blueprint for DOE energy technology development and the enabling science for future technology breakthroughs. The National Laboratories were important partners in the development of the QTR and provided technical input and expertise. The QTR will be refreshed by DOE and the DOE National Laboratories in 2019 to reflect the evolving challenges, technologies, and opportunities facing DOE in the execution of its missions.

The Quadrennial Energy Review (QER) enables the Federal Government to translate policy goals into a set of analytically based, integrated actions—executive actions, legislative proposals, and budget and resource requirements for proposed investments—over a four-year planning horizon. The White House Domestic Policy Council and Office of Science and Technology Policy jointly chair an interagency QER Task Force, while the Secretary of Energy provides support to the QER Task Force, including coordination of activities related to the preparation of the QER report, policy analysis and modeling, and stakeholder engagement. The QER has been enabled by the science, technology, and analytical expertise that resides within the National Laboratory System. Unlike other Federal quadrennial review processes where an analysis is done every four years, the QER is being conducted through installments to allow for granular analysis of key energy subsectors.

On April 21, 2015, the QER Task Force released the first installment of the QER entitled, "Energy Transmission, Storage, and Distribution Infrastructure," which examined the Nation's infrastructure for transmission, storage, and distribution, including liquid and natural gas pipelines, the grid, and shared transport such as rail, waterways, and ports. The second installment of the QER will conduct a comprehensive review of the Nation's electricity system, from generation to end use, including a more comprehensive look at electricity transmission, storage, and distribution infrastructure covered in the first QER installment.

5.1.2 Strategic Management of Nuclear Security

The strategy for management of the nuclear security programmatic work originates with the Nuclear Posture Review, which establishes U.S. nuclear policy, strategy, and capabilities. Requirements are translated through the DOE Strategic Plan. Associated program documents are updated annually (the Stockpile Stewardship Management Plan [SSMP] and Prevent, Counter, and Respond—A Strategic Plan to Reduce Global Nuclear Threats). NNSA's Enterprise Strategic Vision document provides a framework for integrating these missions and crosscutting capabilities (including ST&E, as well as people and infrastructure) to guide the complex in providing unique technical solutions for national security challenges.

Program planning occurs in the context of a five-year budget framework (Future Years Nuclear Security Plan, or FYNSP). Within the SSMP program, guidance for program execution is provided by the Nuclear Weapons Stockpile Memorandum and Requirements and Planning documents, and the National Laboratories generate development and certification plans. Several mechanisms exist to coordinate planning among National Laboratories, headquarters elements, and the Department of Defense. The Office of Defense Nuclear Nonproliferation (DNN) has established the DNN Science Council to improve integration of the National Laboratories, plants, and sites into DNN policy and planning.

Each site plans within the framework of a 10-year site plan, addressing both line item and general purpose infrastructure investments. The Readiness in Technical Base and Facilities (RTBF) Program provides support for the operation and maintenance of NNSA programmatic facilities. This support includes facility operating and maintenance costs; environmental, safety, and health costs; and planning, prioritizing, and constructing state-of-the-art facilities, infrastructure, and scientific tools.

5.2 DOE Management of Labs and Robust and Innovative Contract Models

The Secretary of Energy implements the management and operation of the system of 17 National Laboratories through the three Under Secretaries: Management and Performance, Nuclear Security, and Science and Energy. The organization structure for the DOE can be found at www.energy.gov and was discussed in Chapter 1.

The Secretary uses advisory groups and coordinating councils to provide input on the management and operations of the DOE National Laboratories. The SEAB provides advice and recommendations on the Department's research and development activities, economic and national security policy, educational issues, operational issues and any other activities and operations as directed by the Secretary. A standing SEAB Task Force on the National Laboratories was chartered in June 2014 to provide advice, guidance and recommendations on important issues related to improving the health and management of the National Laboratories. The SEAB National Laboratory Task Force issued recommendations in a June 2015 report and has subsequently been reviewing the Department's efforts to strengthen the DOE-Laboratory partnership, including the Department's implementation of its February 2016 response to the Commission to Review the Effectiveness of the National Energy Laboratories (CRENEL) report as well as efforts to strengthen technology transfer activities.

To reinforce an enterprise-wide view of the National Laboratory System, the Secretary established the LPC to initiate a dialogue between Department and Laboratory senior leadership and the LOB to improve the effectiveness and efficiency of Laboratories and the relationships between the Laboratories and DOE. The Secretary meets three times a year with the LPC. The LOB meets monthly and provides regular reports to the LPC on the activities being pursued, with the objectives of strengthening the partnership between DOE and the Laboratories and improving efficiency and effectiveness.

The NLDC comprises the Laboratory Directors from all of the 17 DOE National Laboratories. The NLDC has a working group structure, and through the working groups provides an interface to DOE organizations on issues and concerns of common interest, both strategic and operational. The NLDC also functions as a forum for information exchange, consensus building, and coordination of matters that affect all of the National Laboratories. The Secretary meets with the Executive Committee (four Laboratory Directors selected by their peers who serve on the LPC) regularly, and the whole NLDC typically twice per year.

The NLDC provides guidance and oversight of other focused National Laboratory working groups, including the Chief Research Officers (CRO), Chief Operations Officers (COO), Chief Financial Officers (CFO), Chief Information Officers (CIO), Chief Human Resources Officers, Chief Communications Officers, Environment, Safety and Health (ESH), General Counsels (GC), and National Laboratory Contractors group. Each group interfaces with the functional counterpart(s) in DOE, including the Program Offices. For example, the CIO group meets regularly and works issues with the DOE CIO and the DOE Program Office CIOs, and serves as a member on the Information Management Governing Board (IMGB) and participates in the DOE Cyber Council.

In an effort to reduce transactional oversight, reduce unnecessary burden, and improve efficiencies, the LOB developed an improved approach to requirements development and management, especially directives. The approach has resulted in a prioritization for the development of directives, a clear set of principles to guide the development of the directives, and improvements to the review and comment process. As a result, the process provides greater visibility and inclusiveness, as well as allowing for senior-level direction at the outset of the process.

Innovative Approaches towards Improvements in Contract Management

Following a charge from the SEAB Lab Task Force, two working groups were established to consider potential changes on a pilot basis relating to contracting and/or management of specific SC Laboratories. The "evolutionary" working group identified specific authorities to be delegated, on a pilot basis at FNAL, to improve efficiency and reduce transactional oversight. Some of the recommendations for this group led to changes in Department-wide policies. The "revolutionary" working group examined the Laboratory contract structure at SLAC, with the objective of developing a more streamlined approach to improve the partnership and reduce transactional oversight. This contract went into effect in October 2016.

5.2.1 DOE Laboratory Strategic Planning

The long-term stewardship of DOE National Laboratories is a shared responsibility between DOE and the Laboratories' M&O contractors (for GOCO Laboratories) or between DOE Program Offices and National Laboratory leadership (for NETL). This shared responsibility requires that DOE Program Offices and DOE National Laboratories maintain a mutual understanding of DOE's and the Administration's evolving vision and long-term strategic plans, and work together to address the necessary evolution of National Laboratory capabilities—both research and facilities—to meet anticipated mission and Program Office needs, as well as national needs. Pursuant to DOE commitments made in its responses to reports from the SEAB and CRENEL, additional mechanisms have been implemented to improve coordination across the complex, and to improve annual Laboratory planning.

Annually, the National Laboratories produce strategic plans that are reviewed and approved by their respective DOE stewards. For the Science and Energy Laboratories, the plans are presented to DOE in June and July. For the NNSA National Laboratories, guidance for program execution is provided by the Nuclear Weapons Stockpile Memorandum and by Requirements and Planning documents, and these National Laboratories also generate development and certification plans. While the planning processes differ slightly, the plans developed by the National Laboratories each address prioritization of RD&D, aspirational and long-term directions, development and stewardship of core capabilities, and multiyear plans to address current and future RD&D priorities that are responsive to the scientific community, industry, and Federal agency priorities and needs. Beginning in FY 2016, DOE instituted a system of inviting all Program Offices to each of the Laboratory reviews, ensuring that (1) the Laboratories receive DOE-wide feedback and (2) the Program Offices become more engaged with Laboratories across the enterprise. DOE provides critical feedback to each Laboratory, and once there is agreement on a path forward for the Laboratory, DOE uses the input to inform the budget planning.

5.3 Effective Resource Management

The National Laboratory System has developed and sustained extraordinary S&T capabilities over many decades. The resources essential to these capabilities—talent, technical expertise, unique physical and digital facilities, infrastructure and equipment—require thoughtful and sound stewardship and resource management, as discussed further below.

5.3.1 Talent and Human Resources

To be ready for the missions and the associated R&D required, the National Laboratory workforce must be maintained and enhanced. Several challenges must be addressed to ensure that the Labs have the appropriate workforce for the missions, including recruitment and hiring a diverse workforce, ensuring retention through a healthy work environment including appropriate salary and benefits, and providing leadership training to allow for continuity. The specialized knowledge and unique skills often require significant recruitment efforts, and once recruited, there is a desire to keep the turnover to a manageable level (enough to be healthy, but not so much to lead to a significant burden to replace).

Creating and maintaining a diverse workforce and inclusive work environment in the National Laboratories is important to the vitality and future of the National Laboratories. In general, increasing the diversity of the STEM workforce is essential for establishing the creative and innovative work environments necessary for developing the solutions to our most challenging problems. Given the DOE National Laboratories' role in carrying out the DOE's missions and their particular role in the R&D ecosystem, the Laboratories have an important responsibility to lead the way on increasing diversity and inclusion.

The current National Laboratory workforce supporting the mission is at significant risk of losing experience and "institutional knowledge" through retirement within the next five years. To address this impending loss of experienced staff, the National Laboratories are developing strategic human capital plans to identify the current and near-term gaps in experience to provide the focus for hiring. A key part of those plans is the hiring of interns and postdoctoral associates (postdocs). Through this strategy, relationships are built with students and postdocs, who are able to form favorable views of careers in a National Laboratory. In addition, relationships with faculty are developed, which can open pipelines to future interns and postdocs, and also can generate interest in pursuing research aligned with the Laboratories' and DOE's missions.

The National Laboratories provide multiple opportunities for scientific and career growth. The Labs have technical and managerial career path options that allow for upward career mobility for technical and operations/support staff. A key challenge is the trend of declining numbers of scientists/researchers and engineers. Labs face fierce competition for research talent. Pending retirements, the competitive landscape of science career opportunities in technology fields, and the declining U.S. graduates in many STEM fields provide a growing concern for talent refreshment. In contrast, the number of Operations Support staff has grown, perhaps reflecting the various oversight activities required at the Laboratories.

Developing scientific and operational talent is a core tenet for the Laboratories. Activities span the range of rotational/temporary assignments, management and leadership training and associated leadership competency assessments, 360-feedback, and mentoring. Specialized recognition and award programs also provide the opportunity to recognize exceptional achievement in science and operations.

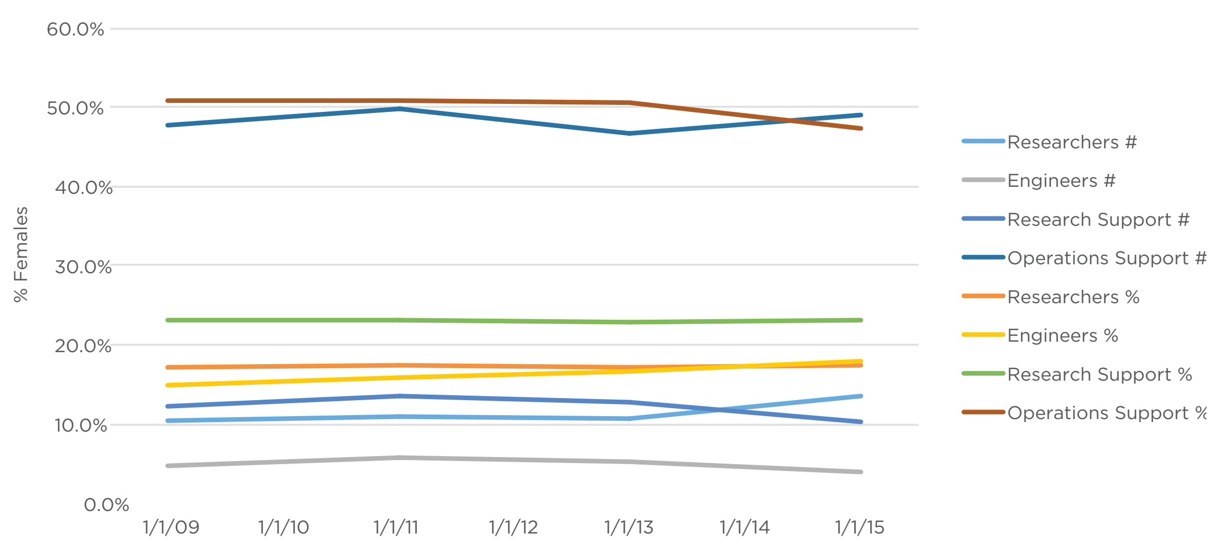
Given the value of specialized training provided to staff in national security programs, retention and leadership has also become a focus, and programs have been created to enhance employee development and knowledge transfer. Some of these programs are multi-Laboratory; for example, the NNSA National Laboratories have begun to host tri-Laboratory leadership development summits.

With the needs to fill specialized jobs and sustain critical core competencies, the Laboratories are engaged in efforts to increase the pipeline for STEM and operational support. For the last few years, the Labs have developed a joint recruiting outreach strategy to unify and elevate the profile of the 17 National Labs and to showcase the National Laboratory System as a preferred employer/best place to work. Diverse recruiting efforts include attendance/representation at key conferences and universities in the quest for underrepresented minorities, veterans, and persons with disabilities. The outreach strategy includes sponsored internship programs for undergraduate students and faculty, training awareness on the value of diversity and inclusion to include implicit bias prevention and mitigation. Additionally, the Laboratories utilize/sponsor employee resource groups to raise diversity awareness by sponsoring Laboratory-wide events in celebration of national heritage and history months as well as to participate in recruiting efforts. Many of the Labs have active mentor programs to ensure employee success in their current roles and enable the pipeline development for STEM leadership roles. In early 2016, educational outreach efforts included Lab sponsorship of My Brother's Keeper, a White House initiative designed to help underrepresented minorities focus on future success in science, technology, engineering, and mathematics through community engagement.

5.3.1.1 Diversity Initiatives

Demographics can be analyzed for trends in different levels of staff. At the senior management levels, males constitute approximately 70 percent of the workforce; women make up 30 percent. Underrepresented minorities (URM) make up 16 percent of the total workforce, while other people of color (OPC) account for 10 percent of the Laboratory workforce. Geographical locations and preferences have tremendous impact on the diversity profile at each Lab. Postdoctoral associates reflect the most robust diversity among the Laboratories and are also a pipeline pool of scientific and engineering talent. Postdocs, Research Support, and Operations Support reflect the highest percentage of females; furthermore, Operations Support reflects the highest percentage of URM, followed by Research Support. Figure 5-1 shows the gender diversity for the last 6 years for Researchers, Engineers, Research Support, and Operations Support. The percentage of female engineers in the workforce is increasing, but the percentages of females in other parts of the workforce are either flat or decreasing over the past couple of years.

Figure 5-1: Trends in Workforce Gender Diversity



Recognizing that having a diverse workforce and an inclusive work environment is important for mission success and noting the lack of significant progress, DOE leadership and the Laboratory Directors focused on this topic at the LPC and NLDC meetings. Over the past two years, the leadership of all 17 Laboratories have convened two workshops to discuss challenges and share best practices in improving diversity and inclusion. As a result of the discussions, the Directors identified a set of actions that the Laboratories will take individually, and collectively, to address key challenges with regard to diversity. The Laboratory Directors are renewing their focus on strengthening the diversity in management and leadership talent by offering training and development opportunities, individual coaching, and project opportunities. Additionally, hosted speakers, webinars and training on implicit bias offered in fiscal years 2015 and 2016 will enable education and awareness on the prevention and mitigation of those factors. Postdocs, interns, and strategic hires enable candidate pools for pipeline growth for senior management roles; so much activity is focused on enhancing and maintaining diversity at lower organizational levels.

Specialized recruiting occurs across the Laboratory community. Individual and joint Lab attendance is common at the Society of Women Engineers (SWE), Society of Hispanic Professional Engineers (SHPE), American Indian Science and Engineering Society (AISES), National Society of Black Engineers (NSBE), Grace Hopper Celebration of Women in Computing, as well as other events at which to recruit diversity and veteran candidates.

Ensuring the National Laboratories' incoming staff is sufficiently diverse in background and experience to provide DOE with the best suite of perspectives for innovative problem solving is critical to realizing the DOE's future vision. For example, DOE-EM has created the Minority Serving Institutions (MSI) Partnership Program (MSIPP) to increase the number of minorities with science and engineering experience in areas of importance in the successful completion of the DOE-EM mission. The MSIPP program will support collaborations between MSI and National Laboratories in STEM research related to DOE-EM needs.

5.3.2. Physical and Digital Infrastructure

The Department is responsible for a vast portfolio of infrastructure (see box) that consists of world-leading scientific instruments and facilities, and the general purpose infrastructure needed to enable the use of those tools. This portfolio of land, facilities, and other assets is the foundation of DOE's ability to conduct its mission, and represents one of America's premier assets for science, technology, innovation, and security.

5.3.2.1 General Purpose Infrastructure

Modern, reliable infrastructure is critical to support DOE in successfully and efficiently executing its missions both today and in the years ahead. While the Department has made significant investments in world-class experimental facilities, much of the supporting or "general purpose" infrastructure—such as office space, general Laboratory spaces, shops and utilities—that enables the mission and forms the backbone of the DOE enterprise, as well as environmental management activities, is in need of greater attention.

DOE has the fourth largest inventory of real property in the Federal Government by square footage, and its complex includes 17 DOE National Laboratories, NNSA plants, and EM cleanup sites. This portfolio of land, facilities, and other assets is the foundation of DOE's ability to conduct its mission and represents one of America's premier assets for science, technology, innovation, and security. However, modernization of DOE's infrastructure, which has its origins in the Manhattan Project, has not kept up in all areas with evolving mission needs in science and technology.

DOE Infrastructure

- 10,095 buildings totaling 119 million square feet (owned and leased)
- Average facility age: 36 years
- Average support structure (utilities, roads, bridges, etc.) age: 39 years
- 2 million acres
- $131 billion total replacement plant value
- $2 billion in annual operating and maintenance costs
- $5.4 billion in deferred maintenance (operational facilities)

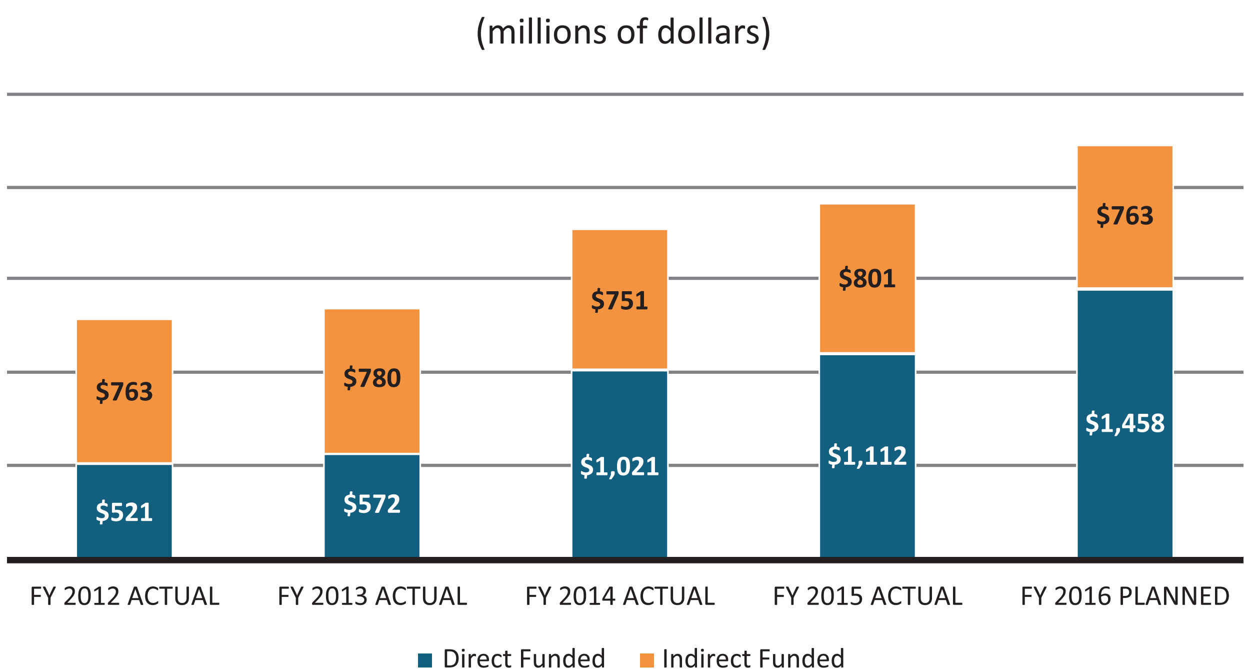
Source: FY 2015 Facility Information Management System snapshot

The Department has been improving its stewardship of infrastructure. Over the past five years, more than $8 billion has been invested in modernization. Investments have steadily increased, rising by nearly 75 percent over that time frame. The 2016 planned investment level of $2.2 billion equates to 1.7 percent of the total replacement plant value. The infrastructure investments are a mix of direct-funded and indirect-funded activities (i.e., funded through Laboratory overhead). Direct-funded general purpose infrastructure investments include

- line item projects, which are capital improvements greater than $10 million;
- general plant projects (GPPs), which are capital improvements less than $10 million;
- excess facilities disposition projects that are funded by direct appropriations; and
- maintenance and repair activities that are funded by direct appropriations for NNSA.

Direct investments have steadily increased over the last five years (Figure 5-2).

Figure 5-2: Investments in general purpose infrastructure



However, despite this investment, the condition of a large percentage of the infrastructure is substandard or inadequate for the mission as a result of more than five decades of aging, deterioration, and insufficient funding to keep pace with needed improvements. Over the past five years, deferred maintenance has increased by 30 percent from $4.2 billion in FY 2011 to $5.4 billion in FY 2015. The Department also has 8.5 million GSF of underutilized space and an additional 2,300 facilities that are excess and awaiting disposition over that time frame.

Beginning in the fall of 2013 and under the leadership of the LOB, the Department began making significant improvements to its stewardship of general purpose infrastructure—those physical assets such as utilities and general office buildings or Laboratory spaces that are used on a broad basis to enable the mission of the entire plant, site, and Laboratory. These efforts were developed and executed by DOE headquarters, site office, Laboratory, and plant employees, as a partnership across the complex. Notable outcomes include the following:

- The Department's process to assess the condition of its assets was overhauled to more directly measure whether the asset is physically able to support the mission it is intended to fulfill.
- Clear and consistent guidance for conducting those assessments was developed through the LOB infrastructure process and issued across the Department;[20] approximately 80 percent of DOE's infrastructure has been evaluated using the methodology.

[20] The "DOE infrastructure" referenced here is for the following DOE Programs/Offices and the respective Laboratories, plants, and sites stewarded by those offices: EERE, EM, FE, NE, SC, and NNSA. Of this infrastructure portfolio, 80 percent has been assessed using the new criteria.

- These LOB assessments revealed that as of the end of FY 2015, only half of the Department's assessed infrastructure portfolio was rated as "adequate" to accomplish its intended mission objective. The remaining half was rated as "substandard" or "inadequate" to meet the mission.
- The Department established an Infrastructure Executive Committee (IEC) as a subcommittee of the LOB. The IEC includes senior leadership from across the Department and is cochaired by line programs on a one-year rotating basis. The IEC is charged with preparing an Annual State of the General Purpose Infrastructure report, which was first issued in November 2016, as well as presenting enterprise-wide, prioritized investment recommendations for infrastructure.
- In its first year, the data developed as a result of this initiative provided the basis for over $100 million requested and appropriated in FY 2016, targeted for general purpose infrastructure projects.
- The Department's FY 2017 budget submission requests additional funding to address infrastructure challenges, including a 36 percent increase over FY 2016 in the Department's request for GPP and similar projects to improve general purpose infrastructure.
- The Office of Science Operations Improvement Council partnered with other Programs to develop a framework and guiding principles to foster consistency among DOE sites in accounting for repair needs and deferred maintenance—two measures that are important indicators of investment needs.
- NNSA has expanded its Asset Management Program, which uses supply chain management economies-of-scale to provide a more centralized and efficient procurement approach to replacing mission-critical aging infrastructure systems that are common throughout the enterprise, such as roof and HVAC systems.
- EM is pursuing coordination, analysis, and concurrence of EM site submissions for infrastructure reporting, such as the Integrated Facilities Infrastructure Crosscut Budget and five-year plans.

Within individual Program Offices, infrastructure planning is now included as an integral component of the annual planning and evaluation process. This has enhanced integration of infrastructure and mission planning and raised the visibility of infrastructure and its mission impact. For example, building from the SC planning model, NNSA is deploying its Master Asset Plan, which is a strategic, enterprise-wide, risk-informed, long-range view (25+ years) of NNSA infrastructure that will be updated on an annual basis.

Finally, to track progress on this issue and provide enterprise-wide data, an Infrastructure Executive Committee comprising line managers and facilities experts from across the complex is charged with providing an annual update to DOE leadership on the state of general purpose infrastructure. The inaugural State of General Purpose Infrastructure Report was issued in November 2016, and going forward will be issued annually by the end of each fiscal year.

The Science Laboratories Infrastructure Program

The SC "Science Laboratories Infrastructure (SLI) Program" funds mission-ready, state-of-the-art facilities and infrastructure that are flexible, reliable, and sustainable. The SLI Program has invested over $700 million in infrastructure and has successfully completed nine line item projects since FY 2006. With these investments, the SLI Program has constructed 875,000 gross square feet (GSF) of new space and has modernized 397,000 GSF of existing space. As a result, an estimated 2,230 Laboratory users and researchers now occupy newly constructed and/or modernized buildings that better support scientific and technological innovation in a collaborative environment.

5.3.2.2 Information Technology and Cyber Security

The National Laboratories operate a diverse and cutting-edge array of computing assets to achieve their missions. The Labs have also been challenged to continuously refine their security programs and find ways to protect sensitive information while continuing to foster an environment of open scientific collaboration, experimentation, and computation. The Office of the Chief Information Officer (OCIO) leads the Department's information technology reform initiatives to steward DOE information assets in an increasingly complex and hostile cyber landscape. The National Laboratories play a key role in the stewardship of these critical assets. The National Laboratory Chief Information Officers (NLCIOs) advise the NLDC. The NLCIOs also provide a critical interface with the DOE Office of the Chief Information Officer and the DOE Cyber Council, which is chaired by the Deputy Secretary and oversees cybersecurity issues, to deal with IT and cyber security issues that impact the Department.

The Labs face significant challenges associated with applying cyber security policies and requirements that were developed for government office environments, not for diverse R&D environments managed as FFRDCs. With dozens of new cyber security initiatives in the pipeline in response to the Office of Personnel Management breach, the Laboratories are facing an unprecedented set of requirements being applied identically to the Labs as to the Agency itself. As DOE continues to be subject to more restrictive cyber security policies developed for Federal agencies, the flow-down of those requirements has the potential to substantially disrupt the missions of the Laboratories as well as having negative budgetary implications. For example, a simple requirement such as multifactor authentication using PIV cards may be completely appropriate for an Agency office environment, but may make it impossible for DOE to host or even participate in large international open science collaborations. The Labs continue to work collaboratively with DOE to develop "R&D friendly" implementations to protect both open and sensitive R&D without putting missions at risk.

In recognition of these challenges, the complex of CIOs has identified cybersecurity and scientific computing as their two key shared strategic initiatives across the complex. Many novel approaches and solutions in these two areas have been developed at the Labs and are widely shared across the complex but also used in the larger government and research and education communities. Likewise, strong information and best practices sharing for monitoring and cyber incident response have been in place for decades and have continued to grow. However, continued investment is needed in cyber security R&D to continue to find new approaches to manage this risk in an R&D environment.

5.4 Strong Mission Execution Capabilities

Effective mission execution also requires a broad array of operational capabilities, ranging from financial stewardship to project management; environment, health, and safety expertise; communications and outreach expertise; procurement capabilities; and other essential support.

5.4.1 Contractor Assurance Systems

Contractor Assurance Systems (CAS) are designed and used by M&O contractors to manage performance consistent with contract requirements. CAS enables the corporate parent to assess performance, provides data to the contractor's management decision-making process, and allows the contractor to more effectively manage processes, resources, and outcomes. CAS provides clear communication of the mission needs and goals and enables DOE to determine the necessary level of Federal oversight. Under CAS, contractors provide reasonable assurance that their management controls are effective and efficient. Each CAS is a risk-based system that focuses on outcomes and seeks to minimize performance risk.

CAS is an integral component of a contractor's management systems and DOE's enterprise risk management. CAS is founded upon principles of trust, accountability, integrity, and respect, along with frequent and open communication. Under these systems, contractors are expected to responsibly oversee their own work, identify concerns, and reliably report unexpected adverse outcomes to prevent recurrence. The Department integrates its oversight activities with CAS (both at individual sites and with the larger family of CAS for activities across the complex) to confirm the adequacy of the contractor's internal controls and integrated management systems.

Following recommendations from CRENEL relating to CAS, a working group led by the LOB reviewed CAS policies and practices. As part of those efforts, the working group developed an updated Departmental CAS policy, which was issued in August 2016 and expands the scope of CAS beyond the environment, safety, security, and health areas to include business and financial systems, and emphasizes the importance of establishing and maintaining productive relationships between contractor, Federal, and corporate parent personnel. In addition, the Office of Management (MA) and the Program Offices convened a first-ever CAS summit in August 2016, with attendees from Headquarters, the field offices, and Laboratories, to share CAS best practices on an enterprise-wide basis.

5.4.2 Financial Stewardship and Management

Laboratory Complex Financial Numbers at a Glance

FY 2015 Lab Costs: $13.8B, 82 percent DOE funded, 18 percent non-DOE funded

Strategic Partnership Project (SPP) [non-DOE] Research: >2,300 SPP projects involving nonfederal sponsors, $2.6B in annual costs for total SPP (Federal and nonfederal) sponsored R&D

Academic Institution Collaborations: 450 institutions collaborate with Labs, $500M in annual funding from Labs

Commercialized Technologies and Active Technology Licenses to Commercial Partners: >6,800

Lab FTEs and Annual Compensation: 57,600 full-time equivalent staff, over $7B in salaries & benefits

Small Business Purchasing by Labs: Over $2B annually

The statistics above illustrate how the Laboratories often drive the Nation's research and innovation and provide significant benefits to industry, small businesses, and local, regional, and national economies. Benefits are realized through funding to and from the Lab network; extensive collaborations with universities and industry partners; technology transfer to move innovations to the market; and Laboratory and employee engagement in communities and economies:

- **Funding to the Laboratories and from the Laboratories to other R&D performers drives collaboration, competition, and innovation across the United States.** Total annual Laboratory funding from DOE and other sponsors through SPPs is $13.8 billion. Annual funding from the Laboratories to universities is approximately $0.5 billion, representing 3.5 percent of the total.
- **The Labs have more than 6,600 commercialized technologies and active licenses with commercial and other business partners.**
- **Laboratory impacts in local communities and across the Nation support the economy.** Annual salary and benefits of more than $7 billion paid to more than 57,000 full-time equivalent Laboratory staff support the economy at local, regional, state, and national levels.
- **Fourteen percent of Laboratory spending supports small business partners with local and national impacts,** as measured by the over $2 billion in annual Lab purchasing from small business partners.

5.4.2.1 Financial Stewardship Successes, Challenges, and Opportunities

The goal of Laboratory financial stewardship is to maximize investment in programmatic missions, while recognizing that accomplishing the unique DOE missions and managing the array of risks requires excellence in all elements of execution, including safety, security, financial management, and facility operations. Achieving this balance provides assurance that the Nation receives the best value for its investment in the Laboratories.

Financial stewardship of the Laboratories is governed by the Laboratories' diverse missions in accordance with Federal financial management requirements. The diversity and complexity of mission scope executed by the Laboratories, the number and complexity of specialized research and technical facilities, the Laboratory geographical locations, and other factors substantially impact the resource mix, operational models, and composition of costs at each Laboratory. Table 5-1 provides a financial overview of aggregated Laboratory costs from FY 2011 through FY 2015.

Table 5-1: Laboratory Costs and Trends, FY 2011-FY 2015

Laboratory Costs and Trends, FY11-FY15 Annual Costs ($B)	FY11	FY12	FY13	FY14	FY15
All Laboratories (1)					
Direct (2)	$9.4	$9.0	$8.3	$8.2	$8.5
Indirect (3)	5.2	5.1	5.1	5.1	5.3
Total All Laboratories (1)	**14.6**	**14.1**	**13.4**	**13.3**	**13.8**
Memo: ARRA Costs included above	*$0.9*	*$0.4*	*$0.2*	*$0.1*	*$0.0*
Indirect/Total Cost Ratio (4)	**35%**	**36%**	**38%**	**39%**	**38%**
Indirect/Direct Cost Ratio (5)	55%	57%	61%	63%	62%
Avg Fully Burdened Person Year, $K (6)	**265**	**271**	**283**	**288**	**290**
NNSA and EM Labs (1)					
Direct (2)	$4.1	$3.9	$3.7	$3.6	$3.9
Indirect (3)	2.8	2.8	2.8	2.8	2.9
NNSA and EM Total (1)	**6.9**	**6.7**	**6.4**	**6.4**	**6.8**
Memo: ARRA Costs included above	*$0.1*	*$0.0*	*$0.0*	*$0.0*	*$0.0*
Indirect/Total Cost Ratio (4)	**40%**	**42%**	**43%**	**44%**	**42%**
Indirect/Direct Cost Ratio (5)	67%	72%	75%	77%	73%
Avg Fully Burdened Person Year, $K (6)	**293**	**306**	**334**	**333**	**335**

Table 5-1: Laboratory Costs and Trends, FY 2011-FY 2015, continued

Laboratory Costs and Trends, FY11-FY15 Annual Costs ($B)	FY11	FY12	FY13	FY14	FY15
Science & Energy Labs (1)					
Direct (2)	$5.3	$5.1	$4.7	$4.5	$4.6
Indirect (3)	2.4	2.3	2.3	2.3	2.4
Science & Energy Total (1)	**7.7**	**7.4**	**6.9**	**6.8**	**7.0**
Memo: ARRA Costs included above	*$0.8*	*$0.4*	*$0.2*	*$0.1*	*$0.0*
Indirect/Total Cost Ratio (4)	**31%**	**31%**	**33%**	**34%**	**35%**
Indirect/Direct Cost Ratio (5)	45%	46%	49%	51%	53%
Avg Fully Burdened Person Year, $K (6)	**240**	**241**	**240**	**250**	**252**

Notes:

(1) Excludes NETL; SRNL included with NNSA/EM Labs for all costs and ratios excluding Avg Fully Burdened Person Year.

(2) Direct Costs are operating and construction costs to execute R&D programs and activities.

(3) Indirect Costs are support costs to manage and operate Lab facilities, provide common services, and invest in general purpose Lab infrastructure and LDRD.

(4) Indirect to Total Cost Ratio is total indirect costs divided by total costs. This ratio is commonly used by Labs to assess trends in indirect costs and is the portion of each dollar of Lab costs spent on indirect services.

(5) Indirect to Direct Cost ratio is total indirect costs divided by total direct costs. This ratio is not commonly used by the Labs. Although the ratio is a rough approximation of the Facilities and Administrative (F&A) rates used by universities, it is not comparable because of significant differences in accounting practices.

(6) Total labor-related costs, including labor costs for support personnel, divided by total direct-funded full-time equivalent (FTE) staff performing research at the Labs.

Over the five years from FY 2011 through FY 2015, the Laboratories spent, on average, approximately $14 billion annually on research, development, and demonstration activities. Of the $14 billion, $11.4 billion was direct DOE funding and $2.6 billion was non-DOE funding from other Federal agencies and other external parties. Laboratory spending declined from $14.6 billion in FY 2011 to $14.1 billion in FY 2012 as American Recovery and Reinvestment Act (ARRA) investments were completed. Laboratory spending declined further to $13.4 billion in FY 2013 and $13.3 billion in FY 2014 primarily as a result of sequestration, which reduced overall Federal spending. In FY 2015 Laboratory spending increased to $13.8 billion as a result of an increase to the DOE budget.

Table 5-1 also provides the breakdown of total Laboratory spending between direct and indirect costs. Direct costs are those charged directly to programs and projects to execute specific RD&D work, including researcher salaries and benefits and procurements of goods and services. Indirect costs span a wide array of functions and services necessary to support mission work and to sustain the Laboratories' unique S&T capabilities and resources. Indirect spending includes managing the Labs, facilities management and maintenance, environment, safety and health, security, business services (e.g., human resources and financial services), information technology, and utilities. Indirect costs are charged to indirect cost pools and allocated to programs and projects according to approved accounting standards.

The indirect to total cost ratio in the above table is commonly used by the Labs to assess trends in indirect costs and shows the portion of each dollar of Laboratory costs spent on indirect operational support functions. Many indirect costs such as facility operations, maintenance and leases, and business systems are fixed. Therefore, increased direct spending can reduce the ratio, such as occurred for the Science and Energy Labs in FY 2011 and FY 2012 when ARRA spending was substantial; conversely, reduced direct spending can increase the ratio as occurred in FYs 2013 and 2014. In addition, as Labs spend more indirect funds to reduce deferred infrastructure maintenance, the indirect to total cost ratio may increase, but would be expected to decrease in future years as higher costs to repair or replace infrastructure drop.

Nuclear and radiological operations at the Labs also drive indirect costs, including those related to environment, safety and health, radiological protection, waste disposition, security, fire protection, and infrastructure maintenance. Finally, certain indirect operational costs such as security, cybersecurity, and information technology grew over the period.

The indirect to total cost ratio is higher for the NNSA Labs because of the higher security and safety costs related to nuclear weapons activities conducted at those Labs. The ratio otherwise reflected the same pattern as the Science and Energy Labs with increased indirect cost ratios in FYs 2013 and 2014 when direct cost spending dropped at the NNSA Labs because of reduced funding.

The Fully Burdened Person Year Cost is the annual cost of a full-time staff member doing research at the Laboratories, including direct and related indirect costs. This cost grew across all Labs from FY 2011 through FY 2015. NNSA person year costs are higher than those at Science and Energy Labs because of the higher operational support needed for NNSA Lab specialized missions and growth in labor-related costs combined with a slight reduction in full-time equivalent (FTE) staff over the five years. Science and Energy Labs had a slight increase in FTEs over the same period combined with somewhat lower labor cost growth.

The Laboratories continually manage costs and identify cost savings. For example, facility operations cost savings have been achieved as Laboratories improve the overall condition of facilities through replacement and modernization. Operating costs were reduced at some Labs as a result of the transition from self-provided services to partnering with local municipalities and others for services such as security, fire department, occupational medicine, waste management, chilled water, gas, and roads. This transition allowed Labs to pay for services based on consumption and eliminated management and operation costs. Increasing costs of utilities are a challenge as many Laboratories operate large scientific facilities, often in remote geographical locations, with significant energy needs. Energy savings have been achieved through negotiations with utility providers for low-cost energy and use of Utility Energy Service Contract (UESC) projects that reduced energy demands.

In addition, Laboratories are addressing the challenge of offering competitive compensation packages to attract the best talent while maintaining a cost profile in line with funding. For example, Laboratories reduced compensation and benefit costs by proactive management of pension plans including removing risk from defined benefit plans to reduce volatility of future pension contributions, retiree medical funding, outsourcing of benefits administration, selection of new medical insurance providers, and offering incentives to employees who move to Consumer Driven Health plans.

The Laboratories are also reducing long-term facilities maintenance costs through increased investments in aging critical facilities, many dating from the 1940s to 1960s, to modernize facilities and support efficient, cutting-edge R&D activities.

5.4.2.2 Project Management

One of the hallmarks of DOE is its ability to design, build, and operate large and complex scientific and technical facilities to address its diverse missions in basic and applied research. These missions and the focus of facilities that DOE builds and operates span a spectrum from energy research and energy systems, to discovery-oriented fundamental research, to nuclear weapons stewardship, to environmental restoration, nuclear waste management, and contaminated facility deactivation and decommissioning,

Table 5-2: Active Capital Asset Projects at the National Laboratories Post Baseline (CD-2)*

Lab	Project Name	Current Total Project Cost ($K)	CD-4 Planned Date (end of project)
ANL	Materials Design Laboratory (MDL)	$96,000	04/30/21
BNL	Large Hadron Collider (LHC) ATLAS Detector Upgrade	$33,250	09/30/19
BNL	National Sychrotron Light Source II (NSLS II) Experimental Tools (NEXT)	$90,000	09/29/17
FNAL	LHC CMS Detector Upgrade	$33,217	12/31/19
FNAL	Muon g-2 Project	$46,400	06/30/19
FNAL	Muon to Electron Conversion Experiment (Mu2e)	$273,677	12/31/22
FNAL	Utilities Upgrade (UU)	$36,000	01/31/19
INL	Accelerated Retrieval Project IX	$26,400	09/30/17
INL	Fort St. Vrain Facility Improvements Project	$11,400	12/31/17
INL	Remote-Handled Low-Level Waste Disposal	$77,576	03/31/19
LANL	CMRR PF-4 Equipment Installation, Phase 1	$394,000	04/30/22
LANL	CMRR RLUOB Equipment Installation, Phase 2	$633,300	01/31/22
LANL	Radioactive Liquid Waste Treatment Facility Upgrade Project Low Level Waste (RLWTFUP – LLW) Subproject	$82,694	05/14/18
LANL	Substation Replacement at TA-3	$28,200	09/30/18
LANL	TA-55 Infrastructure Reinvestment, Phase II, Phase C	$92,696	01/31/18
LANL	Transuranic (TRU) Waste Facility, Phase B, Staging and Characterization Facility	$99,254	01/31/18
LBNL	Integrative Genomics Building (IGB) Project	$91,500	12/31/20
LBNL	LUX-Zeplin Dark Matter Experiment (LZ)	$55,500	03/18/22
LBNL	Mid-Scale Dark Energy Spectroscopic Instrument (DESI)	$56,328	09/30/21
LBNL	Old Town Demolition Project, Phase 1 Project	$30,974	10/03/17
PPPL	Infrastructure and Operational Improvements (IOI) Project	$26,000	10/31/19
SLAC	Linac Coherent Light Source (LCLS) II	$1,045,000	06/30/22
SLAC	LSST Camera	$168,000	03/31/22
SLAC	Science and User Support Building (SUSB)	$65,000	04/28/17
TJNAF	12 GeV Continuous Electron Beam Accelerator Facility (CEBAF) Upgrade	$338,000	09/30/17
TJNAF	Utility Infrastructure Modernization (UIM)	$29,900	12/31/18
	Total: 26 Projects	**$3,960,266**	

** DOE is also managing 31 active pre-CD-2 Laboratory-based capital asset projects with an aggregate value of $34.9 billion based on the upper end of the cost range estimates.*

At the Laboratories, the Department is currently managing 26 projects that have reached their Critical Decision (CD)-2 milestone, meaning that the project has established a performance baseline with a detailed schedule and cost profile, and a set of key performance parameters to which the project will be held. The projects, along with the Laboratory, Total Project Cost and planned Critical Decision 4 (CD-4) date, which is the end of the project construction, are shown in Table 5-2.

The Department's strategy for managing capital assets has steadily evolved since the late 1970s, driven by changes in the project management body of knowledge and overarching institutional management organization and practice. The current strategy described in the DOE Acquisition Management System, as defined in DOE Order 413.3B, Program and Project Management for the Acquisition of Capital Assets, establishes principles and processes by which DOE manages the development and construction of reliable and sustainable facilities, systems, and assets that provide a required mission capability.

To address some of the significant management challenges associated with projects over the last two decades, the Department has taken several measures to improve the enterprise-wide perspective on individual capital asset projects, including sharing best practices and lessons learned. In December 2014, the Secretary took action to strengthen the Energy Systems Acquisition Advisory Board (ESAAB) and establish a Project Management Risk Committee (PMRC). He outlined the overarching aspects of his approach in January 2015 before the National Academy of Public Administration. As the Secretary noted, a core challenge is to bring together the Department's constituent pieces (and their various cultures and business methods) to adopt a common set of best practices while still allowing tailoring for specific problems and environments. The Department has also taken measures to ensure that each capital asset project has a clear project owner, i.e., an entity with the clear mission need and budgetary authority, and each Under Secretary has a project assessment office that does not have line management responsibility for project execution.

5.4.2.3 Environment, Health, Safety and Security

Over the last ten years, the 17 National Labs have reduced their injury rates by 50 percent, from a total recordable case rate of slightly greater than two in 2006, to approximately one in 2015. This improvement is attributed to implementation of integrated safety management and improving Contractor Assurance Systems throughout the complex. Improvements have occurred in several areas, but particular focus has been on (1) enhanced senior leadership involvement, (2) improved employee engagement, (3) increased communication efforts, and (4) researcher safety.

Enhanced senior leadership involvement includes focused management walkthroughs, sessions with the general employee population to increase visibility and transparency, and hosting independent peer reviews of the environmental, safety, and health (ES&H) program elements to seek recommendations for improvement. Senior leaders are driving accountability for ES&H excellence through development of supervisors and employees via on-site training and specialized programs. One example is the Battelle Laboratory Operations Supervisor Academy (LOSA), which focuses on the skill development of front-line supervisors. While started as an effort among five Laboratories, it is now being translated for deployment into other National Laboratory environments.

Improved employee engagement (including union engagement) has been established through involvement in risk-based work planning and control processes that provide tools for ensuring a safe working environment. Employee observation programs, employee-led safety committees, and regular interactions between Lab management and union members has enhanced employee engagement on many levels. In some Laboratories, joint committees with Lab management and union members have proven to be valuable mechanisms for resolving safety and health concerns and soliciting feedback for ES&H improvements. Safety culture surveys are a common tool used across the complex to gauge employee involvement and are indicating improving cultures across the Laboratories.

Increased and improved communication on the topic of ES&H that goes beyond communication about injury rates is having a large impact. The efforts focus on incidents and accidents that have occurred and the resulting human impact. Lessons learned are distributed and discussed to drive improvement in the programs. Actively seeking root causes of unwanted events, as well as reviews to ensure the extent of the condition is understood and controlled, has increased. Communicating with the workforce and involving the employees helps to establish a just culture where the employees are identifying the gaps and management is helping to fill them.

Researcher safety is a continuing focus area, given the nature of the work conducted. In particular, efforts are directed at identifying cultural contributions that can be changed. In 2014, several National Laboratories initiated a Safe Conduct of Research campaign to reinforce institutional values, standards, and expectations for researchers to ensure safe and successful scientific operations. The ongoing effort relies on the enhanced communications and senior management involvement and will continue to emphasize matching the risk to the appropriate work planning and controls.

5.4.2.4 Communications and Public Affairs

The National Laboratory System supports the free flow of scientific and technical information through public affairs offices at each Laboratory as well as centralized support at the DOE. The communications professionals in the National Laboratory System enable the dissemination of research findings while protecting against the release of classified information. They ensure word of Lab breakthroughs travels beyond the Labs' gates to taxpayers who need to understand its value, and to potential partners in government, academia, and industry.

The Department and the National Labs work collectively to share Lab news, stories of scientific discovery and technical achievement, and other publicly relevant information through media distribution channels, social media, and on DOE and Lab websites; prepare public events in cooperation with research partners and other stakeholders; and support public education and outreach initiatives, particularly in STEM fields, to attract the next generation of scientists.

The National Laboratory Chief Communications Officers (NLCCO), a working group of the NLDC, played a key role in developing materials and messaging for National Laboratory Day on the Hill, an event initiated by the Secretary that brings scientists, demonstrations, and discussions of Lab programs to members of Congress and congressional staff. Lab communicators also plan announcements for initiatives such as DOE's multi-Lab high performance computing collaborations (CORAL, the Alliance for Computing at Extreme Scale), lead communications efforts around DOE research hubs and user facilities, and prepare materials on key successes for use by DOE and Lab leadership. In addition, through discussions in the LPC and at the Secretary's direction, the Lab Directors created a Labs as Network presentation, illustrating how the Labs have evolved to meet new challenges and how they have worked together to address the challenges. This presentation and narrative are used in many fora to convey the value of the National Laboratories as a system.

Recently, several initiatives have helped to improve the effectiveness of these efforts. In July 2016, the DOE Office of Public Affairs established a Director of Lab Outreach position to ensure accurate, efficient, and clear communications to the public across the Department's broad portfolio of science, energy, environment, and national security programs. Lab content has become key to the DOE's digital strategy over the past six months. Between February and July 2016, Labs provided 35 articles for Energy.gov, and that content garnered more than 55,000 page views. These stories are regularly shared with DOE's 102,000 fans on Facebook and 316,000 Twitter followers. On Facebook in particular, eight of DOE's top 10 most shared posts (an important measure of audience engagement) have been Lab stories, and individual posts have reached more than 100,000 users. On Twitter, Lab stories are regularly seen tens of thousands of times. These efforts are critical to exposing new and younger audiences to the important work of the National Labs.

5.4.2.5 Procurement

In an effort to continually improve enterprise effectiveness and efficiency to maximize the resources dedicated to accomplishing the Department's missions, the National Laboratories in coordination with the Department have focused on addressing emerging issues, sharing best practices, and using working groups to develop and implement new initiatives. The Acquisition Optimization Working Group focuses on helping the Science and Energy National Laboratories achieve its Strategic Sourcing Goals, enhance acquisition savings by presenting novel and proven procurement savings tools and serving as a resource to Labs by providing access to expert acquisition professionals and tools to help solve procurement challenges. The ideas and information are shared with the National Security Laboratories as well.

Acquisition is one of the most impactful elements of the cost of doing business. Costs saved or avoided in any part of the procurement process life cycle, from operations to the execution of contracts, can result in a large dollar reinvestment back to the Laboratories. In the first nine months of FY 2016, the SC Laboratories reported acquisition savings of $43 million from strategically sourced procurements and another $40 million in savings through "other" procurement means. In FY 2015, the savings and cost avoidances totaled nearly $160 million.

Groups of National Laboratories, such as the ten SC Labs, have historically led in negotiating favorable agreements with National-scale service and commodity organizations for use across the National Laboratory System. The negotiated agreements are made available to all Laboratories via a DOE Integrated Contractor Purchasing Team (ICPT) website. For example, an agreement with Dell for computers saved about $30.5 million in FY 2015 on $76 million in expenditures, and in FY 2016, the savings is about $16 million on $45 million in expenditures. Another agreement with general Laboratory equipment supplier Government Scientific Source, Inc. (GSS), a small business vendor that represents a wide variety of manufacturers, has yielded savings of $2.2 million over the past two years on about $89 million in expenditures. New agreements continue to be pursued for other products and services.

In addition, in FY 2016, several Laboratories are employing new e-purchasing tools. The Vinimaya project was funded by DOE and administered by NNSA to improve the purchasing experience for Lab staff, take advantage of preestablished negotiated savings, and implement a more advanced business-to-business program. The ultimate benefit of the project was to implement a better experience for the Lab purchasers that removes formal approvals, reduces hands in the processes, builds in government requirements in a seamless way, and reduces the cost of purchasing. To date, approximately 104,000 items have been purchased through this Amazon-like purchasing process in FY 2016.

6 Streamlining National Laboratory Management

As noted by CRENEL, over the past 40 years more than 50 reviews and studies of the National Laboratories have been conducted, including the governance review of the nuclear security enterprise by Norman Augustine and Admiral Richard Mies and the reports from SEAB, led by John Deutch and Arun Majumdar. While all have noted the value of the National Laboratory System to the Nation, many have also identified that since the end of the Cold War, oversight by DOE grew increasingly transactional rather than strategically mission-driven.

As a result, the Department has prioritized actions aimed at reestablishing a mission-oriented relationship in which the government sets the "what" of strategic program direction to meet the Nation's needs, while the contracted partners determine precisely "how" to meet the technical and scientific challenges and to carry out programs. Through the LPC, LOB, and the NLDC, the Department has identified areas of opportunity to improve the strategic relationship amongst the Laboratories and with the Department. In pursuit of such opportunities, many actions have been completed; and there is evidence—some of which is presented in this report—indicating the strategic relationships between the National Laboratories and DOE, and the National Laboratory System as a whole, are becoming stronger. However, challenges remain, and several of the actions intended to address these challenges are either just beginning or are still in progress. Following the six overarching themes used in the CRENEL report and as reflected in DOE's response to that report (recognizing value, rebuilding trust, maintaining alignment and quality, maximizing impact, managing effectiveness and efficiency, and ensuring lasting change), this chapter focuses on the actions that have been taken thus far.

6.1 Recognizing Value

Recognizing value involves actions undertaken to demonstrate the critical capabilities and facilities provided by the Laboratories in service of DOE's mission, the needs of the broader national S&T community, and the Nation as a whole.

DOE Strategic Plan: DOE's most recent Strategic Plan for 2014–2018, published in March 2014, provides a roadmap for the core missions of DOE, highlights major priorities, and provides the basis for individual DOE program plans.

Stockpile Stewardship and Management Plan and the Prevent, Counter, and Respond Report: With respect to DOE's national security responsibilities, the NNSA produces two comprehensive planning documents that integrate programmatic requirements across Laboratories, plants, and sites. The Stockpile Stewardship and Management Plan (SSMP) is DOE NNSA's 25-year strategic program of record for maintaining the safety, security, and effectiveness of the nuclear stockpile. The SSMP is published annually, in response to statutory requirements, in report or summary form, to support the President's Budget submission to Congress for weapons activities. In response to recommendations by the SEAB Task Force on Nuclear Nonproliferation, a new report, Prevent, Counter, and Respond—A Strategic Plan to Reduce Global Nuclear Threats, articulates for the first time, in a single document, the NNSA programs to reduce the threat of nuclear nonproliferation and nuclear terrorism. As such, it serves as a companion document to the annual SSMP.

The National Laboratories are and will remain important partners in development of these and other DOE strategic planning documents. The Labs provide important technical input and expertise that informs DOE's analysis and planning efforts. Each of these documents will be refreshed on a periodic basis to reflect the evolving challenges, technologies, and opportunities facing DOE in the execution of its missions. As part of its efforts to strengthen its partnership with the National Laboratories, DOE will continue to engage with them in developing future updates to these documents.

National Lab Day on the Hill: An important aspect of recognizing the value of the National Laboratories is the extent to which this value is communicated to critical stakeholders such as Congress and the taxpayer. Organized by the DOE Office of Congressional and Intergovernmental Affairs, National Lab Day on the Hill is a series of events designed to share the extraordinary work done by the National Laboratories to advance science, clean energy and nuclear security. The events also serve to raise awareness within the Laboratory System of broader congressional interests, and provide a forum for the National Laboratories to hear feedback from stakeholders.

The first Lab Day on the Hill, held in September 2014, showcased demonstration projects across five theme areas: energy innovation and environmental sustainability, manufacturing innovations, high performance computing, discovery science, and national security. Subsequent events have focused on specific scientific and technological areas. The most recent, Environmental Stewardship Day, took place in September 2016 and centered on advances in environmental management, including virtual tools used to train workers in the complex tasks of decontamination and decommissioning of contaminated plutonium facilities, advanced instruments to improve the design of hydroelectric facilities to minimize losses in fish populations, and technologies to address groundwater contamination. Plans are being developed to lay out a schedule for future Lab Days on the Hill.

Annual Report on the State of the DOE National Laboratories: The Annual Report on the State of the DOE National Laboratories, embodied in this document, is intended to promote greater transparency regarding the role of the National Laboratories and the value that they provide to the Nation. This report describes key initiatives of the National Laboratories, including how the system as a whole serves the Nation through collective and crosscutting activities, and articulates DOE's operational successes and continued challenges in stewarding the Laboratories. As the first report in what will be an annual series, this inaugural report is comprehensive, providing a history and background on the National Laboratories and establishing a foundation for future annual updates. This report is a collaborative effort among the Under Secretary offices, facilitated by the LOB, and reviewed by the Lab Policy Council.

6.2 Rebuilding Trust

Rebuilding trust involves actions undertaken to improve the working relationship between DOE and the National Laboratories such that they work as partners to restore trust and accountability to the FFRDC relationship. The activities described below were established to engage the Labs in strategic activities that are directly applicable to the Lab operations.

Laboratory Policy Council: In July 2013, the Secretary established the LPC to provide a forum to include the National Laboratories in strategic discussions of DOE's policy and program planning process, and for DOE to provide strategic guidance on National Laboratory activities. The LPC, chaired by the Secretary and comprising senior DOE leadership and the National Laboratories Directors' Council Executive Committee, convenes three times a year and serves as an important forum for exploring nascent proposals related to new research directions, building human capacity, and improving communications, and for discussing progress and guidance on initiatives, such as technology transition pilots and emergency response. Discussions within the LPC have focused on crosscutting Departmental initiatives, DOE-Lab studies by external bodies, management challenges, and workforce and leadership diversity. Research-related discussions have focused on different approaches to "big ideas" management from early stage consortia to later stage deployment projects, to experimentation through pilots; on crosscuts and how they intersect with the ideas coming out of the Big Ideas Summit; on grand challenges and Lab networks, including new approaches to integrate and coordinate the combined capabilities of DOE, its National Laboratories, and regional U.S. stakeholders to address challenges such as grid modernization; on the need to deliver game-changing solutions through new technologies for high legacy waste cleanup challenges; and on LDRD and its significance in retention and recruitment of staff. Discussions of building leadership and improving diversity included tools such as paid parental leave, conference attendance, and a new leadership development program, the Energy Sciences Leadership Group. Discussions have focused on the need to identify and define what technology transfer means, to clearly establish priority, and to expand Lab authorization to create public/private partnerships. A number of pilots were discussed, including the DOE Lab-Corps pilot, the Lab-Industry Technologists in Residence pilot, and the Small Business Voucher Program. The LPC provides a forum for exploring how to improve communications and for reinforcing an integrated story about the Department and its Labs, and was the genesis for the Labs as Network presentation and narrative and Lab Days on the Hill.

Laboratory Operations Board: The Laboratory Operations Board (LOB) was established in October 2013, with a charge "to strengthen and enhance the partnership between DOE and the National Laboratories, and to improve management and performance." One of its early efforts illustrates the enterprise-wide impact of the group: the LOB led a first-ever enterprise-wide assessment of general purpose infrastructure across all 17 National Laboratories and NNSA sites and plants, using newly established metrics to provide a uniform assessment of infrastructure such as utilities, HVAC systems, and office buildings. This initiative provided the basis for an additional $106 million requested by DOE, and funded by Congress in FY 2016 appropriations, targeted for general purpose infrastructure projects. Since then, the LOB has led DOE on other operations and management issues ranging from the strategic to the targeted. For example, LOB coordinated a similar enterprise-wide strategic effort to provide updated assessments and prioritization of unused and contaminated "excess" facilities and led an effort to identify alternative financing pathways, such as public-private partnerships, enhanced-use leasing arrangements, or other means of financing, to meet future DOE infrastructure needs. And LOB led a targeted effort to update Departmental policy on SPPs and to build a community of practice to promulgate best practices and streamline approvals. Additional examples of major LOB accomplishments include reforms to DOE Directives and Requirements; development of a Departmental policy to clarify roles and responsibilities relating to the Laboratories; improvements to the CAS policy and sharing of best practices; creation of a rotational program for Federal employees to field sites, in connection with the associated Laboratory, to promote leadership development and strengthen partnerships; strategic management of data calls to the Labs, reducing unnecessary burdens and duplication; revisions to the policies and practices governing SPPs; and additional reforms on a wide range of issues, some of which are discussed in detail below.

The LPC and LOB have proven to be successful partnership forums where issues can be raised and solutions can be debated with relevant stakeholders engaged. These bodies are closely integrated with the Laboratory leadership, as the executive committee of the NLDC sits on the LPC, and the chairs of the Laboratory Chief Operating Officer and Chief Research Officer working groups are members of the LOB.

LDRD Annual Approvals Pilot: Following recommendations from CRENEL, DOE is piloting an effort to approve annual LDRD plans for select Laboratories as a group. Following this approval, throughout the year Laboratories can execute individual projects within that plan. The US/SE may expand this pilot effort for annual LDRD approvals to other Laboratories.

"Evolutionary" Working Group and "Revolutionary" Working Group were discussed in Chapter 5 and are related to the Department's efforts toward rebuilding trust.

Safety and Security Oversight: In the areas of Federal safety and security oversight, DOE has enhanced the way oversight is conducted organizationally, procedurally, and operationally. In 2014, the Secretary established the Office of Enterprise Assessments to consolidate and manage all independent safety and security assessments within DOE. At the same time, the Office of Environment, Health, Safety, and Security was established to serve as the organization responsible for policy development and technical assistance; safety analysis; and corporate safety and security programs. These actions provided a clear distinction between operational awareness and independent oversight responsibilities. DOE will continue to work to improve the oversight process, including addressing duplication where appropriate and sharing best practices.

Cyber Council: The DOE has initiated an integrated approach to cyber issues through the establishment of the DOE Cyber Council, in which the Labs are called upon to play a significant role.

6.3 Maintaining Alignment and Quality

Maintaining alignment and quality involves actions undertaken to improve strategic planning; maintain the quality of technical staff; enable the ability to adapt, retool, invest in staff and capabilities, and enter new research areas through LDRD and other support mechanisms; and manage the Laboratories as a system through an overarching strategic plan that provides the flexibility to pursue new lines of inquiry aligned with mission priorities. The activities discussed below were implemented to further these goals.

Agency Priority Goal for FY 2016 – FY 2017: The Secretary has initiated several efforts to bring more consistency to the management and oversight of the DOE Laboratories, and DOE has established an Agency Priority Goal for FY 2016 – FY 2017 that will ensure focus is maintained on these efforts. Specifically, the goal is to deliver the highest quality R&D and production capabilities, strengthen partnerships with DOE headquarters, and improve management of the physical infrastructure of the National Laboratories to enable efficient leadership in science, technology, and national security. To achieve this goal, the Department is committed to developing and implementing a consistent, annual process to track and assess Laboratory planning and evaluation, described in the next paragraph.

Laboratory Planning: DOE established a framework for consistent Laboratory planning processes and implemented the process for all 17 National Laboratories. NNSA, EM, and the applied energy offices used core elements and attributes from the Lab planning process used by SC. The annual Laboratory plans inform the PEMPs, infrastructure plans, and 10-Year Site Plans. In addition, NNSA has established a Laboratory strategic planning function in the NNSA Office of Policy within the Office of the Administrator. Finally, EM established a DOE headquarters function focused on the stewardship of SRNL. This function manages the process for annual Laboratory program guidance, planning, and evaluation, and will serve as a focal point for other key Laboratory stewardship activities, such as SPPs and LDRD.

DOE Crosscut Initiatives and the National Laboratory Big Ideas Summit: For the past three years, the US/SE has sponsored an annual National Laboratory Big Ideas Summit, which brings together subject matter experts from DOE's Science and Energy offices as well as the Office of Energy Policy and Systems Analysis, the NNSA, as all 17 National Laboratories (including their Directors and senior research staff) to propose and explore innovative ideas for solutions to key energy issues. One outcome from the Big Ideas Summits has been to provide ideas for DOE crosscut initiatives, that is, budget requests that cross program lines. For example, the first Summit resulted in major Departmental initiatives in FY 2015 and FY 2016, including the Grid Modernization Laboratory Consortium, which is led by two Federal and two Laboratory representatives. The fourth Big Ideas Summit is planned for March 2017.

Laboratory Directed Research and Development (LDRD): CRENEL recommended that Congress restore the cap on LDRD to 6 percent unburdened, or its equivalent, noting that this will have the largest impact on LDRD at the NNSA Laboratories. The recently enacted FY 2016 National Defense Authorization Act increased funding for LDRD with a minimum rate of 5 percent and a maximum of 7 percent of the NNSA Laboratories' operating budgets, a level more consistent with historic NNSA levels.

DOE also is working to promulgate best practices on LDRD throughout DOE to help the National Laboratories improve the flow of outcomes from LDRD to missions. This working group, led by NNSA but involving the other Under Secretary offices as well, also will develop an electronic forum to document and share best practices. In FY 2016, DOE issued an LDRD Highlights document. NNSA also will share the individual annual Lab reports with Congress and provide an annual briefing for stakeholders on the benefits realized due to LDRD investments.

Pilot Leadership Development Rotational Program: The LOB established a working group with the DOE Chief Human Capital Officer (CHCO) to develop and implement a pilot for a leadership development rotational program that offers DOE Federal mid-level and senior employees opportunities to rotate to field locations, in connection with the associated Laboratory. This rotational program, run by the CHCO office, was launched in April 2016 and is intended to promote greater common understanding of the management challenges and opportunities between the Laboratories and the Federal employees, and to strengthen partnership and trust.

Energy Sciences Leadership Group: In 2016, the US/SE—in coordination with the NLDC—launched the Energy Sciences Leadership Group (ESLG), a leadership development program proposed by the Lab Directors in the LPC for personnel across the DOE's National Laboratory enterprise and their partners in academia and industry. Modeled on the Department of Defense's long-standing Defense Sciences Study Group, the ESLG aims to bring together emerging leaders from the DOE's National Laboratories and academic partners to deeply engage with our current scientific and energy challenges and devise innovative solutions and approaches. The core of this inaugural year of the ESLG is built around a series of five workshops occurring at National Laboratories and in Washington, D.C., between June 2016 and March 2017. These workshops, lasting three to five days, are designed to allow the ESLG participants to

- gain exposure to the diverse science, engineering, and analysis that takes places throughout the National Laboratory System and beyond;
- develop leadership skills;
- develop a systems-level understanding of the Nation's energy system and scientific community;
- meet distinguished leaders from diverse parts of government, the National Laboratories, academia, and industry; and
- gain firsthand exposure to policymaking and the energy regulatory and policy framework.

Candidates for the inaugural 2016 ESLG cohort were nominated by the National Laboratory Directors, with the final class then selected by a Senior Advisory Board consisting of four former National Laboratory Directors. The second cohort has already been chosen using a similar process, and they will start their series of workshops in March 2017.

Conference Management: The Department revised and refined the conference management procedures, including streamlining the approval processes and reducing transactional oversight, while meeting all legal requirements and maintaining appropriate management controls to ensure cost-effectiveness. The Deputy Secretary signed a memorandum issuing this updated guidance in 2015.

6.4 Maximizing Impact

Maximizing impact involves actions undertaken to ensure full realization of the Laboratories' capabilities, such as efforts to enable more external collaboration with small and large businesses, academia, and other Federal agencies, and initiatives to support the design, construction, and operation of leading-edge S&T user facilities. Through the following activities, the Department has made progress in maximizing the impact of the Laboratory System.

Under Secretary for Science and Energy: As described in detail in Chapter 4, Secretary Moniz reorganized the Department to better coordinate and integrate applied energy research and basic scientific research by placing these programs under the purview of a single US/SE. From Departmental crosscut initiatives and the Big Ideas

Summit to Laboratory planning and Strategic Partnership Projects, many of the activities discussed in this and the following chapter represent the efforts of the Office of the US/SE—working with others throughout the Department and National Laboratory enterprise—to enact the vision established by Secretary Moniz.

Strategic Partnership Projects (SPPs): The Department issued an updated policy document, which sets forth the principles for DOE's strategic engagement with partners from other Federal agencies and the private sector. This policy makes clear that DOE is "committed to the maximum use of, and engagement with, the national assets at the DOE National Laboratories, plants, and sites for the benefit of other Federal agencies, private companies, state and local institutions, and international entities, within the limits set forth by [applicable] statutes, regulations, and DOE policy." This work must be consistent with or complementary to DOE's missions or the facility to which the work is to be assigned. The work also should enhance or make use of the facility's core capabilities, but does not need to be associated with a specific mission of the "owning" program. Additionally, the work must not adversely impact DOE programs, result in direct competition with the domestic private sector, or create a detrimental future burden on DOE resources.

In addition, under the leadership of the LOB, DOE established a community of practice on SPPs to ensure communication of best practices across the complex. The community of practice has held two summits and discusses ways to enhance collaboration and streamline processes.

Mission Executive Council (MEC): The MEC was established to bring a more strategic understanding of the capabilities needed for the Labs and facilities to serve the agencies' missions. While DOE is committed to the future success of the MEC, further development of this strategic concept is required, as well as the involvement and commitment of the agencies for which the DOE facilities perform their work. In addition, since the MEC represents only four agencies, it would not be the proper venue to coordinate, streamline, and execute all interagency work because many other stakeholders would not be represented. The MEC is currently pursuing an agenda focused on identifying strategic priorities and critical capabilities to address enduring national security challenges and potential technological surprises raised by the MEC member agencies. This approach and dialogue are starting to work and will result in an actionable MEC strategic framework in 2017 on specific activities for the MEC members to execute.

User Facilities: DOE continues to support user facilities as a key part of its portfolio and will continue to use external peer review and external advisory groups to evaluate facility performance and help inform decisions on existing and future facilities. DOE is working to ensure that best practices by the Office of Science for managing user facilities are incorporated into the management practices of other DOE Program Offices.

Technology Commercialization Fund: DOE has established a Technology Commercialization Fund (TCF), which was described in detail in section 4.6. While the TCF program has started successfully, there are two challenges that, if addressed, would make the program more effective and efficient. The first challenge is due to constraints on how the funding can be used based on the source of the appropriated funding. The second is a 1:1 cost share requirement that is out of alignment with other cost share requirements and that impedes the ability of the Labs to attract private entities to share the high level of risk in developing Laboratory-owned, early-stage technologies. Recommendations to address the challenges were proposed as part of the Administration's budget request in FY 2017.

6.5 Managing Effectiveness and Efficiency

Managing effectiveness and efficiency involves actions undertaken to improve areas critical to a well-functioning FFRDC partnership, such as overhead costs, facilities and infrastructure, and project and program management. Through the following activities, the Department has made progress in enhancing the effectiveness and efficiency of the National Laboratory System.

Directives, Policy Memoranda, and Acquisition Letters: DOE has initiated a comprehensive review of how, when, and why it establishes its own set of requirements, with a charge to take a fresh look at mechanisms including directives, policy memoranda, and acquisition letters. The LOB conducted a workshop in February 2016 with participants from DOE headquarters, site offices, and Laboratories, to examine the Department's approach to requirements development, especially directives. Through leadership from MA and the LOB, the Department has made significant progress implementing the workshop's recommendations for improving requirements development, including the following: increased senior leadership involvement in developing directives; developing an annual prioritization; improving the review and comment process; establishing principles for directives development; and improving implementation.

Laboratory Data Calls: The CRENEL report noted that SC has appropriately managed data calls to SC Laboratories by establishing a single point of contact for data requests. As part of a LOB initiative to continue reducing unnecessary burdens and duplication of efforts, the LOB has focused on better managing data calls issued by DOE. As part of those efforts, MA oversees a working group that is working with specific DOE offices to better manage data calls, including ensuring that they are properly vetted and filtered before they are issued.

Furthermore, in August 2016, NNSA issued a memorandum providing clarification and direction related to data calls from NNSA. As recommended by CRENEL, this updated NNSA process more closely mirrors the process in SC.

Infrastructure: The LOB identified DOE infrastructure as a transformational opportunity for the Department—specifically a focus on revitalizing aging infrastructure across the DOE enterprise to better support mission activities today and in the future. The initiatives were described in detail in Chapter 5.

Procurement: DOE and the National Laboratories worked together to implement mechanisms and other improvements to the acquisition processes, such as reverse auctions and contracts for purchases that can benefit all Laboratories. The aim is to reduce and avoid costs and increase the funds spent on the R&D missions.

Small Business: DOE worked with the Small Business Administration (SBA) to allow the small business contracting completed by the DOE National Laboratories to be included in the DOE reporting to the SBA. The impact is that DOE can make proper decisions for the enterprise overall consistent with mission accomplishment.

Cybersecurity: The Department and Laboratories together are engaged in protecting the DOE enterprise from a range of cyber threats by coordinating strategic and operational aspects of cybersecurity and facilitating cooperative efforts such as the Joint Cybersecurity Coordination Center (JC3) for incident response, and implementation of the Department's Identity, Credentials, and Access Management (ICAM) initiative.

NETL: In efforts to support the Fossil Energy mission, NETL was restructured to a transformative business model that promotes superior science, efficient business operations, and a world-class workforce. The Office of the Director has been streamlined, with principal direct reports to include leadership of a newly created Office of Science and Technology Strategic Plans and Programs; a newly defined Laboratory Operations Center, led by the Chief Operating Officer; and the Finance & Acquisitions Center, led by the Chief Financial Officer. Overall, NETL's restructured business model was designed to promote greater accountability, transparency, and efficiency, and one that anticipates career and leadership development and succession planning needs.

Project Management: To strengthen project management, DOE established a Project Management Risk Committee, restructured the Energy Systems Acquisition Advisory Board, and reinforced the independent peer review process, with the idea that we could head off problems earlier in the process. Finally, DOE updated the Project Management Order (DOE O 413.3B) to institutionalize Secretarial project management reforms.

6.6 Ensuring Lasting Change

Ensuring lasting change involves actions undertaken to ensure that efforts made by the current Secretary of Energy to improve the relationship between DOE and its Laboratories, and thereby the efficiency and effectiveness of the Laboratories, are sustained and have lasting impact. Through the following activities, the Department seeks to achieve this goal.

Annual Report on the State of the DOE National Laboratories: DOE plans to update this inaugural report each year to highlight new results and improvements, and discuss the status of actions taken to improve the Laboratory System and the strategic relationship with DOE.

DOE Transition Plan: The Transition Plan prepared for the new administration describes the improvements and identifies the actions that if supported will lead to further progress for the DOE National Laboratory System.

7 Conclusion and Next Steps for the National Laboratory System

Through its management and operating contracts, the DOE has an adaptable structure for lasting impact and value to the Nation. The reports issued by CRENEL, Mies-Augustine, SEAB, and others describe needed reforms, and DOE and the NLDC are working to address these issues, as reflected in DOE's responses to those reports. Both DOE and the National Laboratories recognize their stewardship responsibilities and the need to ensure the vitality of this invaluable resource that has been built up and adapted over the past eight decades. Collectively, they have pursued actions to substantially improve the Laboratory System. Together, they will continue to work to maintain and develop the most comprehensive research network of its kind—a system of National Laboratories that can effectively tackle long-term, high-risk research and development challenges for the Nation.

Following the six overarching themes articulated in Chapter 6, this chapter focuses on the challenges that remain and the actions that are still being pursued.

7.1 Recognizing Value

The Department has instituted a series of ongoing efforts to communicate the unique, central and exceptional role the National Laboratories play in meeting the needs of DOE's missions, the broader national S&T community, and the Nation as a whole. Key planned activities in this area include the following:

- The second Annual Report on the State of the DOE National Laboratories. As with this initial report, the second installment will be a collaborative effort among the Under Secretarial offices, facilitated by the LOB, and reviewed by the Lab Policy Council.
- The second Science and Energy Plan, discussing key updates to the Department's organization, research agenda, processes, business practices, and Laboratory and external engagements.
- A new annual edition of the Stockpile Stewardship and Management Plan, a comprehensive planning document that integrates programmatic requirements across Laboratories, plants, and sites for the nuclear security enterprise.
- A new Prevent, Counter, and Respond report that will provide a full description of DOE/NNSA's threat reduction strategies and activities, as well as an update on changes in the threat environment and DOE/NNSA programs.
- The Lab Day on the Hill series that will continue in the spring of 2017 to share the extraordinary work done by the National Laboratories with members of Congress.
- Preparatory efforts to frame, organize, and begin research and analysis for future editions of the QER and QTR. In particular, the culmination of the QER cycle should be an integrative energy policy report.

These and other efforts will be used to convey changes throughout the DOE and National Laboratory enterprise, and to communicate the complexity and value of this singular enterprise to stakeholders.

7.2 Rebuilding Trust

Clarifying roles/responsibilities: Several external reviews (including the SEAB Task Force on DOE National Laboratories and CRENEL) have indicated that DOE should provide better clarification regarding roles/responsibilities at DOE and particularly as it relates to the National Laboratories. The Department developed a policy, which articulates core management principles that clarify roles and responsibilities with respect to the National Laboratories. Programs have implemented reforms in this area as well. For instance, NNSA issued a Supplemental Directive on site governance, which clarifies roles and responsibilities in NNSA.

Contractor Assurance Systems: The Department continues to pursue improvements to the Contractor Assurance Systems, including efforts following from the August 2016 CAS summit. The LOB will work to promulgate best practices and implement the updated 2016 policy.

7.3 Maintaining Alignment and Quality

Laboratory Planning Improvements: Planning has already begun for improvements to the second round of Plans for all 17 Labs incorporating lessons from the first year. A pilot is underway with NREL in which the Laboratory presented their overall LDRD plan, and will approve individual projects within that approved framework. The pilot for LDRD will be expanded to include the ten Science Labs and the INL.

"LDRD" for NETL: NETL is the only GOGO Laboratory of the 17 National Laboratories, but the importance of discretionary R&D funding to the vitality of NETL is as important as it is at the other Laboratories. As a result, the path toward establishing a program comparable to the LDRD program is being evaluated for implementation over the next two years.

Diversity and Inclusion: The Laboratories face several ongoing challenges in ensuring continuity for critical skills, particularly in areas that are both core and unique to DOE (e.g., stockpile stewardship and accelerator design); training students, postdocs, and staff for the challenges in national security, science, and energy technology; and managing the complexities of an aging workforce. A special focus has been placed on increasing the diversity of the workforce, and ensuring that the operations at the Laboratory are inclusive of all staff to ensure that the best ideas are integrated into the planning, management, R&D, and operations at the Laboratory. This is a work in progress.

Laboratory Institutional Costs Review: CRENEL provided several recommendations relating to Institutional Cost Reporting (ICR) and transparency. The National Laboratory Chief Financial Officers Working Group, the National Laboratory Chief Operating Officers Working Group, and the DOE CFO office are working on approaches to address the commitments made by the Department in its response.

7.4 Maximizing Impact

Departmental Directives: The Department will continue to implement reforms described in Chapter 6.

General Purpose Infrastructure Report: The LOB will continue activities to improve management of DOE infrastructure, and the Infrastructure Executive Committee will issue its annual State of General Purpose Infrastructure Report by the end of FY 2017.

Technology Transfer Execution Plan: The Plan and an associated policy are being drafted to identify actions that can further enhance the transition of R&D results out of the Laboratories.

R**evolutionary and Evolutionary Working Group Evaluations:** The next steps are to evaluate the success of the changes made, and in parallel, to determine what elements and what processes are appropriate for implementation at other Laboratories. The LOB will facilitate sharing of lessons learned, and will look to whether elements of these pilots may be applicable more broadly within the Department.

Strategic Partnership Projects (SPPs): The SPP working group will continue to promulgate best practices and examine policies and procedures to ensure efficiency and effectiveness.

Excess Contaminated Facilities Working Group (ECFWG): The Department's report on excess facilities was issued in December 2016, and the ECFWG will begin work on the next iteration of the report. In addition, the ECFWG will work to institutionalize changes and update data categories as a result of its efforts, and to conduct walk-downs of higher risk excess facilities around the DOE complex.

Savannah River National Laboratory (SRNL): DOE-EM has requested SRNL develop and begin implementation of a plan that will establish SRNL as a separate, independent business unit within the existing SRNS M&O contract. The goal is to enhance SRNL's ability to (1) provide technical leadership for the EM programs at SRS and at sites across the DOE Complex; (2) lead the research and development programs essential to the completion of the DOE-EM mission; (3) provide the full range of tritium processing and gas transfer R&D, technical support, and supply chain stewardship necessary to maintain the Nation's tritium stockpile; and (4) advance SRNL's status as a world-class, multiprogram DOE National Laboratory.

DOE-Laboratory Crosscuts: The Department will continue its efforts to better coordinate and align strengths and activities throughout the DOE and Laboratory complex through the use of programmatic crosscuts.

7.5 Managing Effectiveness and Efficiency

Cybersecurity and Scientific Computing: The Department and the Laboratories have worked together to develop—and share throughout the Laboratory System—novel approaches and solutions to the challenges presented by cybersecurity concerns and scientific computing. As both of these areas continue to evolve, additional investment and innovation is needed to find new approaches to manage the risk of cybersecurity both in an R&D environment and as it may impact open scientific computing.

7.6 Ensuring Lasting Change

Secretary of Energy Advisory Board (SEAB): Recent external evaluations of the DOE, such as the CRENEL and Mies-Augustine reports, noted the large number of similar evaluations that had been conducted on the National Laboratories over the past 50 years. SEAB is a Federal Advisory Committee, composed of external members, that provides advice and recommendations to the Secretary. The SEAB National Laboratory Task Force has been charged by the Secretary to review the progress of the Department's implementation of its response to the CRENEL and Mies-Augustine reports. This review is ongoing, and SEAB provides its assessment at the public SEAB meetings. Going forward, SEAB can continue to fill that role by periodically reviewing the implementation of actions derived from previous reports and offering further recommendations that build on the previous results.

CRENEL Effectiveness Review: In its response to the CRENEL report, the Department committed that the LOB will conduct a review of the effectiveness of CRENEL Implementation before February 2018.

Appendix A

The DOE Laboratory Management Model

The DOE Laboratory Management Model

There are several terms used regarding the National Laboratories: management and operating (M&O) contracts/contractors, government-owned, contractor-operated (GOCO)—or government-operated (GOGO), Federally funded research and development centers (FFRDC), and National Laboratory. While they are sometimes used interchangeably, each of these terms has a distinct definition and meaning, as described in this appendix. This appendix also provides a table of Laboratory M&O contractors and contract dates.

To tackle the large-scale and changing challenges and opportunities assigned to the DOE and its predecessors, the Federal Government employed the M&O contracting model to enlist the best and brightest researchers and give them wide latitude to pursue their ideas; invest in large-scale, shared core infrastructure; allow for dynamic, community-driven formation of large interdisciplinary teams connected with universities and industry; and equip scientists with the resources necessary to develop the world's most advanced tools for research. This idea of a National Lab, managed and operated in the public interest by university and industry scientist-leaders, is a successful model for discovery and innovation related to problems of great scale.

The M&O contract model that DOE uses is governed by Federal Acquisition Regulation (FAR) and Department of Energy Acquisition Regulation (DEAR) requirements as well. FAR Subpart 17.6 covers the unique characteristics of the M&O contract, including the close working relationship, conduct of work closely related to the agency's mission, facilitation of work that is of a long-term or continuing nature, and transition of personnel and work in the event of a change in contractor. The FAR also describes the special extend/compete process for M&O contracts.[21] DEAR Part 970 supplements the FAR and governs solicitation, award, and administration of DOE's M&O contracts.[22]

Sixteen of the DOE National Laboratories are managed under the GOCO model, while one, NETL, is operated under the GOGO model. GOGO laboratories are usually owned or leased by the Federal Government and are predominantly staffed by Federal employees and supported by nonfederal contract employees. While NETL as a GOGO is unique among the 17 DOE National Laboratories, the GOGO model is used more often for Federal research institutions outside of DOE. In GOCO laboratories, the facilities and equipment are owned by the Federal Government, but the staff is employed by a private or public contractor that manages and operates the laboratory under a contract with the Federal Government. The GOCO management model is implemented through M&O contracts that are competitively awarded by DOE.[23] The current status of each M&O contract used by DOE for a National Laboratory is given in Table A-1 below.

The underlying GOCO stewardship model, which dates to the Manhattan Project, has proven to be remarkably adaptable. In part, this is due to the GOCO management model and the flexibility it affords in the management

[21] Title 48 CFR § 17.6

[22] Title 48 CFR Part 970

[23] DOE uses M&O contracts for non-Laboratory contracts (e.g., the Strategic Petroleum Reserve) as well.

and operation of the Laboratories in, for example, quickly identifying and organizing the necessary scientific and engineering talent for the missions. The GOCO model represents a partnership between the government and private sector: DOE specifies the mission and high-level objectives (the "what") and grants the contractor freedom to determine the best means to achieve them (the "how").

The 16 Laboratories that are managed as GOCOs have been designated as FFRDCs,[24] which codifies a special relationship between a Laboratory contractor and the Federal Government. The referenced FAR and a DEAR clause[25] establish the requirements that an FFRDC must

- meet a special long-term government R&D need that cannot be met as effectively by the government or the private sector;
- work in the public interest with objectivity and independence, and with full disclosure to the sponsoring agency;
- operate as an autonomous organization or identifiable operating unit of a parent organization;
- preserve familiarity with the needs of its sponsor(s) and retain a long-term relationship that attracts high-quality personnel; and
- maintain currency in field(s) of expertise and provide a quick-response capability.

In general, FFRDCs provide continuity, adaptability, and objectivity. The FFRDC construct specifically provides the flexibility necessary to attract and retain leading technical and scientific talent; enables the ability to work closely with the government sponsor on future plans to create, align, and ensure the current and long-term relevancy of the Laboratory; and provides the ability to work with other funding agencies on a noninterference basis. As an FFRDC, a National Laboratory must conduct business in a manner befitting its special relationship with the government (e.g., atypical contractor access to government and supplier data [sensitive and proprietary], and to employees and Federal installations, equipment, and real property).

The M&O contract model matches very well with the FFRDC construct, and is well suited for the DOE supported RD&D activities, which continually change as new discoveries and developments arise. In addition, the M&O contract enables a sponsoring agency to enter into agreements with nongovernment entities that use their own capabilities for day-to-day operations and support functions, while drawing upon the parent organization's expertise when appropriate. DOE uses oversight, annual evaluation, award fees, and potential competition of the M&O contract as mechanisms for ensuring that performance meets the needs of the government sponsor and that the capabilities continue to align with the sponsor's mission. A list of current M&O contractors including contract award dates and maximum contract end dates is provided in Table A-1.

The "National Laboratory" is an entity that is distinct from the M&O contractors, and the National Laboratories are identified in the Energy Policy Act of 2005.[26] In all cases in the DOE, the Laboratory is owned by the government, although what is "owned" varies by Laboratory (e.g., the government may own the land for some Laboratories but have a long-term lease for others). The M&O contractor, or "corporate parent," is a separately organized entity that may be hired to run a National Laboratory under the GOCO model. As FFRDCs, National Laboratories are able to serve as strategic advisors and partners to government, and inform and strengthen program directions.

The GOGO model used in the operation of NETL also affords unique benefits to the Department. As the only GOGO DOE Laboratory, NETL maintains several distinct roles with the DOE Lab community. A GOGO organization often plays a lead coordinating role with other Labs and partners. It has the ability to assemble and lead teams of DOE experts from across the National Laboratory Complex as well as industry and academia to address key issues of National interest. The Carbon Capture and Storage Initiative and the National Risk

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[24] As defined in 48 CFR 35.017, "Federally Funded Research and Development Centers"

[25] Department of Energy Acquisition Regulation, Subpart 970.35 (2013).

[26] Public Law 109–58—AUG. 8, 2005

Assessment Partnership programs are two recent examples. The GOGO model also supports a full-service Laboratory, which enhances program planning, budget formulation and execution, procurement, on-site research, research-focused project management, legal services, and energy system, policy, and program benefit analysis.

Table A-1: Laboratory M&O Contractors and Contract Dates

Laboratory	Contractor	Contract Award Date	Maximum Contract End Date
Ames Laboratory (Ames)	Iowa State University	12/4/2006	12/31/2026
Argonne National Laboratory (ANL)	UChicago Argonne LLC (University of Chicago)	7/31/2006	9/30/2026
Brookhaven National Laboratory (BNL)	Brookhaven Science Associates, LLC (Battelle Memorial Institute, The Research Foundation for The State University of New York Stony Brook University)	12/22/2014	1/4/2035
Fermi National Accelerator Laboratory (FNAL)	Fermi Research Alliance, LLC (University of Chicago, Universities Research Association, Inc.)	11/1/2006	12/31/2025
Idaho National Laboratory (INL)	Battelle Energy Alliance LLC (Battelle Memorial Institute)	11/9/2004	9/30/2019
Lawrence Berkeley National Laboratory (LBNL)	University of California	4/19/2005	5/31/2025
Lawrence Livermore National Laboratory (LLNL)	Lawrence Livermore National Security, LLC (Bechtel National, University of California, Babcock & Wilcox, URS Corporation)	10/1/2007	9/30/2026
Los Alamos National Laboratory (LANL)	Los Alamos National Security, LLC (University of California, Bechtel National, Babcock & Wilcox Technical Services, URS Corporation)	6/1/2006	9/30/2023
National Renewable Energy Laboratory (NREL)	Alliance for Sustainable Energy (Battelle Memorial Institute, MRI Global)	7/29/2008	9/30/2018
Oak Ridge National Laboratory (ORNL)	UT-Battelle, LLC (University of Tennessee, Battelle Memorial Institute)	10/18/1999	3/31/2020
Pacific Northwest National Laboratory (PNNL)	Battelle Memorial Institute	12/30/2002	9/30/2017
Princeton Plasma Physics Laboratory (PPPL)	Princeton University	4/1/2009	3/31/2019

Table A-1: Laboratory M&O Contractors and Contract Dates

Laboratory	Contractor	Contract Award Date	Maximum Contract End Date
Sandia National Laboratories (SNL)	Sandia Corporation (Lockheed Martin Corporation)	10/15/1993	4/30/2017
Savannah River Site (SRS) Savannah River National Laboratory (SRNL)	Savannah River Nuclear Solutions, LLC (Fluor Corporation, Newport News Nuclear, Honeywell International, Inc.)	1/10/2008	7/31/2018
SLAC National Accelerator Laboratory (SLAC)	Stanford University	11/1/1962	9/30/2017
Thomas Jefferson National Accelerator Facility (TJNAF)	Jefferson Science Associates, LLC (Southeastern Universities Research Association (SURA), Inc., Pacific Architects and Engineers (PAE) Applied Technologies, LLC)	4/14/2006	5/31/2024

Appendix B

Formation of the U.S. Department of Energy's National Laboratory System

Formation of the U.S. Department of Energy's National Laboratory System

Rooted in the race to harness the atom and win World War II, the DOE National Laboratory System today is the largest research system of its kind in the world. Its 17 Laboratories, located across the United States, provide the Nation with scientific and technological leadership in clean energy, national security, discovery science, and environmental stewardship. The evolution and management of this diverse network of Labs serves as an example of Government, academia, and industry working together to meet national needs with global benefits.

The 1940s:

August 1, 1946

President Harry Truman signs the Atomic Energy Act of 1946, creating the U.S. Atomic Energy Commission (AEC). The AEC's primary mission is nuclear energy R&D for national security, but the Act also provides for nuclear R&D directed toward "improving the public welfare, increasing the standard of living, strengthening free competition in private enterprise, and promoting world peace." The Act also establishes a Joint Congressional Committee on Atomic Energy and directs it to "make continuing studies of the activities of the Atomic Energy Commission and of problems relating to the development, use, and control of atomic energy."

April 28, 1946

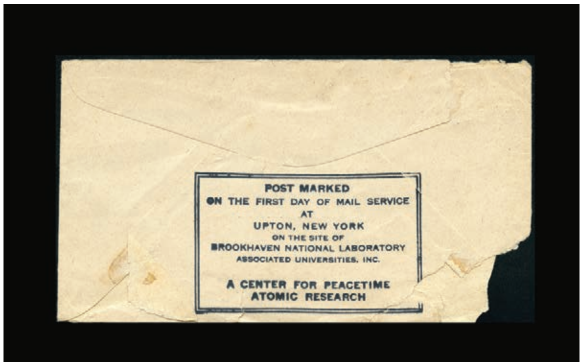
Cyclotrons at Berkeley allow scientists to create radioactive elements and test materials. Here scientific and technical staff are shown with inventor E.O. Lawrence (seated in suit and tie, hands clasped, at center right) at the magnet of the lab's 184-inch cyclotron.

January 1, 1947

The AEC assumes responsibility for the research and production facilities involved in the development of the atomic bomb. Seven sites hosting these facilities will provide the foundation for today's system of National Laboratories:

- The University of California Radiation Laboratory, established in August 1931 at the university's Berkeley campus;
- Argonne National Laboratory, created in 1946 as the successor organization to the University of Chicago's Metallurgical Laboratory (Met Lab), established in 1941;
- The Ames Project at Iowa State College (now Iowa State University), a secret chemical R&D program launched in February 1942 to develop improved methods of purifying uranium for the Met Lab;
- Clinton Laboratories in eastern Tennessee, established in 1942 as a satellite of the Met Lab for the demonstration of plutonium production and separation;
- The Hanford Works at Richland, Washington, the site selected in 1942 for the full-scale production and separation of plutonium;
- Los Alamos Scientific Laboratory in Los Alamos, New Mexico, established in January 1943 as Project Y, where the first atomic weapons were designed and fabricated; and
- Sandia Base near Albuquerque, New Mexico, home to the Z Division of Los Alamos Scientific Laboratory since September 1945.

In arranging for the management and operation of these facilities, the AEC follows the government-owned, contractor-operated model developed by the Army's Manhattan Engineer District during World War II. Contracts are established with the University of California for management of the Radiation Laboratory at Berkeley and of Los Alamos Scientific Laboratory, including Sandia Base; with the University of Chicago for management of ANL; and with Iowa State College for management of the Ames Project. At the Hanford Works, the General Electric Company retains its position as general site contractor. At Clinton Laboratories, contract negotiations with the Monsanto Chemical Company are unsuccessful, and the AEC assumes direct responsibility for management and operations until a new contractor can be identified.

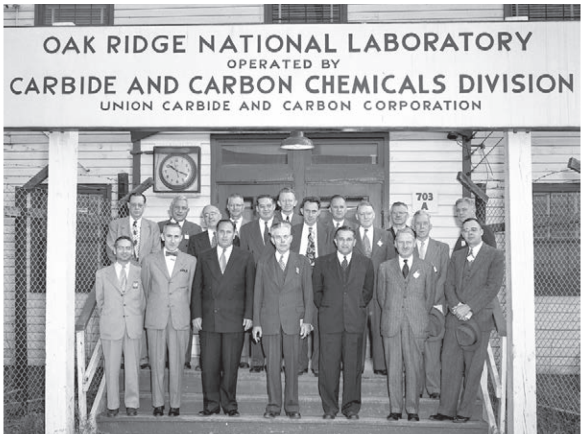


January 31, 1947

BNL is established at Camp Upton, a surplus Army base on New York's Long Island. The new Laboratory fulfills a request made to General Leslie R. Groves in 1946 for the Manhattan Project to establish a nuclear Laboratory, including a research reactor, near New York City. It is managed and operated for the AEC by Associated Universities, Inc., a consortium of nine regional universities.

May 17, 1947

The Ames Project becomes Ames Laboratory, managed and operated for the AEC by the Iowa State College Institute for Atomic Research.

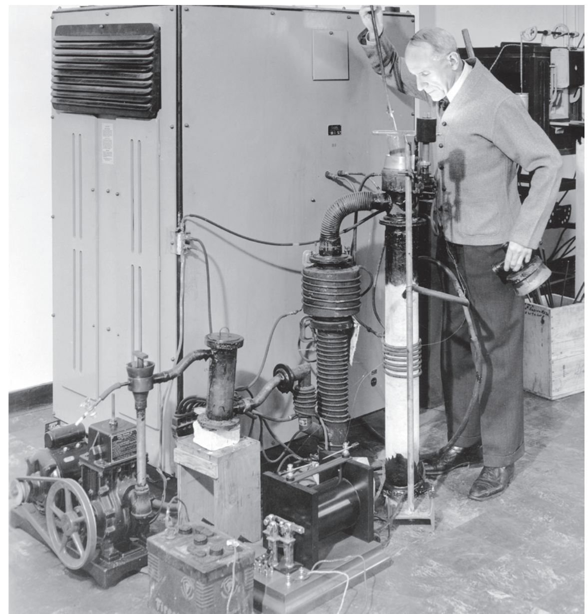


March 4, 1948

Clinton Laboratories becomes Oak Ridge National Laboratory, managed and operated for the AEC by the Carbide and Carbon Chemicals Corporation (later Union Carbide Corporation). Union Carbide Research Committee members are pictured here with ORNL staff including Alvin Weinberg (front row, left), director of research and future ORNL Lab director, and Laboratory Director C.E. Larson (front row, third from left).

April 1, 1948

Los Alamos Scientific Laboratory's Z Division, which performs ordnance engineering and assembly aspects of the Laboratory's nuclear weapons design work, is redesignated Sandia Laboratory. Shortly thereafter, the University of California formally requests release from its management responsibilities for Sandia.



1948

Famed metallurgist Dr. William Kroll spearheads the development of zirconium casting in the 1940s at the Northwest Electrodevelopment Laboratory in Albany, Oregon. Zirconium proved to be the key for nuclear power applications. In 2005, the Albany laboratory, by then known as DOE's Albany Research Center, joined National Energy Technology Laboratory.

1948

Dwight D. Eisenhower (center, seventh from left) visits the construction site of the Brookhaven Graphite Research Reactor in 1948. At this time, Eisenhower is president of Columbia University.

April 4, 1949

The National Reactor Testing Station is established near Idaho Falls, Idaho. To support its reactor development program, ANL establishes an Idaho Division, which will later occupy a portion of the 890-square-mile site designated "Argonne National Laboratory–West."

May 13, 1949

President Truman writes to Leroy Wilson, president of the American Telephone and Telegraph Company (AT&T), to inform him that the AEC intends to ask the Bell Telephone Laboratories to "accept under contract the direction of the Sandia Laboratory at Albuquerque, New Mexico."

October 1949

The first successful solvent extraction process for the recovery of pure plutonium and uranium is developed at ORNL. Designated PUREX (plutonium and uranium recovery by extraction), it becomes the nuclear industry standard for reprocessing of spent nuclear fuel.

November 1, 1949

Sandia Corporation, a wholly owned subsidiary of Western Electric (the manufacturing arm of AT&T), assumes responsibility for the management and operation of Sandia Laboratory.

The 1950s:

The Cold War

The Atomic Age dawned with two superpowers and unprecedented military capabilities that required extraordinary care, diplomacy, and technical expertise. National Labs supported the development of the U.S. nuclear arsenal while exploring new fields of science accessible thanks to Lab research.

January 31, 1950

Following the detonation of an atomic weapon by the Soviet Union and the establishment of the Peoples' Republic of China, President Truman directs the AEC to continue and intensify research on thermonuclear weapons.

July 1, 1951

The AEC awards a contract to Princeton University for nuclear fusion research, under the code name Project Matterhorn. Princeton astrophysicist Lyman Spitzer (pictured here), founder and first director of the Princeton Plasma Physics Laboratory, originally named it "Project Matterhorn" because the work at hand was arduous, like climbing a mountain.

December 20, 1951

The Experimental Breeder Reactor (EBR-1) at Argonne National Laboratory–West proves the feasibility of electricity production and nuclear fuel breeding. Pictured here are those present for Argonne's generation of the first useful electricity from nuclear energy, and they wrote their names on the wall beside the generator. From that point until its decommissioning in 1964, the reactor was capable of generating all of the electricity for its building, which it often did.

March 31, 1952

The Materials Test Reactor begins operating at Idaho, providing fuels and materials testing for nuclear power plants.

September 2, 1952

With the approval of the AEC, the University of California Radiation Laboratory establishes a branch in Livermore, California, to assist in the development of thermonuclear weapons.

July 1953

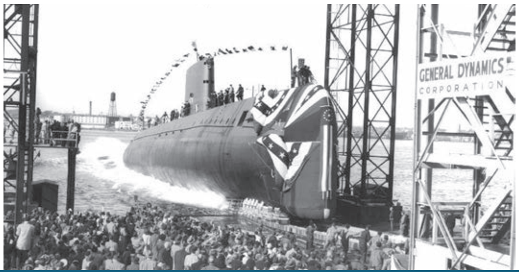
The Savannah River Laboratory begins operations at the AEC's Savannah River Plant near Aiken, South Carolina. Operated by E. I. du Pont de Nemours Company, the Laboratory supports the plant's mission of producing materials for the fabrication of nuclear weapons by providing for "the solution of process improvement and process development problems which may arise in connection with the work."

1953

Lawrence Livermore Laboratory made its entry into the realm of supercomputing with delivery of UNIVAC, which operated until 1959. By then, the Lab had acquired computers capable of 15,000 additions per second. By comparison, today's computers run at quadrillions of operations per second. The last UNIVAC, or Universal Automatic Computer, run was done by Johnnie Daw, seated.

December 1953

Savannah River put its first High-Level Caves into operation in December 1953. The shielded caves allow highly radioactive materials to be handled using master-slave manipulators. The shielded cells have been updated and expanded several times and continue to be used today.



January 21, 1954

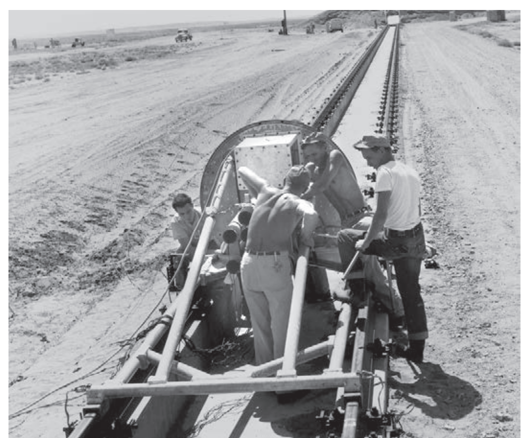
The world's first nuclear-powered submarine, the USS Nautilus, is launched. The ship's pressurized water reactor draws on work performed at ANL, ORNL, the National Reactor Testing Station in Idaho, and two AEC laboratories focused solely on naval nuclear power: Bettis Atomic Power Laboratory and Knolls Atomic Power Laboratory.

August 30, 1954

The Atomic Energy Act of 1954 becomes law, broadening opportunities for private enterprise to engage in the development of atomic power, with the assistance of the National Laboratories. The Act also authorizes the AEC to conduct research on the biological effects of ionizing radiation and permits the Laboratories to perform work for other clients if the activities are "appropriate to the development of atomic energy." This program of reimbursable work for non-AEC sponsors will become known as the Work for Others (WFO) program.

July 17, 1955

Arco, Idaho, becomes the first city in the world entirely powered by nuclear-generated electricity.



March 8, 1956

With the establishment of a second Sandia site in Livermore, California, to provide engineering support to the Livermore branch of the University of California Radiation Laboratory, Sandia Laboratories comes into existence. Pictured here, at Sandia's new sled track, preparations are made for a rocket-propelled sled impact test. The personnel from left to right are Walter Drake, Donald McCoy, Fred Brown and Sid Cook.

May 26, 1958

President Eisenhower officially opens the Shippingport Atomic Power Station. The first commercial nuclear power plant, it was jointly operated by the AEC and Duquesne Light Company.

August 1958

The Materials Test Reactor at Idaho is the first reactor to operate using plutonium-239 as fuel at power levels up to 30 megawatts thermal.

1958

The Brookhaven National Lab Visitor's Day exhibit of the "Tennis for Two" game, which is recognized by many as the world's first true video game. The simulated game was played on a converted oscilloscope.

October 1958–July 1959

Operation of two prototype nuclear reactors, A1W-A and A1W-B, at the Nuclear Reactor Testing Station proves the feasibility of a nuclear propulsion system for U.S. Navy aircraft carriers.

November 7, 1958

Following the death of Ernest O. Lawrence, the regents of the University of California change the name of the University of California Radiation Laboratory to the Lawrence Radiation Laboratory. The new name applies to both the Berkeley and Livermore locations.

1959

Senator John F. Kennedy (D-Mass.), visits ORNL. Pictured left to right: DOE Oak Ridge Office Manager Sam Sapirie, Jackie Kennedy, Senator Kennedy, ORNL Director Alvin Weinberg, and Senator Al Gore, Sr. (D-Tenn.)

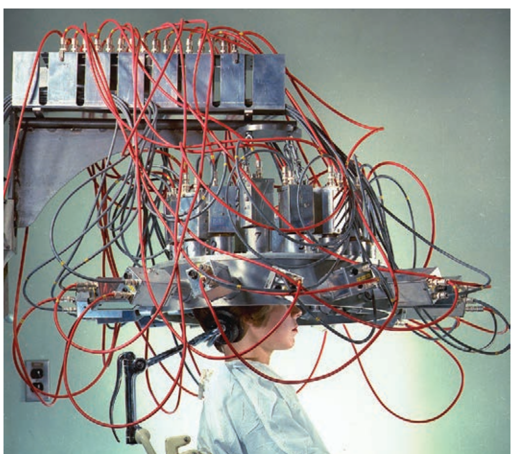
The 1960s:

Expanding research

As nuclear science and technology matured, the National Laboratories played a key role in deployment of power reactors and application of scientific capabilities to new areas.

July 29, 1960

The Alternating Gradient Synchrotron (AGS) at BNL becomes the world's premiere accelerator when it reaches its design energy of 33 billion electron volts. Home to three Nobel Prizes in particle physics, today the AGS receives protons and other ions from the AGS Booster, accelerates them to near-light speeds and delivers them to the Relativistic Heavy Ion Collider for studies of matter as it existed milliseconds after the Big Bang.



1961

Chemists at BNL study how to detect small brain tumors by analyzing the decay of radioactive material injected into the patient's bloodstream and preferentially absorbed by the tumor. To help them, BNL's Instrumentation Division builds different arrays of detectors, and this circular type proves best. In the 1970s, BNL helps reconstruct the raw data received by the detectors into an image of the working brain. This breakthrough ultimately leads to more practical devices for imaging areas of the brain: today's positron emission tomography (PET) machines.

February 12, 1960

In response to a request from the Joint Committee on Atomic Energy, the AEC conducts an assessment of the future role of the National Laboratories. The AEC's report to the Committee notes that "the strong capabilities of the Laboratories are not the exclusive resources of the atomic energy field; they are held in trust for the Nation as a whole. Urgent work for other Federal agencies on matters of national concern will be accommodated in the Laboratories when their skills are needed."

February 1, 1961

Project Matterhorn becomes Princeton Plasma Physics Laboratory.

"…the strong capabilities of the Laboratories are not the exclusive resources of the atomic energy field; they are held in trust for the Nation as a whole. Urgent work for other Federal agencies on matters of national concern will be accommodated in the laboratories when their skills are needed."

1961

Edward Teller (right), who had served as director of Lawrence Livermore Laboratory from 1958 to 1960, was a strong advocate of the Plowshare Program, which explored using nuclear explosives for construction purposes. He tours the preparations for the Gnome test in New Mexico with Gary Higgins in 1961.

1963

The National Reactor Testing Station begins solidification of liquid high-level waste (HLW) from reprocessing.

IT'S BATTELLE!

- To Operate Laboratories At Hanford

Offer Described As Outstanding; Objectives Met

Tri-City Growth Seen

Chance Seen

January 4, 1965

The research laboratories at the Hanford Site are administratively separated from Hanford operations and reorganized as Pacific Northwest Laboratory, with a mission focus on nuclear technology and the environmental and health effects of radiation. Battelle Memorial Institute (Battelle), the contractor selected to manage and operate the Laboratory, negotiates a unique "use permit" with the AEC that allows it to contract directly with third parties for the use of the Laboratory's personnel and government-owned facilities and equipment. This arrangement is designed to stimulate economic diversity and private investment in the local community.

April 30, 1962

The AEC awards a contract to Stanford University for the construction and operation of the Stanford Linear Accelerator Center as a national facility for subatomic research. Pictured are Stanford University Trustees Morris M. Doyle and Ira Lillick, seated, with (standing, left to right) Stanford University Business Manager Dwight B. Adams, Project Director W.K.H. "Pief" Panofsky, and Robert Minge Brown, university counsel.

September 18, 1963

The Zero Gradient Synchrotron at ANL accelerates its first proton beam at full energy. The bubble chamber and its superconducting magnet were the largest in the world. In 1970, scientists would observe the first tracks of a neutrino in a hydrogen bubble chamber.

August 26, 1964

The Atomic Energy Act of 1954 is amended to permit industry to own nuclear facilities and materials. As Government support for nuclear-related R&D declines, the National Laboratories begin to diversify their programs.

August 25, 1965

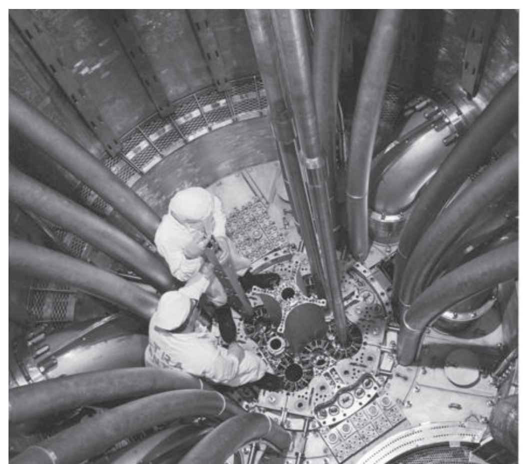
The High Flux Isotope Reactor reaches criticality, beginning operations at ORNL that continue to provide one of the highest steady-state neutron fluxes of any research reactor in the world. Scientists worldwide use the reactor to study physics, chemistry, materials science, engineering, and biology, and to produce isotopes for medical, industrial, and research applications.

May 21, 1966

The SLAC linear accelerator produces its first particle beam. It is the single largest civilian science project ever undertaken by the U.S. government, and to this day the longest linear accelerator ever built. Designed as a discovery machine for particle physics, it enables groundbreaking experiments that advance our understanding of nature's fundamental building blocks and forces. Today it continues to drive research programs in accelerator development and x-ray science.

November 1, 1966

A new M&O contract for ANL is signed by the AEC, the University of Chicago, and Argonne Universities Association, a consortium of 26 Midwestern universities incorporated in July 1965.



July 1967

The Advanced Test Reactor, the largest and most versatile research reactor in the world, begins operation at the Idaho National Engineering Laboratory. Rated at 250 megawatts, ATR also has one of the highest neutron flux levels in the world. Its unique cloverleaf-shaped core provided an unmatched irradiation capability and flexibility for supporting development of nuclear fuels and structural materials, as well as supporting the U.S. Navy and many industrial customers in the U.S. and around the world.

September 9, 1967

The Stanford Linear Accelerator Center is officially dedicated. Pictured left to right are Glenn Seaborg (Director, Atomic Energy Commission—predecessor agency to the present-day DOE), Pief Panofsky (SLAC Director), J. E. Wallace Sterling (Stanford University President), Don Horning (U.S. Presidential Science Advisor) and Edward L. Ginzton (former Professor of Applied Physics, Stanford University, and the Director of Project M). Prof. Ginzton (1955-1998) stepped down as Director in 1961—the same year that the project was officially named The Stanford Linear Accelerator Center.

1967

The Savannah River Laboratory conducted experiments to problem-solve and improve operations throughout the site. The first successful tubular assembly for tritium production was one of the Lab's advancements in the area of fuel and target manufacturing that led to further improvements in later years.

November 21, 1967

President Lyndon B. Johnson signs legislation authorizing the construction of the National Accelerator Laboratory in Weston, Illinois.

December 14, 1967

The Atomic Energy Act of 1954 is amended to authorize the AEC Laboratories to conduct research for other clients relating not only to the development of atomic energy but also to the protection of public health and safety. Shortly thereafter, the AEC asks its Laboratories to consider the areas of environmental research to which they might contribute.

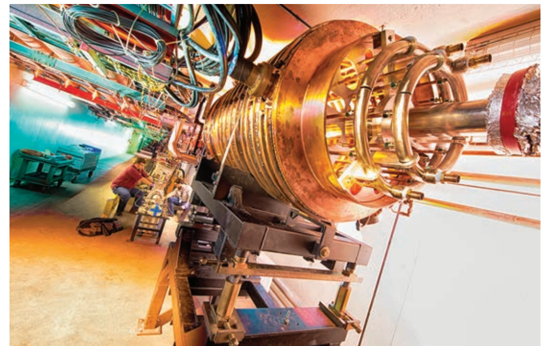
1969

The Vela series of satellites, which spanned 1963-1984, carried Los Alamos-designed-and-built sensors for detecting x-rays, gamma rays, neutrons, and the natural background of radiation in space. They functioned as "watchdogs" for possible clandestine nuclear testing and more.

The 1970s:

Meeting the energy crisis

Americans began to experience the effects of energy shortages firsthand, and National Laboratories—now part of the newly formed DOE—pursued a growing portfolio of technologies to meet national energy needs.



November 30, 1970

The linear accelerator (LINAC) at Batavia, Illinois, sends a 200 MeV proton beam through its nine cavities for the first time. The LINAC is the starting point of today's Fermilab complex, which has been used to discover three elementary particles (the top quark, the bottom quark and the tau neutrino). The Laboratory's flagship accelerator, the Main Injector (pictured), will soon be used to send neutrinos to the Deep Underground Neutrino Experiment, the largest experiment of its kind to be built in the United States.

June 1971

The Berkeley location of the Lawrence Radiation Laboratory is renamed the Ernest O. Lawrence Berkeley Laboratory. The Livermore location is administratively separated from Lawrence Berkeley Laboratory and becomes the Ernest O. Lawrence Livermore Laboratory. Both Laboratories continue to be managed and operated by the University of California.

July 23, 1971

A Federal court, in a decision on a planned nuclear power plant at Calvert Cliffs, Maryland, orders revisions to AEC environmental impact statements as an essential part of reactor licensing procedures. For assistance in completing 92 environmental impact statements by 1972, the AEC turns to three of its National Laboratories: ANL, ORNL, and PNNL.

August 11, 1971

The Atomic Energy Act is amended to authorize the AEC Laboratories to conduct research for other clients "relating to the development of energy." The Laboratories expand their R&D programs to tackle challenges in areas such as superconducting power transmission systems, energy storage, solar energy, geothermal resources, and coal gasification.

May 11, 1974

At a formal dedication ceremony, the National Accelerator Laboratory becomes Fermi National Accelerator Laboratory. It is managed and operated for the AEC by the Universities Research Association. Among those in attendance are eminent physicist Leon Lederman, Illinois Senator Charles Percy, Laura Fermi, and Director Robert Wilson.

July 1974

The Controlled Thermonuclear Research Computer Center provides its first computing cycles at Lawrence Berkeley Laboratory. Today, the renamed National Energy Research Scientific Computing Center (NERSC) is a world leader in accelerating scientific discovery through computation and data analysis. More than 5,000 scientists use NERSC to perform basic research across a wide range of disciplines, including climate modeling, high energy physics, new materials, simulations of the early universe and a host of other scientific endeavors.

August 14, 1974

AEC Commissioner William Anders announces that the National Reactor Testing Station is redesignated the Idaho National Engineering Laboratory (INEL).

1974

Some quantities of californium (Cf) produced at SRS were processed through the Medical Source Facility in the SRL's Isotope Process Development Lab to be used as a cancer treatment. In 1974, plans were being made for the first small plastic tube containing thin seeds of Cf-252 to be implanted into a patient's tumor.

October 11, 1974

The Energy Reorganization Act of 1974 abolishes the AEC and creates three new Federal entities: the Energy Research and Development Administration (ERDA), the NRC, and an Energy Resources Council. It also provides the NRC with special access to the capabilities of the National Laboratories.

December 31, 1974

The Federal Nonnuclear Energy Research and Development Act of 1974 authorizes ERDA to conduct a comprehensive nonnuclear energy research, development, and demonstration program that includes investigations of the environmental and social consequences of energy technologies.

1974

The Solar Energy Research, Development, and Demonstration Act of 1974 authorizes the establishment of a Solar Energy Research Institute, to be located "at any new or existing Federal Laboratory." President Jimmy Carter (center) is welcomed to the Solar Energy Research Institute at NREL on May 3, 1978, by Director Paul Rappaport (left) to inspect panels and address the staff.

1974

The independent discovery of the J/psi particle by Samuel Ting (front) of the Massachusetts Institute of Technology, at BNL's Alternating Gradient Synchrotron, and by Burton Richter, of the Stanford Linear Accelerator, earned its codiscoverers the 1976 Nobel Prize in Physics. Shown with Ting in this photo are members of his experimental team.

January 19, 1975

ERDA officially begins operations, taking on not only the AEC Laboratories, but also five Energy Research Centers previously managed by the U.S. Interior Department's Bureau of Mines. To support ERDA's broad energy mission, the National Laboratories seek and secure new programs in nonnuclear R&D.

1976

The M&O contract for the Idaho National Engineering Laboratory is awarded to EG&G Idaho, Inc.

July 1977

The Solar Energy Research Institute—predecessor to NREL—begins operations in Golden, Colorado. It is managed and operated for ERDA by Midwest Research Institute.

August 4, 1977

The Department of Energy Organization Act becomes law, consolidating more than 30 energy functions previously carried out by ERDA and other Government agencies within the U.S. DOE. Shortly thereafter, legislation is passed to dissolve the Joint Committee on Atomic Energy and transfer its functions to other Congressional committees.

October 1, 1977

DOE is officially activated. The new agency's responsibilities include the National Laboratories and the ERDA Energy Research Centers, which become DOE Energy Technology Centers (ETCs). Staff at these GOGO facilities continue to be Federal employees.

1978

The Energy Research Advisory Board, a standing committee to advise the Secretary of Energy, is formed.

March 28, 1979

The National Atmospheric Release Advisory Center (NARAC) at Lawrence Livermore Laboratory provides support and resources for emergency planning and response to the nuclear accident at Three Mile Island. NARAC predicts and maps the atmospheric release of hazardous materials, whether nuclear, radiological, chemical, biological or natural, to provide real time assessment accurate and emergency response.

1979

BNL's Joanna Fowler is shown with an early ^{18}FDG (radiolabeled fluorodeoxyglucose) synthesis apparatus in 1979. ^{18}FDG, used to measure glucose metabolism in the living human brain, is now the standard radiotracer used for positron emission tomography (PET) neuroimaging and cancer diagnosis, with more than 1.5 million ^{18}FDG PET scans performed annually.

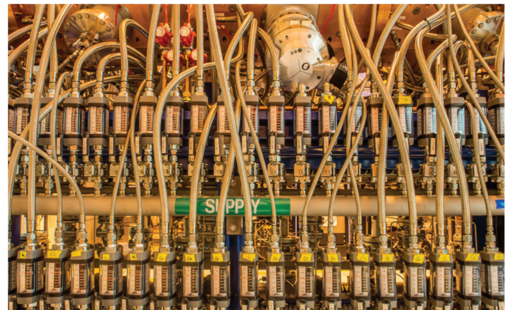
December 29, 1979

The Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980 redesignates Los Alamos Scientific Laboratory as Los Alamos National Laboratory; Lawrence Livermore Laboratory as Lawrence Livermore National Laboratory; and Sandia Laboratories as Sandia National Laboratories.

The 1980s:

Taking tech to market

Interest grew in applying Lab science to fields ranging from medicine to industry, and efforts to move discoveries into the private sector accelerated.



June 26, 1980

The Argonne Tandem Linear Accelerator System (ATLAS) becomes the world's first superconducting accelerator for projectiles heavier than the electron. ATLAS has hosted thousands of scientists from around the world to study the properties of the nucleus, the core of matter, and the fuel of stars.

October 21, 1980

The Stevenson-Wydler Technology Innovation Act of 1980 requires Federal Laboratories, including DOE's National Laboratories, to actively participate in and budget for technology transfer activities.

December 11, 1980

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) becomes law. Many of DOE's older National Laboratories are subsequently declared Superfund sites.

August 12, 1981

First beam is circulated around the vacuum ultraviolet ring at BNL's National Synchrotron Light Source (NSLS). More than 19,000 users have conducted experiments using its beams of x-ray, ultraviolet, and infrared light, leading to many discoveries and two Nobel Prizes.

October 1, 1981

The Materials Preparation Center (MPC) opens its doors to researchers worldwide, providing research quantities of the highest purity rare-earth and other bulk and single-crystalline materials, as well as access to fabrication capabilities and scientific knowledge at Ames.

1981–82

The Raft River geothermal pilot power plant developed and operated by the Idaho National Engineering Laboratory demonstrates the feasibility of binary-cycle geothermal electricity production.

May 1983

The White House Science Council's Federal Laboratory Review Panel, chaired by David Packard, releases a report calling for clearly defined missions and greater autonomy for the DOE National Laboratories.

1983

Meteorological monitoring was developed by Savannah River's Environmental Technology section. While SRS had conducted meteorological research since the site's construction had begun, a more formal program began as new environmental laws were passed in the 1970s. Local observation towers, such as the WJBF-TV tower that had meteorological instruments installed in 1965, were used to collect data. The first tower on site was built in 1985.

August 3, 1984

DOE provides initial funding for research, development, and design of the CEBAF at Newport News, Virginia.

February 15, 1985

NREL dedicates its Field Test Laboratory Building as a national resource of innovative solar energy design and energy conservation practices, touting it as a nonpolluting and noiseless research facility for significant renewable energy advances that would lessen U.S. dependence on foreign oil.

1983

FNAL employees celebrate the record beam energy of 512 GeV produced at the newly operational Tevatron.

April 1, 1984

Martin Marietta Energy Systems, a subsidiary of Martin Marietta Corporation, assumes responsibility for management and operation of ORNL. Its contract with DOE contains provisions aimed at accelerating technology transfer.

1984

Advanced battery technology developed at INEL is used in a cooperative research project with the U.S. Advanced Battery Consortium.

April 1986

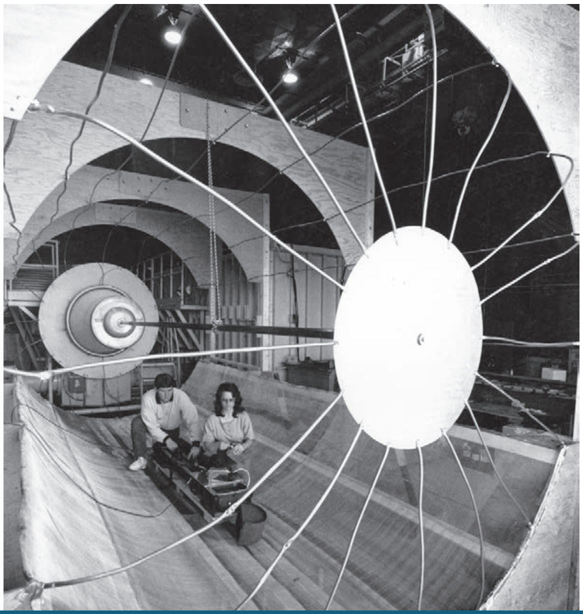
DOE announces a Human Genome Initiative that will capitalize on the resources of the National Laboratories. Shortly thereafter, DOE and the NIH develop a plan for a joint Human Genome Project that officially begins in 1990.

October 7, 1986

Lawrence Berkeley Laboratory creates ESnet to provide high-bandwidth, reliable connections linking scientists at national laboratories, universities and other research institutions, enabling them to collaborate on some of the world's most important scientific challenges including energy, climate science, and the origins of the universe.

1988

Savannah River's free-walking "robotic insect," Robin, was one of the most advanced robots of its time, used primarily for emergency response and maintenance. Each of six legs had its own computer, but most significant was its telescoping, jointed arm. NASA borrowed it in the early 1990s and Robin returned to the site in 1994.



1989

As of June 1, Sandia's Lightning Simulation Facility had delivered 2,845 "zaps" during a seven-year period. The facility, used for testing lightning effects on weapon electronics, began operation in 1981.

July 25, 1989

The Center for Accelerator Mass Spectrometry at LLNL develops and applies ultra-sensitive isotope-ratio measurement and ion-beam analytical techniques to advance the frontiers of knowledge in forensics, biology, environment science, and public health. CAMS is one of the most productive spectrometry centers in the world.

1989

The National Competitiveness Technology Transfer Act allows National Laboratories to enter into CRADAs with nongovernmental entities, including private customers.

The 1990s:

After the Cold War

The end of the Cold War brought a moratorium on nuclear weapons testing and a reexamination of the National Laboratory System. The Labs strengthened their management, infrastructure, and expertise for U.S. economic competitiveness and national security.

1990

The Secretary of Energy Advisory Board is established to provide advice, information, and recommendations to the Secretary on the Department's basic and applied research activities, economic and national security policy, educational issues, and Laboratory management. SEAB replaces the Energy Research Advisory Board.

September 16, 1991

President George H. W. Bush (right) announces the designation of the Solar Energy Research Institute as DOE's National Renewable Energy Laboratory in the presence of Deputy Secretary W. Henson Moore.

December 8, 1991

With the dissolution of the Soviet Union, the Cold War comes to an end, calling into question the purposes and potential of the DOE National Laboratories.

December 11, 1991

The first Internet server outside of Europe is installed at SLAC, which hosts the first websites in North America. The websites are among the oldest original content available on the Web. These first websites, which are merely a collection of a few links, may not have looked like much but they marked the beginning of today's user-friendly and indispensable Internet. The links include a phone book with e-mail addresses, databases and a web interface to SPIRES-HEP, already a very popular database among high energy physicists. Physicists were thrilled with the improved and instantaneous access to SPIRES-HEP provided by SLAC's new web interface.

May 13, 1992

First measurements are gathered at the ARM Climate Research Facility Southern Great Plains site near Lamont, Oklahoma. Pacific Northwest Laboratory has expanded and adapted ARM to meet the observation needs of the climate research community. These measurements and associated data resources support the study of clouds and aerosols, their interaction with the earth's energy balance, and representation in climate models. Today, the ARM Facility includes over 350 instruments at locales around the world.

October 2, 1992

President George H.W. Bush declares a moratorium on nuclear testing. The last U.S. nuclear weapons test occurs at the Nevada Test Site (pictured) on September 23, 1992.

October 22, 1993

Berkeley Lab dedicates the Advanced Light Source (ALS), an electron accelerator/storage ring that serves as one of the world's premier sources of x-ray and ultraviolet light for scientific research ranging from advanced materials to protein crystallography and 3D biological imaging. As a DOE national user facility, the resources of the ALS are available to qualified users around the world, attracting more than 2,000 researchers and students annually.

February 1994

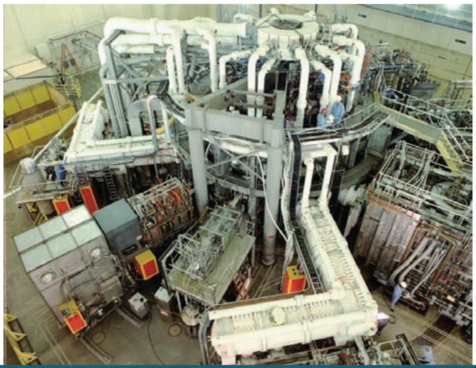
Secretary of Energy Hazel O'Leary charters a Task Force on Alternative Futures for the Department of Energy National Laboratories. Chaired by Robert Galvin of Motorola Corporation, the task force is informally known as the Galvin Commission.

July 7, 1993

Following a decision by AT&T to withdraw from its contract to manage and operate SNL, DOE awards the M&O contract to Sandia Corporation, a wholly owned subsidiary of Martin Marietta Corporation (now Lockheed Martin Corporation).

1994

A new, 35–stage version of the Sandia coilgun is checked by Roque Feliciano, Jr., of Electromagnetic Propulsion and Beams Applications. Coilgun technology had a variety of potential military and commercial uses.



February 11, 1994

The Tokamak Fusion Test Reactor, the first fusion facility to run on a high-powered mixture of deuterium and tritium, produced a world-record 10.7 million watts of fusion power. The achievement at PPPL laid the foundation for use of the fuel in all future tokamaks.

May 5, 1994

President Bill Clinton asks the National Science and Technology Council (NSTC) to conduct an interagency review of the DOE, DOD, and NASA Federal Laboratories. The NSTC submits its final report on May 15, 1995.

July 1, 1994

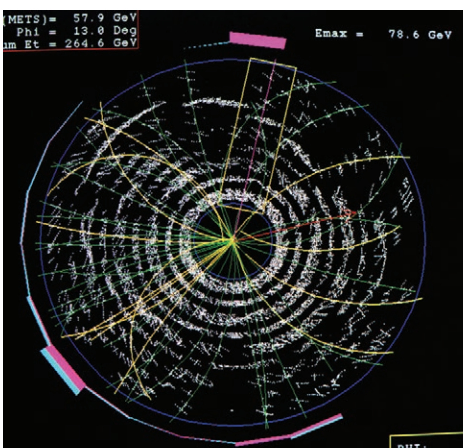
The Continuous Electron Beam Accelerator Facility accelerator delivers first beam to an experimental hall at TJNAF, marking the beginning of operations of the first large installation of superconducting radiofrequency technology. More than 1,500 scientists worldwide use CEBAF in precision studies of the structure and dynamics of the protons and neutrons that comprise the mass of the visible universe.

October 1994

Lockheed Martin Idaho Technologies assumes responsibility for managing and operating the Idaho National Engineering Laboratory.

October 25, 1994

The National Wind Technology Center is dedicated at NREL. It would expand its research capabilities with a blade test facility and state-of-the-art 2.5 MW dynamometer to stress-test wind-turbine blades and drive trains. The levelized cost of wind energy has declined from 40 cents per kilowatt-hour when the lab was founded to 4 to 7 cents today.



1995

This display shows a top quark event. The top quark is one of the fundamental building blocks of the universe and the heaviest of the six quarks. It was discovered at FNAL in 1995 by scientists on the Collider Detector at Fermilab (CDF) and DZero collaborations.

February 1, 1995

The Galvin Commission issues its report, *Alternative Futures for the Department of Energy National Laboratories*. While acknowledging the key roles played by the National Laboratories in energy, national security, environment, and fundamental science, the Commission calls for a more disciplined focus on missions.

March 26, 1995

The giant synchrotron Advanced Photon Source (APS) produces its first x-rays at ANL. In the years since, the APS's brilliant, high-energy x-rays lit the way to two Nobel Prizes and drugs to treat HIV, Alzheimer's, and cancer, in addition to insights in everything from volcanoes and comet dust to car engines and the inner workings of batteries.

April 1995

Secretary O'Leary establishes a Laboratory Operations Board, made up of DOE management officials and external advisors from the private sector, to review and improve the operations of the National Laboratories.

June 16, 1995

With the approval of DOE and the University of California, Board of Regents, Lawrence Berkeley Laboratory officially becomes Ernest Orlando Lawrence Berkeley National Laboratory.

August 11, 1995

President Clinton (shown here visiting SNL) announces the Science-Based Stockpile Stewardship Program, setting in motion an ambitious effort to improve the science and technology for assessing the Nation's aging nuclear weapons stockpile without relying on nuclear testing. The Accelerated Strategic Computing Initiative is established to provide new capabilities for nuclear weapons simulation and modeling.

September 25, 1995

The White House Office of Science and Technology Policy releases guidance based on the results of the NSTC Federal Laboratory Review. The guidance states that President Clinton has concluded that the DOE, NASA, and DOD Laboratory Systems provide essential services to the Nation in fundamental science, national security, environmental protection, energy, aerospace, and technologies that contribute to industrial competitiveness; it also sets out guidelines and principles for improving agency management and reducing unnecessary redundancy in these systems.

October 26, 1995

Dr. Martha Krebs, director of DOE's Office of Energy Research, announces that Pacific Northwest Laboratory will now be officially known as Pacific Northwest National Laboratory.

May 24, 1996

U.S. Secretary of Energy Hazel R. O'Leary dedicates the Thomas Jefferson National Accelerator Facility (TJNAF) in Newport News, Virginia, as the world's most advanced nuclear physics research facility. Formerly the Continuous Electron Beam Accelerator Facility (CEBAF), it houses a unique, superconducting accelerator for studying the fundamental structure of matter. The M&O contractor is Southeastern Universities Research Association.

1997

DOE creates the Joint Genome Institute, uniting expertise and resources in DNA sequencing, informatics, and technology development pioneered at three of its national laboratories: LBNL, LLNL, and LANL. It will later expand to include ORNL and PNNL.

1997

Michael Hannah inspects cables in one of the eight disconnect cabinets that are part of the new Intel teraflops supercomputer in Bldg. 880 at SNL. The disconnect cabinets are used to separate portions of the machine so that classified and unclassified operations can be run at the same time.

July 1996

The Laboratory Operations Board issues the *Strategic Laboratory Missions Plan—Phase 1*, a compilation of information on the structure, funding, and missions of DOE's national laboratories.

December 2, 1996

The Pittsburgh Energy Technology Center and the Morgantown Energy Technology Center merge, becoming the Federal Energy Technology Center, a GOGO facility.

June 11, 1997

SNL announces its ASCI Red architecture has begun operations. The computer is the first worldwide to break one teraflop, or a trillion operations per second. In 2014, in partnership with Cray Inc., SNL developed the Red Storm platform, which grew into a commercial success for Cray and evolved into the Red Sky and Red Mesa supercomputers.

October 1, 1997

EMSL, the Environmental Molecular Sciences Laboratory, opens its doors at PNNL. The user facility leads molecular-level discoveries for DOE and its Office of Biological and Environmental Research with an interdisciplinary and collaborative approach. Scientists from industry, academia and government rely on EMSL capabilities and staff expertise to advance solutions to the nation's most critical energy and environmental challenges.

March 2, 1998

SNL announces that its Z machine, Earth's most powerful pulsed-power facility and x-ray generator, has achieved output of 80 times the entire world's output of electricity. Z compresses energy in time and space to achieve extreme powers and intensities, found nowhere else on Earth.

June 13, 1999

A Special Investigative Panel of the President's Foreign Intelligence Advisory Board releases *Science at its Best, Security at its Worst: A Report on Security Problems of the U.S. Department of Energy*. The report concludes that responsibility for nuclear weapons research and stockpile management should be transferred to a new semiautonomous organization.

1999

By the end of 1999, the U.S. total installed wind capacity had reached 2,500 megawatts. NREL's National Wind Technology Center certification team is pictured.

March 1998

Brookhaven Science Associates, a not-for-profit partnership between the Research Foundation of the State University of New York and Battelle Memorial Institute, assumes responsibility for managing and operating BNL.

October 5, 1999

President Clinton signs legislation establishing the NNSA as a semiautonomous agency within DOE, with responsibility for enhancing national security through the military application of nuclear science.

December 10, 1999

The Federal Energy Technology Center becomes the National Energy Technology Laboratory.

September 30, 1999

Bechtel B&W Idaho, LLC, assumes responsibility for managing and operating Idaho National Engineering and Environmental Laboratory.

The 2000s:

Science and security

The terrorist attacks of September 11, 2001, brought renewed focus on homeland security, and the National Laboratories played an increasing role in support of the military, law enforcement, and foreign entities seeking to secure vulnerable nuclear materials.

National Nuclear Security Administration

March 1, 2000

The NNSA begins operations. Among the National Laboratories and nuclear weapons facilities reporting to the NNSA are LLNL, LANL, SNL, and the Savannah River Technology Center.

April 1, 2000

UT-Battelle, LLC, a partnership of the University of Tennessee and Battelle Memorial Institute, assumes responsibility for managing and operating ORNL.

June 12, 2000

Scientists detect the first head-on collisions between gold nuclei in the RHIC, a world-class particle accelerator for nuclear physics research at BNL where scientists are exploring the most fundamental forces and properties of matter and the early universe, including quark-gluon plasma and the spin of the proton. Among RHIC's many discoveries is the surprising fact that instead of behaving like a gas as was expected, the early-universe matter created in RHIC's energetic gold-gold collisions appears to behave more like a "perfect" liquid, flowing with zero viscosity.

November 25, 2002

In July 2002, President George W. Bush visits ANL and is briefed on counterterrorism technologies developed by several DOE National Laboratories. On November 25, 2002, President Bush signs the Homeland Security Act of 2002, which gives the U.S. Department of Homeland Security special access to DOE's National Laboratories.

April 30, 2003

Secretary of Energy Spencer Abraham announces that DOE's Idaho Site will become the premier national nuclear energy laboratory. Sponsorship of the site is transferred from DOE's EM to NE.

June 24, 2003

The Senate Committee on Energy and Natural Resources begins a series of hearings on DOE's management of the National Laboratories.

July 23, 2003

The Blue Ribbon Commission on the Use of Competitive Procedures at Department of Energy Laboratories is established to provide the Secretary of Energy with advice and recommendations about issues related to renewing and extending the M&O contracts for DOE's National Laboratories. In its report, issued on November 24, 2003, the Commission recommends that DOE institute a competitive bidding schedule for all of its National Laboratories.

December 3, 2003

The 21st Century Nanotechnology Research and Development Act becomes law. The act authorizes nearly $2 billion in funding for nanotechnology R&D as part of the National Nanotechnology Initiative, including the construction of nanoscale science research centers at six DOE National Laboratories: ANL LBNL, ORNL, LANL, and SNL. Pictured here is the Molecular Foundry at Berkeley, a nanoscale science research center.

2004

The Accelerated Strategic Computing Initiative becomes the Advanced Simulation and Computing (ASC) Program, administered by the NNSA.

January 27, 2004

DOE announces that it will compete the M&O contracts for five National Laboratories: Ames, ANL, LBNL, LLNL, and LANL.

May 7, 2004

The Savannah River Technology Center becomes Savannah River National Laboratory, conducting R&D on waste processing, environmental remediation, nonproliferation technologies, and national security.

August 13, 2004

DOE announces its intent to obtain new M&O contractors for its Idaho Site, supporting two discrete mission objectives: nuclear energy research, development, and demonstration, for DOE's NE, and accelerated environmental cleanup, for DOE's EM.

February 1, 2005

Idaho National Engineering and Environmental Laboratory and Argonne National Laboratory–West are consolidated into Idaho National Laboratory, which reports to DOE's NE and is charged with leading and integrating U.S. nuclear energy research, development, demonstration, and deployment efforts. DOE awards the contract for managing and operating the Laboratory to Battelle Energy Alliance, LLC.

April 19, 2005

DOE awards a new five-year contract to the University of California to continue managing and operating LBNL.

August 8, 2005

While visiting SNL in Albuquerque, New Mexico, President George W. Bush signs the Energy Policy Act of 2005, supporting expanded development of nuclear power. The Act also establishes the Next Generation Nuclear Plant Project and designates INL as the project's lead National Laboratory.

October 27, 2005

The Livermore Computing Complex (LCC) at LLNL is the first building constructed expressly to house high performance computer systems. The LCC is home to some of the world's most powerful supercomputers, including Sequoia, Vulcan, BlueGene/L and ASC Purple. The large-scale multi-physics codes and 3D simulations run on these systems allow DOE/NNSA to ensure the safety, security and reliability of the nation's nuclear deterrent without underground testing.

November 27, 2005

The Albany Research Center in Oregon becomes part of the NETL.

2006

SRNL is recognized as EM's "corporate laboratory."

April 17, 2006

SNL dedicates its Compound Semiconductor MicroFab, a third of its MESA (Microsystems & Engineering Sciences Applications) complex. Its Silicon Fab was completed in 1988. MESA is the center of SNL's investment in microsystems research, development and prototyping. The 400,000-square foot complex of cleanrooms, labs and offices is home to design, development, manufacture, integration and qualification of trusted microsystems for national security applications.

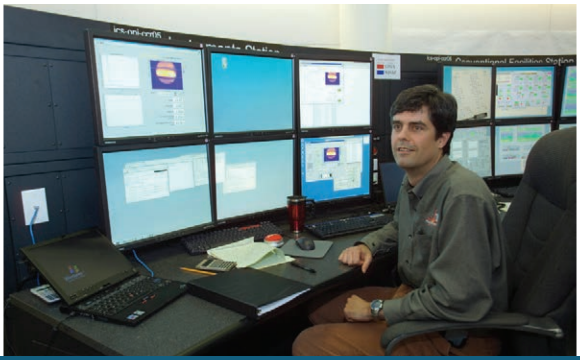
June 1, 2006

Los Alamos National Security, LLC, a for-profit corporation that includes Bechtel National, the University of California, Babcock & Wilcox, and URS, assumes responsibility for managing and operating LANL.

Jefferson Lab

April 17, 2006

Jefferson Science Associates, LLC, a partnership between the Southeastern Universities Research Association, Inc., and CSC Applied Technologies, Inc., assumes responsibility for managing and operating the TJNAF.



April 28, 2006

The Spallation Neutron Source (SNS) at ORNL accelerates its first protons to a mercury target, producing neutrons that have allowed thousands of scientists worldwide to conduct unique experiments across a broad range of disciplines including physics, chemistry, materials science, and biology. SNS provides the most intense pulsed neutron beams in the world to reveal the structure and behavior of materials, for scientific research and industrial development.

August 2006

The Critical Infrastructure Test Range Complex (CITRC) at INL begins replicating the area and infrastructure associated with a city or region to address the potential cascading consequences associated with the compromise of critical infrastructure(s).

November 17, 2006

DOE announces plans to compete the M&O contracts for three National Laboratories: BNL, PPPL, and the Stanford Linear Accelerator Center.

January 1, 2007

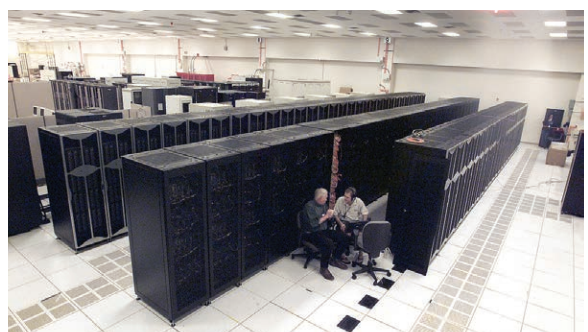
Fermi Research Alliance, LLC, a partnership of the Universities Research Association and the University of Chicago, assumes responsibility for managing and operating FNAL.

January 1, 2007

Iowa State University continues its management and operation of Ames under a new M&O contract with DOE.

October 1, 2007

Lawrence Livermore National Security, LLC, a for-profit corporation that includes Bechtel National, the University of California, BWXT Government Group, Inc., URS, and Battelle Memorial Institute, assumes responsibility for managing and operating LLNL.



2008

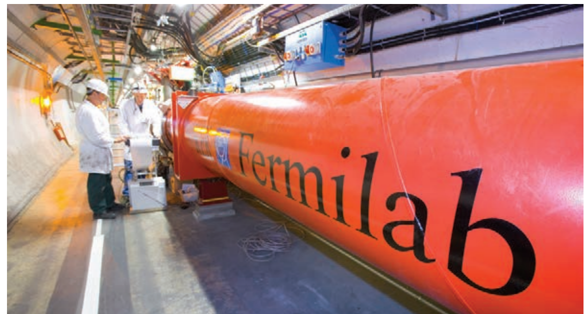
Roadrunner, a hybrid supercomputer housed at LANL, is the first supercomputer to reach the petaflop, a million billion calculations per second.

August 1, 2008

Savannah River Nuclear Solutions, LLC, assumes responsibility for managing and operating SRNL.

October 1, 2008

The Alliance for Sustainable Energy, LLC, a partnership of Midwest Research Institute and Battelle, assumes responsibility for managing and operating NREL.



October 3, 2008

FNAL's Tier 1 computing center becomes part of the world's biggest computing grid, created to manage immense amounts of information from the Large Hadron Collider at CERN. This Tier 1 computing center, founded in 2003, helps process data for the CMS experiment, one of the two experiments that discovered the Higgs boson in 2012. FNAL also designed, developed, manufactured, and tested some of the 19-ton, 13-meter-long superconducting magnets that focus the particle beams at the LHC.

October 15, 2008

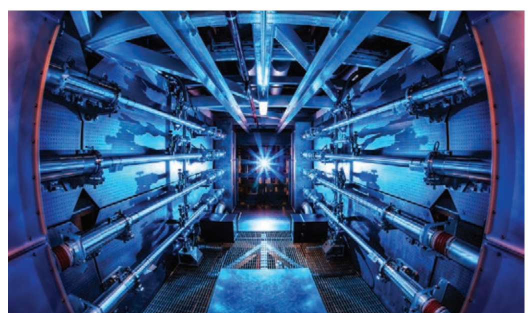
The Stanford Linear Accelerator Center becomes SLAC National Accelerator Laboratory, reflecting the broadening of the Laboratory's focus from high-energy physics to include strong photon science and particle astrophysics programs.

April 1, 2009

Princeton University continues its management and operation of PPPL under a new M&O contract.

April 10, 2009

The brightest source of X-rays on the planet, the Linac Coherent Light Source, lights up at SLAC, surprising even its creators with how quickly it produces its first laser beam. The scientific and technical progress it enables will be no less luminous. Among its major scientific milestones are helping to identify a possible new way to combat African sleeping sickness, proving that LCLS can be used to resolve the structure of delicate membrane proteins that are a key target for many modern medicines, and timing ultrafast on-off electrical switching speeds in materials that could be used in next-generation computers.



May 9, 2009

Dedication and commissioning of the NIF at LLNL opens the door to inertial confinement fusion experiments that yield valuable insight into the safety and security of the nuclear stockpile, fusion energy research, the formation of stars and planets and basic science. NIF is the world's largest and most energetic laser.

The 2010s:

Powerhouses of innovation

The DOE National Labs steward distinctive scientific facilities that attract researchers from around the world and continue building partnerships with industry, Government, and academia that advance technology and U.S. competitiveness.

2010

The DARHT houses two electron accelerators used to study key aspects of nuclear weapons physics with high-quality x-ray images.

November 26, 2011

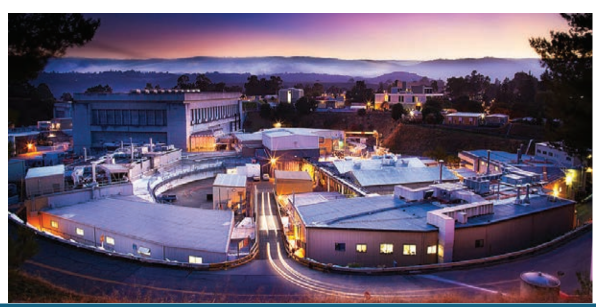
NASA's Curiosity rover launches for Mars with technology from the National Labs. The ChemCam unit from LANL fires a powerful laser to vaporize rocks and then uses its spectrometer to analyze the samples. ORNL developed and fabricated the protective iridium alloy cladding that's central to the generator that powers the rover. Today, ORNL produces plutonium-238 in partnership with LANL and INL to fuel future NASA missions.

December 2011

DOE announces that eight National Laboratories will participate in a pilot program for its ACT mechanism, which is designed to overcome the difficulties of negotiating traditional technology agreements between the National Laboratories and the commercial sector.

September 17, 2012

The Dark Energy Camera, built and tested at FNAL, sees first light. Mounted on a four-meter telescope in Chile, it is one of the most powerful digital imaging devices on the planet, able to see eight billion light years away and capture photos of the distant cosmos in perfect digital quality.



October 1, 2012

Stanford University continues its management and operation of SLAC under a new M&O contract.

October 1, 2012

Battelle's contract to manage and operate PNNL is extended for five years. With new mechanisms such as ACT in place to encourage technology transfer by the National Laboratories, the "use permit" awarded in Battelle's 1965 contract with the AEC is phased out.

October 29, 2012

ORNL introduces Titan, the latest in a series of ORNL supercomputers to rank No. 1 in the world. Its hybrid architecture—which adds GPUs to traditional CPUs—greatly increases its capability with a relatively modest increase in electricity consumption, overcoming power and space limitations inherent in previous generations of high-performance computers. Titan's peak speed is 27 petaflops (a petaflop equals a quadrillion calculations per second). It will be replaced in 2018 by Summit, which is expected to be five to 10 times more powerful.

April 9, 2013

Mira, a 10-petaflops IBM Blue Gene/Q supercomputer, comes online at ANL. Topping the charts for energy efficiency before it was even installed, it is capable of 10 quadrillion calculations per second. Mira provides billions of hours of computing time every year to researchers who simulate supernovas, blood flow, plane design, nuclear reactors, climate models, and much more.

July 10, 2013

Secretary of Energy Ernest Moniz announces the establishment of a National Laboratory Policy Council and the reestablishment of the Laboratory Operations Board. The role of the Policy Council is to advise the Secretary on strategic directions for the Department's science and technology programs and on the Laboratories' critical role in advancing the Department's missions and the Nation's innovation ecosystem. The role of the Laboratory Operations Board is to provide an enterprise-wide forum to engage the National Laboratories in finding opportunities to improve effectiveness and efficiency.

September 11, 2013

Allowing for megawatt-scale testing and modeling of multi-source, highly complex energy systems and technologies, the Energy Systems Integration Facility (ESIF) at NREL features one of the world's fastest, most efficient high-performance supercomputers, known as Peregrine. The ESIF was named by R&D Magazine as the 2014 Laboratory of the Year and is the first facility to conduct integrated research and development of the nation's electrical distribution grid at the 1 megawatt level.

January 17, 2014

The Consolidated Appropriations Act, 2014, establishes the Commission to Review the Effectiveness of the National Energy Laboratories (CRENEL).

June 16, 2014

SEAB creates a standing Task Force on DOE National Laboratories to provide advice, guidance, and recommendations on important issues related to improving the health and management of the Laboratories.

October 26, 2014

FNAL's NOvA experiment comes online at full power, a crucial step for scientists to better understand mysterious particles called neutrinos that are all around us. Neutrinos are poorly understood, but could hold the key to why matter exists in our universe.

December 19, 2014

President Obama signs the 2015 National Defense Authorization Act into law, creating the Manhattan Project National Historical Park. The park includes facilities at three DOE sites: LANL, ORNL, and the Hanford site in Washington state.

January 5, 2015

Brookhaven Science Associates continues its management and operation of BNL under a new M&O contract.

February 11, 2015

Energy Secretary Ernest Moniz announces the launch of OTT to help expand the commercial impact of DOE-sponsored research. The office is charged to work closely with the National Laboratories and engage with industry to commercialize technology and strengthen the global competitiveness of U.S. industries based on scientific and technological innovations.

April 23, 2015

DOE officially changes the name of its WFO program to Strategic Partnership Projects (SPP) to better convey the importance and strategic nature of the work done by the National Laboratories for non-DOE entities, including other Federal agencies, universities, and the private sector.

June 17, 2015

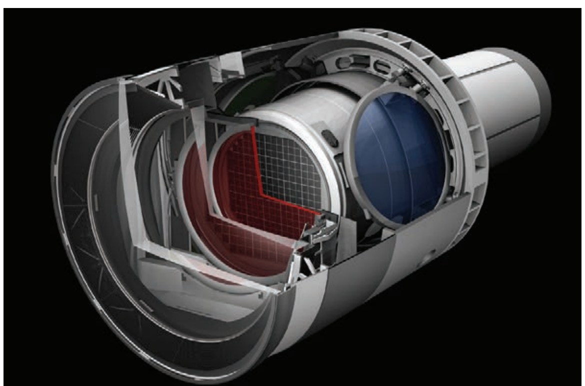
The SEAB Task Force on DOE National Laboratories issues an interim report that proposes improvements in M&O contracts, technology transfer, and the LDRD program.

July 8, 2015

DOE announces a Small Business Vouchers Pilot designed to connect clean energy innovators with the scientists, engineers, and world-class facilities at LBNL, ORNL, PNNL, SNL, and NREL. Pictured are (left to right) Deputy Secretary of Energy Elizabeth Sherwood-Randall, SNL's Dan Koleske, iBeam Materials' Vladimir Matias, SNL Director Jill Hruby, U.S. Rep. Michelle Lujan Grisham (N.M.), and NNSA Principal Deputy Administrator Madelyn Creedon.

August 19, 2015

Ten years after its launch, the state-of-the-art Electricity Infrastructure Operations Center moves to a new location in the state-of-the-art Systems Engineering Building at PNNL. Featuring two 452-square-foot video walls, the facility's control rooms make it possible to design, test and evaluate tools and concepts for the power grid in a setting that mirrors industry conditions.



August 31, 2015

Construction begins at SLAC on the digital camera for the Large Synoptic Survey Telescope. The 3.2-gigapixel digital camera – the world's largest for a ground-based telescope – will take digital images of the entire visible southern sky every few nights from atop a mountain called Cerro Pachón in Chile starting in 2022.

September 22, 2015

The Orpheus test at LANL examines a surrogate material in place of the plutonium typically present in a primary. Orpheus is executed in the U1a facility at DOE's Nevada Nuclear Security Site using an advanced diagnostic suite – including a world-record 192 channels of optical velocimetry, two high quality Cygnus flash x-radiographs, dynamic stereo surface imaging, chirped fiber Bragg gratings, and electrical shorting switches. Contributors include divisions at LANL and SNL, and National Security Technologies.

October 28, 2015

In its final report, CRENEL describes the DOE National Laboratories as "national assets that have contributed profoundly to the Nation's security, scientific leadership, and economic competitiveness," but presents a set of recommendations "intended to ensure that the Laboratories are able to operate as efficiently and effectively as possible so that the Nation realizes the maximum benefit from this national asset in the years ahead."

November 6, 2015

The White House announces that DOE is establishing the Gateway for Accelerated Innovation in Nuclear (GAIN) to provide the nuclear energy community with a single point of access to a wide range of capabilities and facilities, including those located at ten of its national laboratories: ANL, BNL, INL, LANL, LBNL, LLNL, ORNL, PNNL, SNL, and SRNL. Pictured here, workers load an experiment at INL's Advanced Test Reactor.

February 22, 2016

The Department issues its response to the CRENEL report that outlines a set of commitments intended to strengthen the partnership between DOE and the National Laboratories and to improve efficiency and effectiveness.

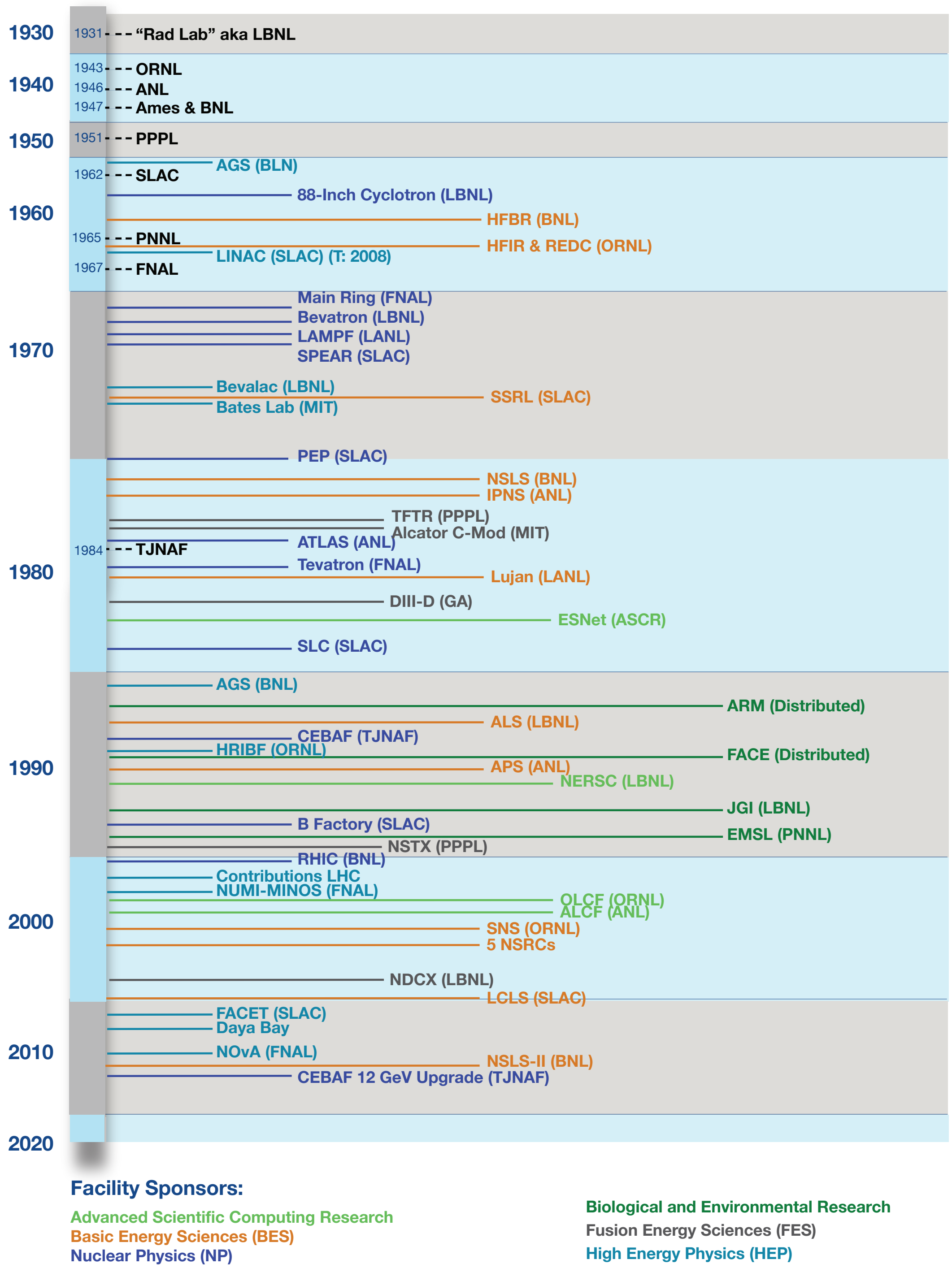
April 13, 2016

The 21 Tesla Ultra-High-Resolution Mass Spectrometer comes online at PNNL, allowing scientists to analyze and separate atoms and molecules according to their size and molecular structure with a clarity and precision well beyond conventional mass spectrometers. The unique instrument enables scientists to address pressing science challenges related to the environment, biology and energy.

November 30, 2016

The International Union of Pure and Applied Chemistry approves the names and symbols for four new elements: nihonium (element 113, Nh), moscovium (115, Mc), tennessine (117, Ts), and oganesson (118, Og). ORNL and LLNL are credited on the discovery team for 115 and 117, and LLNL also is recognized for its role in discovery of 118, just the latest in decades of National Lab contributions to expansion of the periodic table of the elements.

Figure B-1: Office of Science User Facilities by Date the Facility Became Operational



Of the more than 55 scientific user facilities established since 1960, nearly half have been terminated to date (a listing of all acronyms can be found in Appendix E).

Timeline entries and photos are drawn from DOE historical documents available at energy.gov/management/history/historical-resources/history-publications; from resources available at National Laboratory websites; and from legislative documents available at www.congress.gov.

Appendix C

Partnership Agreement Mechanisms

Partnership Agreement Mechanisms

Non-DOE entities can engage in collaborative research efforts and access the unique capabilities housed at the National Laboratories in several ways. Each of the contractual mechanisms is summarized below.

10.1 SPP Agreements

Strategic Partnership Project (SPP) Agreements permit DOE Laboratories to conduct work for other Federal agencies and nonfederal entities on a 100 percent 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. An SPP agreement typically allows the nonfederal customer to own intellectual property and data generated under the SPP agreement, although the government will normally retain a royalty-free license for use of intellectual property or data by or on behalf of the government (i.e., Government Use License).

The U.S. Department of Defense, the U.S. Department of Human Services (including NIH), NASA, and the NRC are typically the largest Federal SPP sponsors.

10.2 Cooperative Research and Development Agreements

A Cooperative Research and Development Agreement (CRADA) is a collaborative, legal agreement that allows the Federal Government, through its Laboratories, and nonfederal partners to optimize their 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. The nonfederal parties must provide funds or in-kind contributions. As is the case with SPP Agreements, a CRADA allows for protection of both intellectual property and data generated under the Agreement.

10.3 Agreement for Commercializing Technology

Agreements for Commercializing Technology (ACT) is a pilot program that enables M&O contractors to act in a private capacity and conduct privately sponsored research at the contractor's risk for third parties. Under an ACT arrangement, typical concerns from an SPP arrangement, such as requirements for advance payments, indemnification, lack of fixed price contracting, and lack of performance guarantees, can be assumed by the contractor who may then contract with a business using terms that are more typically aligned with industry practices. ACT agreements allow more flexible intellectual property arrangements and allow the participants to mark generated data as proprietary and obtain ownership of the data. Unlike SPPs or CRADAs, the Laboratory may charge the participant a fee in excess of its actual costs for ACT activities. By FY 2014 there were 67 active ACT partnerships, which accounted for $29.0 million in direct private sector partner funds-in. The ACT pilot program runs through October 2017.

10.4 User Agreements

User Agreements are specialized, standard agreements to expedite access to DOE user facilities. Each facility manages its allocation of facility resources, typically granting access through merit review of submitted research proposals. Prospective nonproprietary users may propose independent or collaborative research. In most cases, there is no charge for users who are doing nonproprietary work, with the understanding that results will be published in the open literature. Access to user facilities is also available on a full cost recovery basis for proprietary research that is not intended for publication.

10.5 Technology Licensing Agreements

A Technology Licensing Agreement typically provides commercialization rights to patented and/or copyrighted IP developed at DOE's National Laboratories, which is normally held and licensed by the M&O contractor. Because of the unique set of laws and policies governing the licensing of Federally funded research and due to DOE policies regarding intellectual property, technology licensing agreements may include provisions such as march-in-rights, government use rights, and indemnification provisions.

10.6 Technical Assistance Agreements

Technical Assistance Agreements allow for Laboratory scientists and engineers to help members of the small business community solve important challenges with no cost to the small business. Examples of assistance include advising on existing or emerging products, providing advanced technology for hardware and software applications, improving production and manufacturing processes, and recommending energy conservation and environmental technologies.

10.7 Material Transfer Agreements

A Material Transfer Agreement (MTA) protects biological materials and tangible research products provided either 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.

10.8 Small Business Agreements

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) are U.S. Government programs in which DOE can set aside a fraction of their funding to be competitively awarded to small businesses. The small businesses are encouraged to commercialize the technology, and they retain the rights to technology that they develop. The DOE solicits proposals on a set of specified topics annually.

The Small Business Vouchers (SBV) program aims to improve the industry's awareness of and access to National Laboratory capabilities. The SBV concept is based on the successful Technology Assistance Agreements but focused on regional small businesses.

Appendix D

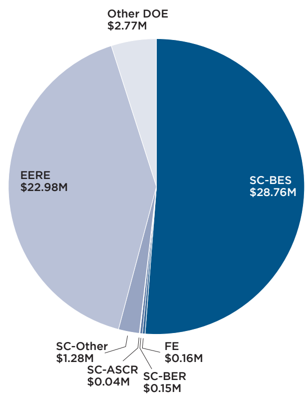
Lab-at-a-Glance Pages & “Accomplishments” Page

Ames Laboratory
At a Glance

U.S. DEPARTMENT OF ENERGY

Ames Laboratory's location on the campus of its contractor, Iowa State University, has instilled a culture of interdisciplinary science and innovation. The Lab tightly couples theory, computation and experiments to design new materials; synthesize and fabricate those materials; and perform characterization and testing at its new Sensitive Instrument Facility with its world-class characterization equipment. Invention of lead-free solder, a hybrid catalyst that more efficiently converts crops to biodiesel, and metamaterials with remarkable optical properties are just a few examples of Ames Laboratory's materials that are impacting our world.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $57M

FY 2015 DOE/NNSA costs: $56.1M

FY 2015 SPP (Non-DOE/ Non-DHS) costs: $0.9M

FY 2015 SPP as % total Lab operating costs: 1.6%

Facts

Location:	Ames, Iowa
Type:	Single-program Laboratory
Year Founded:	1947
Director:	Adam Schwartz
Contractor:	Iowa State University of Science and Technology
Responsible Site Office:	Ames Site Office

Physical Assets

10 acres and 13 buildings
340,968 GSF in buildings
Replacement plant value: $88.6M

Human Capital

309 full-time equivalent employees (FTEs)
73 joint faculty
43 postdoctoral researchers
45 undergraduate students
59 graduate students
84 visiting scientists

Core Capabilities

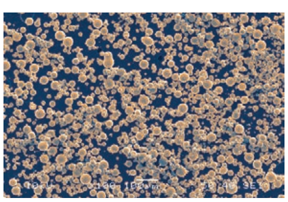
Applied Materials Science and Engineering
Chemical and Molecular Science
Condensed Matter Physics and Materials Science

Mission Unique Facilities

Materials Preparation Center
CaloriCool – Energy Materials Network
Critical Materials Institute – An Energy Innovation Hub
Dynamic Nuclear Polarization NMR Facility
Sensitive Instrument Facility
Powder Synthesis Facility for Additive Manufacturing

Accomplishments

Research Highlight
Powder Synthesis Facility



Ames is a world leader in producing fine, uniform, and high-purity spherical metal powders ideal for high-tech applications in 3D printed parts that are revolutionizing manufacturing. The facility's high-pressure gas atomization units and a unique module for clean melting and superheating produce fine titanium powders with highly sought-after properties of strength, stiffness, and heat and corrosion resistance. Fortune 250 company Praxair purchased the Laboratory's spin-off company, Iowa Powder Atomization Technologies, and offers fine, spherical titanium powder for aerospace, medical, and industrial parts.

Unique Facility
Metamaterials

Imagine a material with no counterpart in nature that could lead to development of a superlens with resolution so powerful researchers could use it to see inside a human cell or observe DNA. Ames' metamaterials research offers this and other potential applications including wireless power transmission. Exotic, artificially created metamaterials provide atypical optical properties such as refraction of light at negative angles, a backward-bending characteristic that lets scientists control light, opening a range of applications such as flat superlenses, superfast optical communication switching, and designer optics.

AMES LABORATORY
Creating Materials & Energy Solutions
U.S. DEPARTMENT OF ENERGY

Argonne National Laboratory
At a Glance

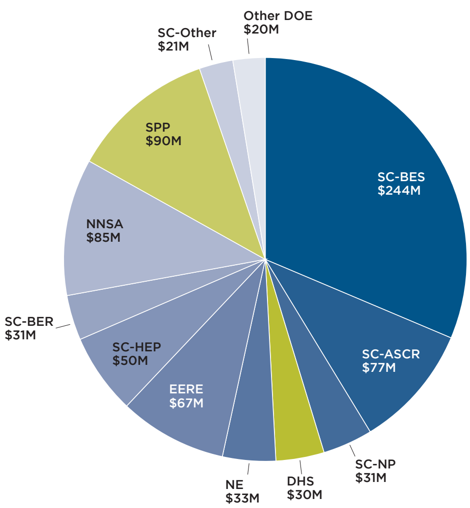
U.S. DEPARTMENT OF ENERGY

ANL is a multidisciplinary science and engineering research center where talented scientific minds work together to answer the biggest questions facing humanity, from how to obtain affordable clean energy to protecting our Nation and our environment.

The Lab's research spans the scientific and engineering spectrum. Experimental, theoretical, and modeling work in materials science, physics, chemistry, biology, mathematics, and supercomputing give us the raw material for new breakthroughs. Applied science and engineering help find practical solutions to society's problems, including transportation, nuclear energy, grid modernization, and battery science.

ANL also designs, builds, and operates scientific user facilities — large national research facilities that would be too expensive for a single company or university to run, such as the Mira supercomputer and the giant X-ray synchrotron Advanced Photon Source. These facilities are relied on by thousands of researchers from universities and industry each year for breakthroughs in fields from construction and aeronautics to batteries and pharmaceuticals.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $734.1M
FY 2015 DOE/NNSA costs: $617.4M
FY 2015 SPP costs (non-DOE/non-DHS): $88.1M
FY 2015 SPP as % total Lab operating costs: 12%
FY 2015 DHS costs: $28.6M

Facts

Location:	DuPage County, Illinois
Type:	Multiprogram Laboratory
Year Founded:	1946
Director:	Paul Kearns (interim)
Contractor:	UChicago Argonne, LLC
Responsible Site Office:	Argonne Site Office

Physical Assets

1,517 acres and 157 buildings
5.0 million GSF in buildings
Replacement plant value: $3.11B
50,779 GSF in 15 excess facilities
339,673 GSF in leased facilities

Human Capital

3,298 full-time equivalent employees (FTEs)
248 joint faculty
315 postdoctoral researchers
250 undergraduate students
207 graduate students
7,186 facility users
1,362 visiting scientists

Core Capabilities

Accelerator Science and Technology
Advanced Computer Science, Visualization, and Data
Applied Materials Science and Engineering
Applied Mathematics
Biological and Bioprocess Engineering
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
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
Center for Nanoscale Materials
Transportation Research and Analysis Computing Center

Argonne NATIONAL LABORATORY

Argonne National Laboratory
Accomplishments

Unique Facility
X-ray facility full of discoveries

The Advanced Photon Source (APS) serves as the Nation's highest energy synchrotron light source and is used for studies in nearly every scientific discipline. It houses several unique beamlines and the Nation's premier consortium for high pressure studies. More than 5,500 researchers use the APS annually, making it the most frequented DOE user facility. The winners of the 2009 and 2012 Nobel Prizes in Chemistry used the APS for their research. Numerous drug discoveries and products have grown from work at the APS, including the 2016-approved leukemia drug Venclexta developed by AbbVie and Genetech. Plans for an upgrade of the APS in the early part of the next decade will make the APS four hundred times brighter and vastly expand the available research opportunities.

Research Highlight
Nanoscrolls could revolutionize lubrication

Friction and wear cost the national economy millions annually in lost energy efficiency, the need for replacement parts, and disposal of petroleum-based lubricants. For example, approximately 30 percent of a vehicle engine's power is sacrificed to frictional loss, and wear is a consistent destroyer of engines and other parts. ANL researchers found a novel way to combine diamond nanoparticles and graphene to create "superlubricity" where friction drops to near zero. Any application that involves lubricants or ball bearings has the potential to be revolutionized by graphene nanoscrolls, including automobiles, turbines, and energy production.

Technology to Market Highlight
ANL materials help power Chevy Volt

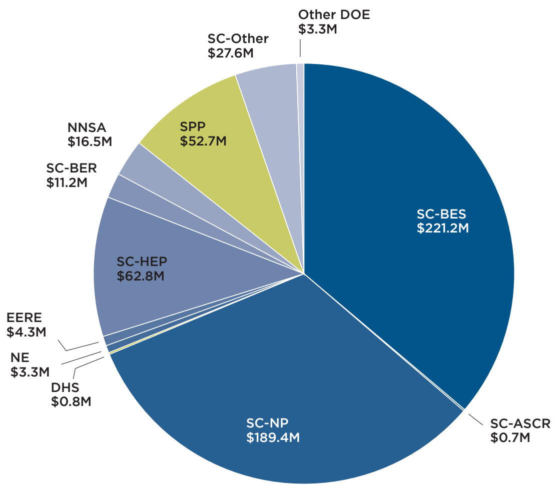
The battery that helps power GM's plug-in hybrid Chevy Volt is based in part on a chemistry breakthrough at ANL Scientists used the Advanced Photon Source, above, as part of their toolkit to better understand the reactions that happen inside a battery in real time. Then they created new materials that were licensed and now help the Volt's battery—a lithium-ion battery similar to those in a cell phone or laptop—last longer, run more safely, cost less, and perform better than previous batteries.

Brookhaven National Laboratory
At a Glance

U.S. DEPARTMENT OF ENERGY

BNL brings world-class facilities and expertise to advance fundamental research in nuclear and particle physics to gain a deeper understanding of matter, energy, space, and time; apply photon sciences and nanomaterials research to energy challenges of critical importance to the Nation; and perform cross-disciplinary research on climate change, sustainable energy, computation, and earth's ecosystems. The Lab's 2,750 scientists, engineers, and support staff are joined each year by thousands of visiting researchers who use the large-scale scientific facilities. BNL is operated and managed by Brookhaven Science Associates, founded by the Research Foundation for the State University of New York on behalf of Stony Brook University, and Battelle, a nonprofit applied science and technology organization.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $584M
FY 2015 DOE/NNSA costs: $530M
FY 2015 SPP costs (non-DOE/non-DHS): $53M
FY 2015 SPP as % total Lab operating costs: 9%
FY 2015 DHS costs: $0.8M

Facts

Location:	Upton, New York
Type:	Multiprogram Laboratory
Year Founded:	1947
Director:	Doon Gibbs
Contractor:	Brookhaven Science Associates
Responsible Site Office:	Brookhaven Site Office

Physical Assets

5,322 acres and 312 buildings
4.84M GSF in buildings
Replacement plant value: $2.31B
57,520 GSF in 11 excess facilities

Human Capital

2,671 full-time equivalent employees (FTEs)
24 joint faculty
133 postdoctoral researchers
256 undergraduate students
150 graduate students
2,041 facility users
2,147 visiting scientists

Core Capabilities

Accelerator Science and Technology
Advanced Computer Science, Visualization, and Data
Applied Materials Science and Engineering
Biological Systems Science
Chemical Engineering
Chemical and Molecular Science
Climate Change Science and Atmospheric Science
Condensed Matter Physics and Materials Science
Large Scale User Facilities/Advanced Instrumentation
Nuclear Physics
Nuclear and Radio Chemistry
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

BROOKHAVEN NATIONAL LABORATORY

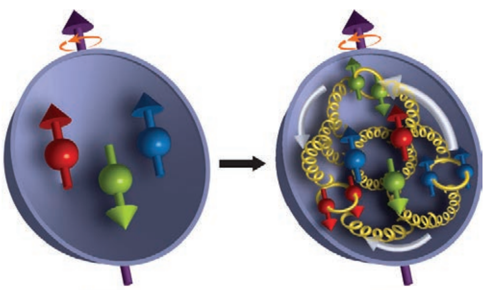
Brookhaven National Laboratory
Accomplishments

U.S. DEPARTMENT OF ENERGY

Unique Facility
World's most advanced synchrotron light source

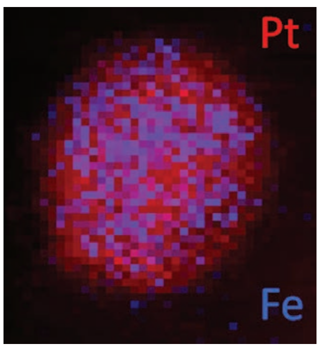
BNL is entering an exciting new chapter of discovery with one of the newest and most advanced x-ray facilities in the world. The National Synchrotron Light Source II (NSLS-II) delivers beams of extremely bright x-rays used by researchers to study a material's properties and functions with nanoscale resolution and exquisite sensitivity. This facility is open to scientists from academia, industry, and other Labs, and provides the research tools needed for basic and applied research, thereby fostering key discoveries in biology and medicine, materials and chemical sciences, geosciences and environmental sciences, and nanoscience. These discoveries will advance new technologies and generate breakthroughs in energy security, human health, and more.

Research Highlight
Gluons make big contribution to proton spin



"Spin" is a fundamental property that influences a proton's optical, electrical, and magnetic characteristics—put to use every day in MRI scans. But the source of spin is a mystery: quarks, the proton's inner building blocks, account for only about a third. New data from high-energy collisions of spin-aligned protons—possible only at the Relativistic Heavy Ion Collider—indicate that gluons, glue-like particles that bind quarks, play a substantial role in spin, possibly more than the quarks. These high-resolution experiments gave scientists access to gluons that carry the lowest fraction of the proton's overall momentum. Though these gluons are "lightweight," they're abundant, which explains their outsized contribution to spin.

Technology to Market Highlight
Custom nanocatalysts advance fuel cell vehicle production

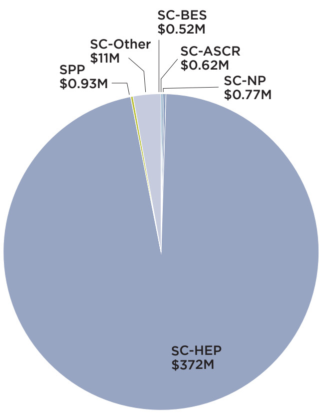


Hydrogen fuel-cell electric vehicles could significantly reduce the harmful emissions associated with fossil fuels, but these fuel cells rely on costly precious metals for peak performance. To reduce reliance on platinum—the most expensive, fragile, and critical fuel cell catalyst component—BNL scientists developed a breakthrough nanocatalyst that uses just a one-atom thick platinum coating over less-expensive metals like palladium. Experiments showed that the new nanocatalyst outperformed its expensive precursors. N.E. Chemcat Corporation, Japan's leading catalyst manufacturer, has licensed the nanoparticle design and synthesis process and is working with leading automotive manufacturers to accelerate production of an eco-friendly fleet of zero-emission vehicles.

Fermi National Accelerator Laboratory
At a Glance

FNAL is America's particle physics and accelerator Laboratory. FNAL's vast complex of particle accelerators powers research into the fundamental nature of the universe. The flagship Deep Underground Neutrino Experiment, supported by the Long-Baseline Neutrino Facility, will be the first international mega-science project based at a DOE National Laboratory. FNAL integrates U.S. researchers into the global particle physics enterprise through its experiments and programs. The Laboratory's scientific R&D advances particle accelerator, detector and computing technology for use in science and society.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $386.7M

FY 2015 DOE costs: $385.7M

FY 2015 SPP costs (non-DOE/ non-DHS): $0.93M

FY 2015 SPP as % total Lab operating costs: 0.2%

Facts

Location:	Batavia, Illinois
Type:	Single-program Laboratory
Year Founded:	1967
Director:	Nigel Lockyer
Contractor:	Fermi Research Alliance, LLC
Responsible Site Office:	Fermi Site Office

Physical Assets

6,800 acres and 365 buildings
2.4 million GSF in buildings
Replacement plant value: $1.942B
10,800 GSF in 4 excess facilities
19,771 GSF in leased facilities

Human Capital

1,801 full-time equivalent employees (FTEs)
9 joint faculty
53 postdoctoral researchers
2,634 facility users
19 visiting scientists

Core Capabilities

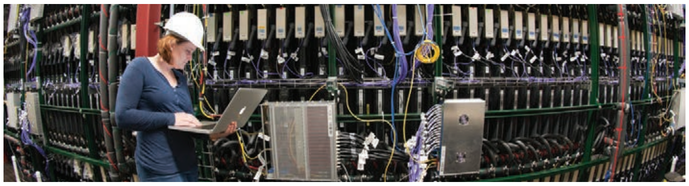
Accelerator Science and Technology
Advanced Computer Science, Visualization, and Data
Large Scale User Facilities/ Advanced Instrumentation
Particle Physics

Mission Unique Facilities

Fermilab Accelerator Complex

Accomplishments

Research Highlight
Capturing the elusive neutrino



Our universe is permeated with neutrinos: nearly massless particles that interact so rarely with other matter that trillions of them pass through our bodies each second without leaving a trace. Neutrinos could reveal how matter originated and point the way to discovering new particles and forces in nature. NOvA, the most powerful accelerator-based neutrino experiment ever built in the United States, started up in 2014 and has published its first results on neutrinos' shape-shifting properties. With two more experiments in operation, two more under construction and the flagship international Deep Underground Neutrino Experiment being developed, FNAL leads the way toward a deeper understanding of the neutrino universe.

Unique Facility
High-energy beams for discovery

The Fermilab Accelerator Complex powers forefront research into the particles and forces that make up our universe. Comprising seven particle accelerators and storage rings, it is the only facility in the world that simultaneously operates two accelerator-based neutrino beams. These beams drive an ensemble of experiments that study neutrinos at low and high energies and over short and long distances. Upgrades to the complex will position FNAL as the world center for the study of muons, with the first experiment using high-intensity beams beginning operation in 2017.

Fermilab

Idaho National Laboratory
At a Glance

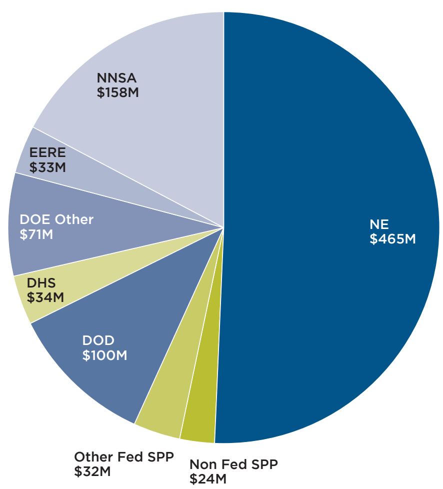
INL serves as the United States command center for advanced nuclear energy research, development, demonstration and deployment, and is home to an unparalleled combination of nuclear energy research, development and deployment test-bed facilities focused on fuel fabrication, steady-state and transient irradiation, and macro- and micro-scale post-irradiation examination.

INL's applied engineering discipline and problem-solving approach helps the Defense and Homeland Security departments, as well as industry partners, solve significant national security challenges in critical infrastructure protection and nuclear nonproliferation. Scientists and engineers are also exploring solutions to grand challenges in the areas of clean energy technologies and improving the water and energy efficiency of industrial manufacturing processes.

Under direction of DOE-NE, INL is leading the Gateway for Accelerated Innovation in Nuclear (GAIN) initiative to provide the nuclear community with access to the technical, regulatory and financial support necessary to move innovative nuclear energy technologies, such as small modular reactors, toward commercialization while ensuring the continued safe, reliable and economical operation of the existing nuclear fleet.

INL is managed by Battelle Energy Alliance for the DOE's Office of Nuclear Energy.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $916M
FY 2015 DOE/NNSA costs: $668M
FY 2015 SPP costs (non-DOE/non-DHS): $215M
FY 2015 SPP as % total Lab operating costs: 23%
FY 2015 DHS costs: $34M

Facts

Location:	Idaho Falls, Idaho
Type:	Multiprogram Laboratory
Year Founded:	1949
Director:	Mark Peters
Contractor:	Battelle Energy Alliance
Responsible Site Office:	DOE - Idaho

Physical Assets

890 square miles and 500 buildings
2.3 million gross square footage (GSF) in operating buildings
13.7K GSF in operational standby buildings
$4.8B in replacement plant value
115K GSF in 13 excess facilities
1M GSF in leased facilities
61-mile test grid - 138kV dual-fed power loop complete with seven substations and a control center all linked with state-of-the-art communications and instrumentation capabilities

Human Capital

3,891 full-time equivalent employees (FTEs)
19 joint faculty
33 postdoctoral researchers
173 undergraduate students
96 graduate students
49 facility users
472 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
Computational Science
Condensed Matter Physics and Materials Science
Cyber and Information Sciences
Decision Science and Analysis
Environmental Subsurface Science
Large Scale User Facilities/Advanced Instrumentation
Mechanical Design and Engineering
Nuclear Engineering
Nuclear Physics
Nuclear and Radio Chemistry
Particle Physics
Plasma and Fusion Energy Science
Power Systems and Electrical Engineering
Systems Engineering and Integration

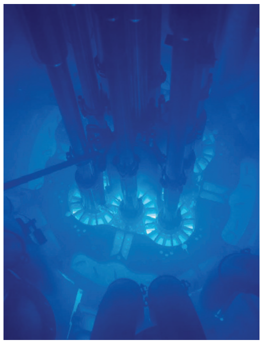
Mission Unique Facilities

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

Idaho National Laboratory
Accomplishments

U.S. DEPARTMENT OF ENERGY

Unique Facility
Advanced Test Reactor

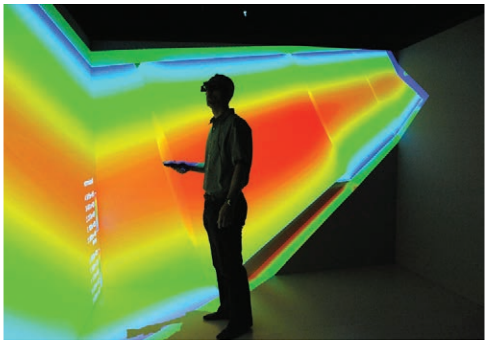


INL's capabilities center around the Advanced Test Reactor (ATR). The ATR is a pressurized water test reactor with a unique serpentine core that allows the reactor's corner lobes to be operated at different power levels, making it possible to conduct multiple simultaneous experiments under different testing conditions. The ATR is the only U.S. research reactor capable of providing large-volume, high-flux neutron irradiation in a prototype environment, and the reactor makes it possible to study the effects of intense neutron and gamma radiation on reactor materials and fuels. The ATR supports a variety of government, university and privately sponsored research, as well as medical isotope production. The ATR provides the critical testing capability that has helped develop the U.S. Navy's nuclear propulsion program.

Research Highlight
INL-built 'Space Battery' Powers NASA's New Horizons Mission to Pluto

After a 10-year journey of three billion miles, NASA's New Horizons swept by Pluto and its moons in July 2015. The New Horizons spacecraft has given scientists their first close-up look at Pluto and enabled discovery of four additional moons during the historic mission. The craft uses a radioisotope thermoelectric generator (RTG) assembled, tested and prepared for launch by INL researchers. RTGs use the decay heat of plutonium-238 to provide a reliable source of electricity and heat for the craft and its instruments in the frigid environment of deep space.

Technology to Market Highlight
MOOSE Herd accelerates application development



Multi-physics Object Oriented Simulation Environment (MOOSE) is the INL development and runtime environment for the solution of multi-physics systems that involve multiple physical models or multiple simultaneous physical phenomena. The development of MOOSE at INL has resulted in a unique approach to computational engineering that combines computer science with a strong underlying mathematical description in a unique way to allow scientists and engineers to develop engineering simulation tools in a fraction of the time previously required. With MOOSE, only the Kernel development is required from the application developer.

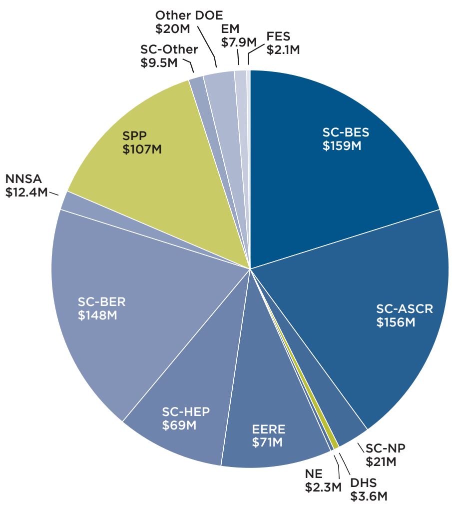
BISON was the first MOOSE-based animal and models nuclear fuel rod behavior inside working nuclear reactors. There are now more than 40 MOOSE-based animals worldwide in various stages of development, ranging from recently obtaining preliminary results to being National recognized as state-of-the-art efforts.

Lawrence Berkeley National Laboratory
At a Glance

U.S. DEPARTMENT OF ENERGY

Berkeley Lab performs research at the forefront of science. We search for cleaner, more reliable and sustainable sources of energy. We study the planet to understand why our climate is changing and what we can do about it. We explore the universe to understand how it began and where it's going. We are leaders in energy conservation, designing better materials and greener buildings. We design and build the most powerful microscopes, brightest x-ray light sources and fastest computers. Our research aims to coax more power from solar cells, build better batteries and develop clean biofuels for the future.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $786M
FY 2015 DOE/NNSA costs: $790.1M
FY 2015 SPP costs (non-DOE/non-DHS): $103.5M
FY 2015 SPP as % total Lab operating costs: 13.6%
FY 2015 DHS costs: $3.6M

Facts

Location:	Berkeley, California
Type:	Multiprogram laboratory
Year Founded:	1931
Director:	Michael Witherell
Contractor:	University of California
Responsible Site Office:	Berkeley Site Office

Physical Assets

202 acres and 97 buildings
1.98M GSF in buildings
Replacement plant value: $1,348B
55,756 GSF in 6 excess facilities
339,258 GSF in leased facilities

Human Capital

3,304 full-time equivalent employees (FTEs)
245 joint faculty
476 postdoctoral researchers
149 undergraduate students
330 graduate students
10,798 facility users
2,170 visiting scientists

Core Capabilities

Accelerator Science and Technology
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 Physics
Nuclear and Radio Chemistry
Particle Physics
Power Systems and Electrical Engineering
Systems Engineering and Integration

Mission Unique Facilities

Advanced Light Source
The Molecular Foundry
National Energy Research Scientific Computing Center (NERSC)
Energy Sciences Network (ESnet)
Joint BioEnergy Institute
Joint Genome Institute
Advanced Biofuels Process Demonstration Unit
FLEXLAB

BERKELEY LAB

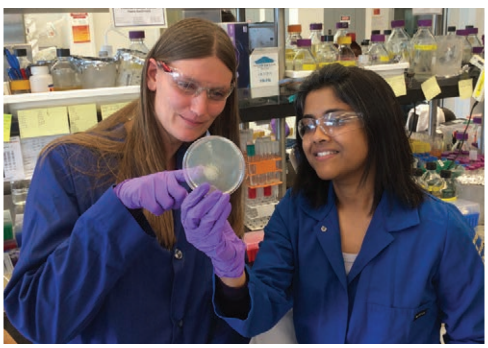
Lawrence Berkeley National Laboratory
Accomplishments

U.S. DEPARTMENT OF ENERGY

Unique Facility
Advanced Light Source

The Advanced Light Source (ALS) is one of the most sophisticated scientific instruments ever built. It produces hair-thin beams of x-rays and ultraviolet light, precisely focused and a billion times brighter than the sun. The ALS hosts more than 2,000 visiting scientists annually. Experiments range from environmental, materials, and energy sciences to physics and biology. ALS beams have revealed the structures of nearly 3,300 proteins and analyzed bacteria found in the Gulf of Mexico oil spill. Its beamlines are vital analytical tools leading to better medicines, stronger materials, and more efficient solar cells and batteries.

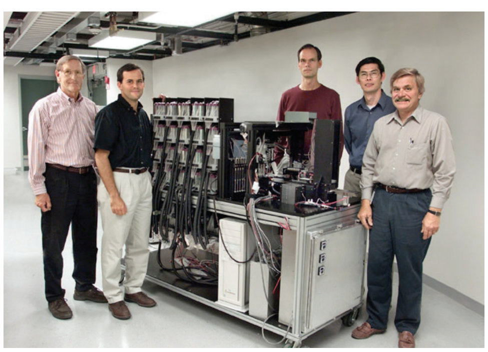
Research Highlight
Berkeley Lab Scientists Brew Jet Fuel in One-Pot Recipe



Researchers at Berkeley Lab have engineered a strain of bacteria that enables a "one-pot" method for producing advanced biofuels. The Escherichia coli (E. coli) is able to tolerate the liquid salt used to break apart plant biomass into sugary polymers. Because the salt solvent, known as ionic liquids, interferes with later stages in biofuels production, it needs to be removed before proceeding, a process that takes time and money. Developing ionic-liquid-tolerant bacteria eliminates the need to wash away the residual ionic liquid.

The achievement is critical to making biofuels a viable competitor to fossil fuels because it helps streamline the production process.

Technology to Market Highlight
Automating Drug Discovery with Robots



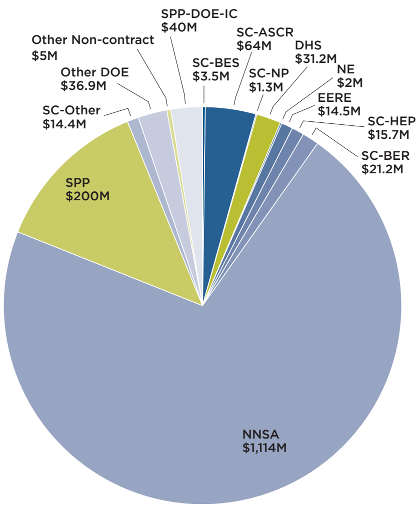
Most available pharmaceuticals target proteins. Crystalizing a protein to map out its atomic structure and determine whether a potential drug might bind with it is now a common path to drug discovery. In the late 1990s, crystalizing a protein could take months and even years. Berkeley Lab's bioinstrumentation group helped create a solution by designing a nanodroplet protein crystallization robot, which sped up the crystallization process by a factor of 10. Syrrx licensed the Lab's technology in 2000 and designed a series of robots to create an automated drug discovery system. One drug Syrrx developed using the system received FDA approval in 2013 to treat type 2 diabetes.

Lawrence Livermore National Laboratory
At a Glance

U.S. DEPARTMENT OF ENERGY

Science and technology on a mission – These are the hallmarks of LLNL. In service to the DOE/NNSA and other Federal agencies, LLNL develops and applies world-class ST&E to ensure the safety, security and reliability of the Nation's nuclear deterrent. LLNL also applies ST&E 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 employs unmatched facilities, LLNL pushes the boundaries to provide breakthroughs for counter-terrorism and nonproliferation, defense and intelligence, and energy and environmental security. LLNL was founded in 1952; Lawrence Livermore National Security, LLC has managed the Lab since 2007.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $1,5531M
FY 2015 DOE/NNSA costs: $1,238M
FY 2015 SPP costs (non-DOE/non-DHS): $257M
FY 2015 SPP as % total Lab operating costs: 21 %
FY 2015 DHS costs: $35.2M

Facts

Location:	Livermore, California
Type:	Multidisciplinary National Security Laboratory
Year Founded:	1952
Director:	William H. Goldstein
Contractor:	Lawrence Livermore National Security, LLC
Responsible Site Office:	Livermore Field Office

Physical Assets

7,700 acres and 535 buildings/trailers
6.4 million GSF in active buildings
0.8 million GSF in 142 non-operational buildings
24 thousand GSF in facilities leased
Replacement plant value: $6.8 billion

Human Capital

6,500 full-time equivalent employees (FTEs)
20 joint faculty
200 postdoctoral researchers
500 undergraduate students
50 graduate students
4,300 facility users
1,500 visiting scientists

Core Capabilities

Advanced Materials and Manufacturing
Bioscience and Bioengineering
Earth and Atmospheric Sciences
High-Energy-Density Science
High-Performance Computing, Simulation, and Data Science
Lasers and Optical Science and Technology
Nuclear, Chemical, and Isotopic Science and Technology
All Source Intelligence Analysis
Nuclear Weapons Design
Safety, Risk, and Vulnerability Analysis

Mission Unique Facilities

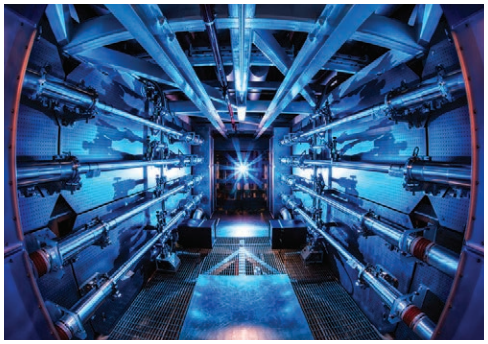
National Ignition Facility
Livermore Computing Complex
National Atmospheric Release Advisory Center
High Explosives Applications Facility
Contained Firing Facility
Forensic Science Center
Center for Micro and Nanotechnology
Center for Bioengineering
Jupiter Laser Facility
Center for Accelerator Mass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

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory
Accomplishments

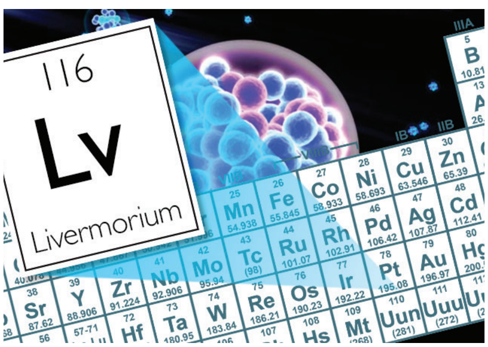
U.S. DEPARTMENT OF ENERGY

Unique Facility
The World's Largest, Most Energetic Laser



LLNL is home to one of the complex's flagship user facilities, the National Ignition Facility (NIF). The world's largest and most energetic laser, NIF surpassed expectations to fire a record-breaking 417 experiments in FY 2016, including shots that safely used minute amounts of plutonium to generate data relevant to understanding nuclear weapon performance – information critical to DOE's stockpile stewardship mission. NIF also is used to study fundamental properties of matter at high energies and densities, such as astrophysical plasmas and planetary cores. NIF will begin using complex new diagnostic capabilities to directly observe the burning hot spot in fusion experiments. LLNL's long-standing leadership in high performance computing is indispensable for effectual design and interpretation of these complex NIF experiments.

Research Highlight
LLNL's Long History of Super-Heavy Element Research



LLNL has solidified its place on the periodic table of elements. In collaboration with researchers in Dubna, Russia, and ORNL, LLNL scientists discovered five super-heavy elements: 114, 115, 116, 117, and 118. These discoveries provide new insights into fundamental nuclear physics and formation processes for elements in the universe. In 2011, the International Union of Pure and Applied Chemistry (IUPAC) approved the name of livermorium for element 116, calling attention to the Laboratory as well as the city in which it is located. In 2015, IUPAC confirmed that LLNL scientists and their collaborators officially discovered elements 115, 117, and 118. In November 2016 these elements were officially named moscovium (115), tennessine (117) and oganesson (118).

Technology to Market Highlight
Rapid Radiation Detection

A public-private partnership between LLNL and Tennessee-based ORTEC helped speed critical homeland-security technology to the marketplace. Radscout is a portable radiation detector developed by the Lab's weapons program for emergency first responders and inspection personnel who need rapid detection and identification of material to determine the nature and scope of a threat. The product, now under the names of Detective and Detective-EX, has been used to screen for dangerous radioisotopes in luggage or shipping containers and rapidly reports its results on-the-spot. The detector also is being used at border crossings, cargo ship docks, and transportation terminals.

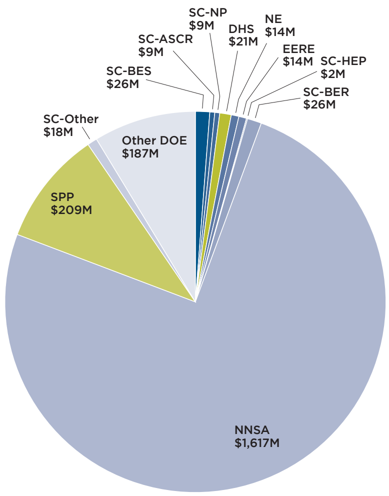
Los Alamos National Laboratory
At a Glance

U.S. DEPARTMENT OF ENERGY

As the Nation's premier national security science Laboratory, LANL applies innovative and multidisciplinary science, technology, and engineering to help solve the Nation's toughest challenges and protect the Nation and world.

In delivering mission solutions, LANL 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.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $1,964M
FY 2015 DOE/NNSA costs: $1,721M
FY 2015 SPP costs (non-DOE/non-DHS): $218M
FY 2015 SPP as % total Lab operating costs: 11.1%
FY15 DHS costs: $25M

Facts

Location:	Los Alamos, New Mexico
Type:	National security Laboratory
Year Founded:	1943
Director:	Charlie McMillan
Contractor:	Los Alamos National Security LLC (LANS)
Responsible Site Office:	Los Alamos Field Office

Physical Assets

22,400 acres and 1,000 buildings
8.2 million GSF in buildings
Replacement plant value: $14.2B
346,000 GSF in 100 excess facilities
385,000 GSF in leased facilities

Human Capital

10,609 full-time equivalent employees (FTEs)
333 postdoctoral researchers
655 undergraduate students
359 graduate students
1,228 facility users
582 visiting scientists

Core Capabilities

Accelerator Science and Technology
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 a nd Engineering
Environmental Subsurface Science
Large Scale User Facilities/ Advanced Instrumentation
Mechanical Design and Engineering
Nuclear Engineering
Nuclear Physics
Nuclear and Radio Chemistry
Particle Physics
Plasma and Fusion Energy Science
Systems Engineering and Integration

Mission Unique Facilities

Dual-Axis Radiographic Hydrodynamic Test Facility
Plutonium Science & Manufacturing Facility
Los Alamos Neutron Science Center: Isotope Production Facility, Proton Radiography (pRad) Facility, Ultra Cold Neutron Facility, Weapons Neutron Research Facility
Metropolis Center for Modeling & Simulation
Center for Integrated Nanotechnologies
Electron Microscopy Lab
National High Magnetic Field Laboratory
Nonproliferation & Internal Security Facility
Trident Laser Facility
SIGMA Complex for Materials Manufacturing & Machining
Center for Explosives Science

Los Alamos NATIONAL LABORATORY

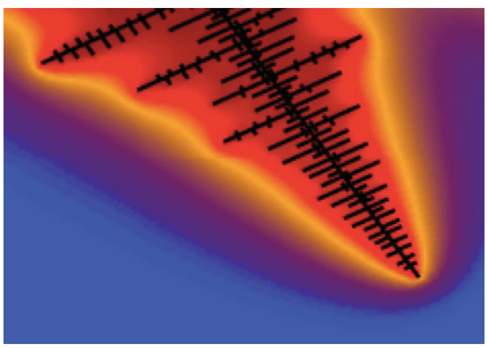
Los Alamos National Laboratory
Accomplishments

U.S. DEPARTMENT OF ENERGY

Unique Facility
Advanced Technology for National Security

LANL houses mission-essential facilities that ensure the safety, security, and effectiveness of the Nation's nuclear deterrent in the absence of testing, including the DARHT facility and one of world's fastest supercomputers, Trinity. DARHT, the world's most powerful x-ray machine, analyzes nuclear weapons mockups. The facility produces freeze-frame radiographs of materials imploding at speeds greater than 10,000 miles an hour, freezing the action of an imploding mockup to less than a millimeter, and providing 3D information. The Trinity supercomputer, at 40 petaflops, is the first platform large and fast enough to begin to accommodate 3D, full-scale, end-to-end weapons simulations. By combining Trinity's 3D modeling and DARHT's experimental data, LANL enhances the confidence and credibility of the Nation's nuclear deterrent.

Research Highlight
Predicting Materials Properties and Performance



By coupling experimental and modeling approaches in materials science, LANL is developing an integrated predictive process, structure, property, and performance capability that optimizes manufacturing processes and ensures performance. For example, LANL routinely uses casting simulations to guide manufacturing processes supporting stockpile stewardship. By adding a microstructural model to the code (TRUCHAS), researchers can predict microstructure variations in a casting. Proton radiography experiments then validate the predicted macroscopic fluid flow and solidification behavior. Ex-situ characterization validates the microstructural models. With these integrated capabilities, LANL is developing the ability to predict materials properties and performance, including aging phenomena, and modifying this capability to address new technologies such as additive manufacturing.

Technology to Market Highlight
Innovation in Oil Flow Measurements

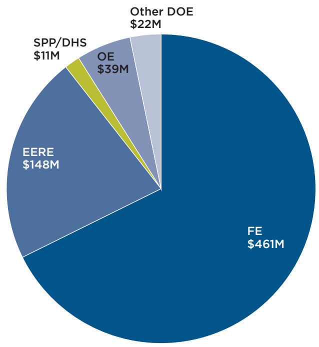
Like many LANL innovations, technology leading to the Safire multiphase flow meter originated in national security work. LANL developed swept frequency acoustic interferometry to noninvasively identify static liquids (chemical warfare agents) inside sealed containers. LANL teamed up with Chevron Energy Technology Corporation (ETC) and General Electric (GE) to adapt the technology to multiphase fluids (oil, water, and gas) in motion within pipes. The resulting simple-to-use Safire meter provides noninvasive, continuous, and accurate estimates of fluid production for wells, resulting in better reservoir management, improved production, and huge cost savings by eliminating environmentally unsafe separations tanks. Chevron has begun installing and evaluating meters in its oil fields, and GE is marketing the meters internationally.

National Energy Technology Laboratory
At a Glance

U.S. DEPARTMENT OF ENERGY

NETL is the DOE's fossil energy research Laboratory. The Laboratory's mission is to discover, integrate, and mature technology solutions to enhance the Nation's energy foundation and protect the environment for future geneations. The Laboratory maintains technical competencies in areas critical to the discovery, development, and deployment of affordable, sustainable fossil energy technologies and systems. Through collaboration with partners in industry, academia, and other national and international research organizations, NETL nurtures emerging fossil energy technologies across the full breadth of the maturation cycle. Partners in NETL's research programs number in the thousands and include small and large U.S. businesses, national research organizations, colleges and universities, and other government Laboratories. NETL is DOE's only government-owned, government-operated National Lab.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $234M

FY 2015 DOE costs: $670M

FY 2015 SPP costs (non-DOE/ non-DHS): $11M

FY 2015 SPP as % total Lab operating costs: 4.7%

FY 2015 Active Research, Development, Demonstration, and Deployment (DOE + Cost Share): $13+B

Facts

Location:	Pittsburgh, PA; Morgantown, WV; Albany, OR; Sugar Land, TX; Anchorage, AK
Type:	Single-program Laboratory
Year Founded:	1910
Director:	Grace M. Bochenek

Physical Assets

242 acres and 109 buildings
1,157,849 GSF in buildings
Replacement plant value: $596.9M
39,120 GSF in 8 excess facilities
14,259 GSF in leased facilities

Human Capital

1,336 full-time equivalent employees (FTEs)
47 joint faculty
94 postdoctoral researchers
12 undergraduate students
50 graduate students
916 technology development partner institutions

Core Capabilities

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

Mission Unique Facilities

Simulation-Based Engineering Laboratory
Energy Conversion Technology Center
Advanced Alloy Development Facility
Materials & Minerals Characterization Facility
Geological Science & Engineering Facility
Mobile Environmental Monitoring Laboratory
Energy Data Exchange
Computational Engineering Laboratory

Accomplishments

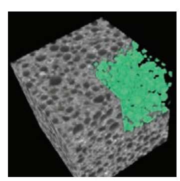
Unique Facility

Alloy Development Facility Delivers Material Solutions

NETL houses one of the finest melting, casting, and thermal processing research facilities in the United States. New alloy production starts with design employing advanced numerical modeling techniques. The important characteristics of the alloy are estimated, then the alloy is melted, solidified, and rolled, formed, machined, or cast into specimens for service environment testing. Testing includes corrosion, erosion, creep, wear, and a variety of hot and cold mechanical tests. Prototype alloys are then evaluated for service life. This integrated approach, coupled with the infrastructure for melting, processing, and testing of the alloys, has yielded successful results in such varied applications as turbine alloys, military armor, solid oxide fuel cells, and medical devices.

Research Highlight

Foamed Cement Research Changes the Industry



NETL is closing the knowledge gap on the behavior and performance of foamed cement used to ensure wellbore integrity in applications that include shale gas, off-shore oil and gas, and geothermal wells. NETL initiated Laboratory characterization studies of common formulations of foamed cements, obtained the first CT images of foamed cement systems, and developed a reliable methodology to analyze the microstructure of foamed cements under in situ conditions. NETL is now working with the oil and gas industry to update a 25-year-old testing standard to ensure quality, reduce cost and waste, and enable safer operations.

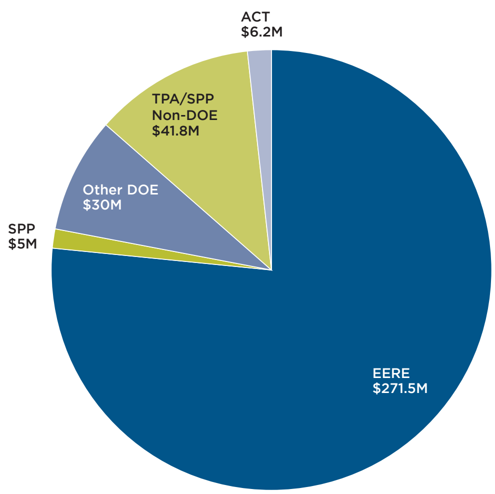
NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

National Renewable Energy Laboratory
At a Glance

U.S. DEPARTMENT OF ENERGY

NREL is the U.S. DOE's primary National Laboratory for renewable energy and energy efficiency research and development. NREL delivers impactful scientific discoveries, innovations and insights that transform clean energy technologies, systems and markets. The Lab's research focuses on engineering of energy efficiency, sustainable transportation, and renewable power technologies and provides the knowledge to integrate and optimize energy systems, delivering foundational knowledge, technology and systems innovations, and analytic insights to catalyze a transformation to a renewable and sustainable energy future.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $395.4M
FY 2015 DOE/NNSA costs: $348.9M
FY 2015 SPP costs (non-DOE/non-DHS): $46.5M
FY 2015 SPP as % total Lab operating costs: 13%

Facts

Location:	Golden, Colorado
Type:	Single-program Laboratory
Year Founded:	1977
Director:	Martin Keller
Contractor:	Alliance for Sustainable Energy, LLC
Responsible Site Office:	Golden Field Office

Physical Assets

627 acres and 69 buildings
107,074,447 GSF in buildings
Replacement plant value: $517,556K
182,827 GSF in leased facilities

Human Capital

1,459 full-time equivalent employees (FTEs)
7 joint faculty
40 postdoctoral researchers
112 undergraduate students
62 graduate students
29 facility users
56 visiting scientists

Core Capabilities

Advanced Computer Science, Visualization, and Data
Applied Materials Science and Engineering
Biological and Bioprocess Engineering
Biological Systems Science
Chemical Engineering
Chemical and Molecular Science
Decision Science and Analysis
Large Scale User Facilities/Advanced Instrumentation
Mechanical Design and Engineering
Power Systems and Electrical Engineering
Systems Engineering and Integration

Mission Unique Facilities

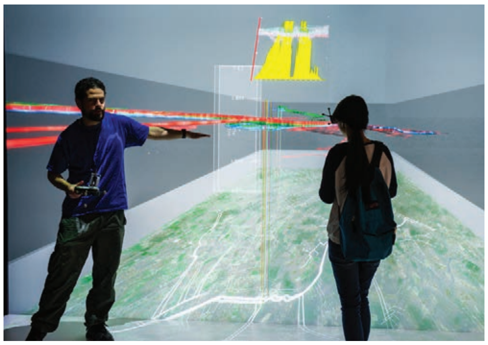
Battery Thermal and Life Test Facility
Controllable Grid Interface Test System
Distributed Energy Resources Test Facility
Energy Systems Integration Facility
High-Flux Solar Furnace
Integrated Biorefinery Research Facility
Outdoor Test Facility
Renewable Fuels & Lubricants Laboratory
Science & Technology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

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

National Renewable Energy Laboratory
Accomplishments

U.S. DEPARTMENT OF ENERGY

Unique Facility
Energy Systems Integration Facility Takes on Nation’s Energy Challenges



The Energy Systems Integration Facility (ESIF) is the Nation’s premier facility for research, development, and demonstration of the components and strategies needed to optimize our energy system. Since 2013, the ESIF team and more than 100 industry and academic partners have tackled the Nation’s biggest energy challenges—how to incorporate new technologies into our existing infrastructure and operate a system with higher levels of variable supply and demand. With our partners, NREL has examined how to keep the lights on and the fuel flowing through extreme weather events, cyber threats, and aging infrastructure. Future projects include new business models, regulatory frameworks, and value propositions for consumers.

Research Highlight
NREL Finds Nanotube Semiconductors Well-Suited for PV Systems

Laboratory researchers have shown that single-walled carbon nanotube semiconductors (SWCNT) can be favorable for photovoltaic (PV) systems because they can potentially convert sunlight to electricity or fuels without losing much energy. In organic PV devices, after a photon is absorbed, charges (electrons and holes) generally need to be separated across an interface so that they can live long enough to be collected as electrical current. NREL researchers (who published their findings in Nature Chemistry) found little energy was lost when pairing SWCNT semiconductors with fullerene molecules. They discovered that this particular system—nanotubes with fullerenes—has an exceptionally low “reorganization energy,” along with the nanotubes themselves.

Technology to Market Highlight
Partnership with SolarCity and Hawaiian Electric Company Benefits Consumers

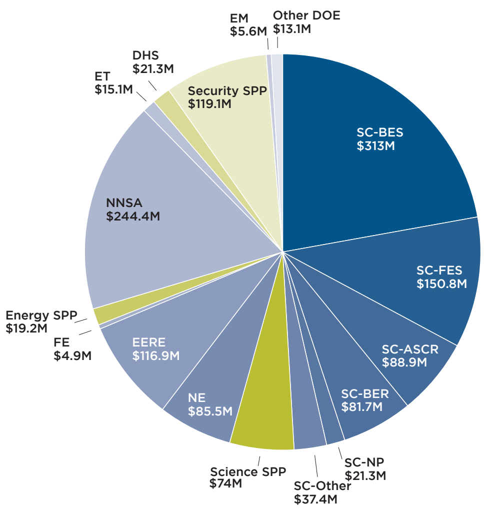
NREL is collaborating with SolarCity to address the safety, reliability, and stability challenges of interconnecting high penetrations of distributed photovoltaics (PV) with the electric power system. The work includes a partnership with the Hawaiian Electric Companies (HECO) to analyze high-penetration solar scenarios using advanced modeling and inverter testing at the ESIF. SolarCity aims to increase the penetration of renewable energy on the grid by addressing the system-level challenges of interconnecting high-penetration distributed PV; the ceiling will be raised from 120% minimum daytime load to 250%. For HECO, this testing will allow the company to approve PV deployment for customers who have been waiting for interconnection on these high-penetration solar circuits.

Oak Ridge National Laboratory
At a Glance

U.S. DEPARTMENT OF ENERGY

ORNL is the largest multiprogram science and energy Laboratory in the U.S. DOE system. Its mission is to deliver scientific discoveries and technical breakthroughs that accelerate the development and deployment of solutions in clean energy and global 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, ORNL 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 nuclear science and technology; leadership-class computers including Titan, the Nation's fastest; and a diverse set of programs linked by an urgent focus on clean energy and global security.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $1,412.1M
FY 2015 DOE/NNSA costs: $1,145.5M
FY 2015 SPP costs (non-DOE/non-DHS): $212.2M
FY 2015 SPP as % total Lab operating costs: 15.0%
FY 2015 DHS costs: $21.3M

Facts

Location:	Oak Ridge, Tennessee
Type:	Multiprogram Laboratory
Year Founded:	1943
Director:	Thomas E. Mason
Contractor:	UT-Battelle, LLC
Responsible Site Office:	ORNL Site Office

Physical Assets

4,421 acres and 308 buildings
4.4M GSF in buildings
Replacement plant value: $6.4B
207,000 GSF in 26 excess facilities
1M GSF in leased facilities

Human Capital

4,628 full-time equivalent employees (FTEs)
155 joint faculty
328 postdoctoral researchers
252 undergraduate students
283 graduate students
2,899 facility users
1,728 visiting scientists

Core Capabilities

Accelerator Science and Technology
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
High Flux Isotope Reactor
Manufacturing Demonstration Facility
National Transportation Research Center
Oak Ridge Leadership Computing Facility
Spallation Neutron Source

OAK RIDGE National Laboratory

Oak Ridge National Laboratory
Accomplishments

U.S. DEPARTMENT OF ENERGY

Unique Facility
Spallation Neutron Source

The Spallation Neutron Source (SNS) was completed in 2006 as a third-generation neutron source capable of delivering the world's brightest beams of pulsed neutrons for scientific research and industrial development. Today, SNS is a world leader in particle accelerator science, and it has advanced the state-of-the-art in several areas of accelerator technology. As a user facility, SNS hosts scientists from around the world—10,500 to date—and offers a wide variety of experiment stations that provide research capabilities across a broad range of disciplines including physics, chemistry, materials science, and biology. Conceptual designs for a power upgrade and second target station are moving forward, which will transform SNS into a fourth-generation source capable of addressing gaps in materials research that require the combined use of intense, cold neutrons and instruments optimized for exploration of complex materials.

Research Highlight
Unlocking Lignin Benefits Biofuels, Batteries, and Plastics

ORNL is cracking the mystery of lignin, a tough component of plant cell walls, through research that is exploiting simulations on its Titan supercomputer and experimental analysis at the Lab's two neutron sources. Understanding lignin at the molecular level is guiding researchers toward more efficient, cost-effective conversion of woody plants such as switchgrass and poplar into ethanol, a renewable substitute for gasoline. These insights are also transforming lignin—a low-cost waste product of the pulp, paper and biofuels industries—into a valuable commodity. Researchers found that lignin's unique fiber structure could make it useful as a battery anode, improving on graphite materials found in most lithium-ion batteries. ORNL scientists also used lignin as a substitute for styrene, the petroleum-based component in ABS plastic. The new material, called ABL, is a stronger, cheaper, recyclable raw material that could replace plastics in many of today's consumer products.

Technology to Market Highlight
Big Area Additive Manufacturing

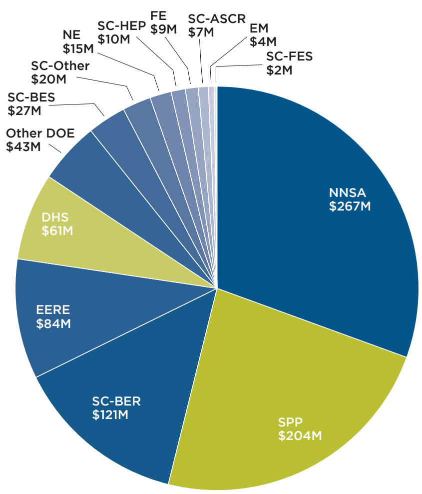
ORNL worked with Cincinnati Incorporated, one of the oldest machine tool manufacturers in the United States, to set new standards in large-scale additive manufacturing by developing a platform known as Big Area Additive Manufacturing. BAAM can 3D print components 10 times the size of those that could be produced by previous commercial processes, and it prints them 200 times faster. BAAM is also the first manufacturing project capable of depositing carbon fiber reinforced plastic into printed materials, which yields products with greater strength and four to seven times the material's original stiffness. In addition, BAAM is more energy efficient than traditional manufacturing methods such as stamping and blow molding. Cincinnati commercialized the technology, which is being used in the automotive, aerospace and prototyping industries.

Pacific Northwest National Laboratory
At a Glance

U.S. DEPARTMENT OF ENERGY

For more than 50 years, PNNL's world-class researchers have been making fundamental scientific discoveries that illuminate the mysteries of our planet and the universe. They also apply PNNL's scientific expertise to tackle some of the most challenging problems in energy, the environment and national security. PNNL leverages its foundational capabilities in chemistry, environmental science and data analytics to provide national leadership in deepening the understanding of climate science, shaping the future power grid, preventing nuclear proliferation and cleaning up the environment for the DOE and other sponsors. EMSL, one of DOE's scientific user facilities, is located at PNNL. PNNL also makes important contributions in energy storage, microbial biology and cyber security. PNNL partners extensively with other Labs, academia and industry in its research, development and deployment.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $875M
FY 2015 DOE/NNSA costs: $610M
FY 2015 SPP costs (non-DOE/non-DHS): $204M
FY 2015 SPP as % total Lab operating costs: 23%
FY 2015 DHS costs: $61M

Facts

Location:	Richland, Washington
Type:	Multiprogram Laboratory
Year Founded:	1965
Director:	Steven Ashby
Contractor:	Battelle Memorial Institute
Responsible Site Office:	Pacific Northwest Site Office

Physical Assets

582 acres and 78 buildings
2,304,520 GSF in buildings
Replacement plant value: $459,790,018
956,713 GSF in leased facilities

Human Capital

4,061 full-time equivalent employees (FTEs)
12 joint faculty
244 postdoctoral researchers
218 undergraduate students
207 graduate students
1,915 facility users
104 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 Engineering
Chemical and Molecular Science
Climate Change Science and Atmospheric 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
Nuclear Engineering
Nuclear and Radio Chemistry
Particle Physics
Power Systems and Electrical Engineering
Systems Engineering and Integration

Mission Unique Facilities

Atmospheric Radiation Measurement (ARM) Climate Research Facility
Applied Process Engineering Laboratory
Bioproducts, Sciences, and Engineering Laboratory
Environmental Molecular Sciences Laboratory
Marine Sciences Laboratory (Sequim, Washington)
Radiochemical Processing Laboratory
Systems Engineering Building, which includes the Electricity Infrastructure Operations Center

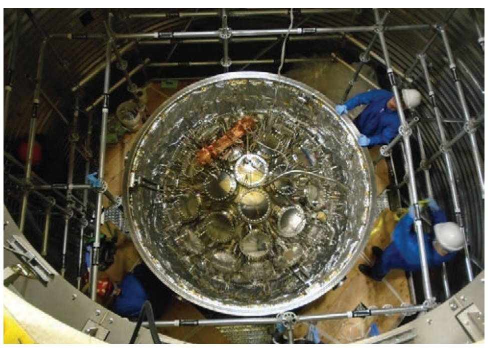
Pacific Northwest NATIONAL LABORATORY

Pacific Northwest National Laboratory
Accomplishments

Unique Facility
At EMSL, Team is in our DNA

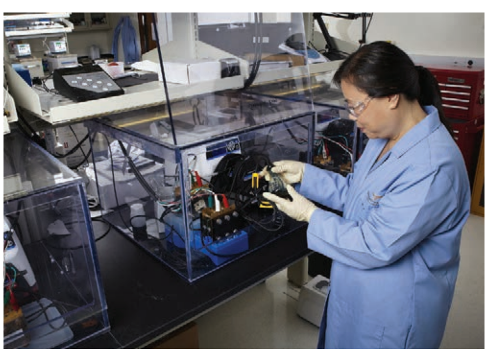
The Environmental Molecular Sciences Laboratory (EMSL) is a national scientific user facility located at PNNL and sponsored by DOE's Office of Biological & Environmental Research. EMSL draws together the global scientific community and assembles the people, instruments and resources for molecular-level discoveries and predictive understanding to accelerate solutions for national energy and environmental challenges. The nearly 800 scientists who use EMSL's 150 experimental instruments and high-performance supercomputer each year are gaining a deeper understanding of molecular-level processes needed to advance predictive, systems-level understanding of climate, biological, environmental and energy systems.

Research Highlight
A Deeper Look for Dark Matter



PNNL researchers are leading an experiment at the forefront of the hunt for dark matter. According to physicists' models, the majority of the matter in the universe has never been identified. The PNNL team has spent the last nine years creating a sophisticated instrument designed to directly detect a form of dark matter known as WIMPs—weakly interacting massive particles. The MiniCLEAN experiment (CLEAN stands for cryogenic low energy astrophysics with nobles) takes place in a clean, isolated laboratory 6,800 feet below ground in Sudbury, Ontario, where scientists carry out ultrasensitive experiments not possible elsewhere. The work builds upon PNNL's expertise sniffing out the faintest traces of compounds in a variety of settings helping answer compelling fundamental science questions and providing the foundation for solutions to national security challenges.

Technology to Market Highlight
Storage Battery Accelerates Power Grid of the Future



With breakthrough battery chemistry technology from PNNL, UniEnergy Technologies (UET) is helping usher in the power grid of the future. The advanced vanadium redox flow battery safely stores energy from generation sources, including wind and solar, and discharges it when needed on the grid for milliseconds to hours. That reduces costs and produces revenues while improving energy efficiency, reliability and security. In 2015, UET deployed in Washington State the largest-capacity containerized flow battery operating globally. Now UET provides energy storage systems worldwide for utilities, independent power producers, microgrids, and commercial and industrial customers.

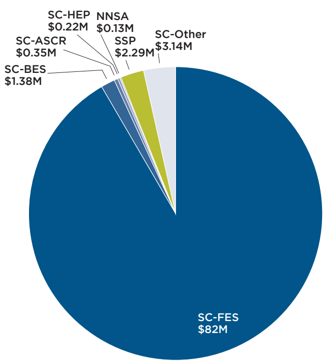
Princeton Plasma Physics Laboratory

At a Glance

U.S. DEPARTMENT OF ENERGY

PPPL is a collaborative national center for plasma and fusion energy sciences. It is the only DOE Laboratory devoted to these areas, and it is the lead U.S. institution investigating the science of magnetic fusion energy. PPPL has two coupled missions. First, the Laboratory develops the scientific knowledge to realize fusion energy as a clean, safe and abundant energy source for all nations, leading development of the physics of high-temperature plasmas needed for fusion. Second, PPPL develops plasma science over its broad range of physics challenges and applications. Modern plasma physics began with the advent of the world fusion program, and continues to lead to new discoveries in the nonlinear dynamics of this complex state of matter.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $90.0M

FY 2015 DOE/NNSA costs: $87.7M

FY 2015 SPP costs (non-DOE/ non-DHS): $2.3M

FY 2015 SPP as % total Lab operating costs: 2.6%

Facts

Location:	Princeton, New Jersey
Type:	Single-program Laboratory
Year Founded:	1951
Director:	Terrance Brog (Interim)
Contractor:	Princeton University
Responsible Site Office:	Princeton Site Office

Physical Assets

90.7 acres and 30 buildings
765K GSF in buildings
Replacement plant value: $660M

Human Capital

462 full-time equivalent employees (FTEs)
5 joint faculty
12 postdoctoral researchers
40 graduate students
350 visiting scientists

Core Capabilities

Plasma and Fusion Energy Science
Large-Scale User Facilities/ Advanced Instrumentation
Mechanical Design and Engineering
Power Systems and Electrical Engineering
Systems Engineering and Integration

Mission Unique Facilities

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

Accomplishments

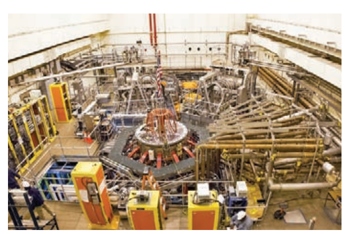
Research Highlight

The Power Behind Solar Storms, and Measuring the Precision of Magnetic Fields

Magnetic reconnection, in which the magnetic field lines converge, break apart and reconnect, creates massive eruptions of plasma from the sun and triggers brilliant auroras and geomagnetic storms. PPPL research has provided fresh insight into how the stunning transformation of magnetic energy into kinetic energy takes place. PPPL physicists also have been making important contributions on fusion experiments around the world. For example, PPPL scientists and collaborators recently confirmed that the stellarator Wendelstein 7-X in Germany produces magnetic fields with a deviation from the designed configuration of less than one part in 100,000. These results are a key step toward verifying the feasibility of stellarators as models for future fusion power plants.

Unique Facility

A Powerful Spherical Tokamak



Using powerful magnetic fields to confine a plasma hotter than the core of the sun, the National Spherical Torus Experiment-Upgrade (NSTX-U) is more compact than a typical tokamak device and studies whether this configuration can lead to a smaller, cheaper, and more efficient nuclear fusion energy power plant. When operational, fusion will be a safe, clean and abundant source of energy to generate electricity for humankind. An extensive upgrade to the original NSTX device doubles the heating power, magnetic field strength and plasma current of its predecessor and will narrow or close critical gaps on the path to fusion energy. When running at full strength, experiments on NSTX-U will provide key information for the next major steps in the U.S. fusion program.

PPPL

Sandia National Laboratories
At a Glance

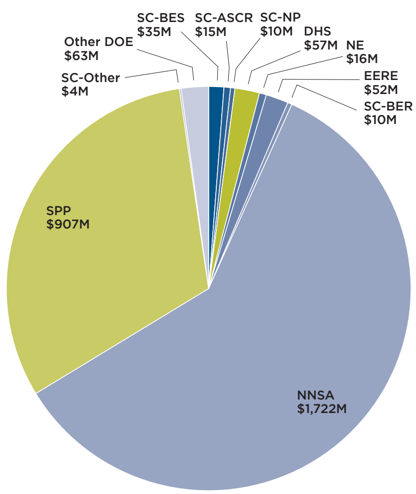
U.S. DEPARTMENT OF ENERGY

SNL grew out of the effort to develop the first atomic bombs. Today, keeping the U.S. nuclear stockpile safe, secure, and effective is a major part of SNL's work as a multi-mission national security, engineering Laboratory. SNL's role has evolved to address the complex threats facing the United States through research and development in the following areas:

- Nuclear Weapons – Supporting U.S. deterrence policy by helping sustain and secure the nuclear arsenal,
- Defense Systems & Assessments – Supplying new capabilities to U.S. defense and national security communities,
- Energy & Climate – Ensuring the stable supply of energy and resources, and protection of infrastructure,
- International, Homeland & Nuclear Security – Protecting nuclear assets and nuclear materials, and addressing nuclear emergency response and nonproliferation worldwide.

SNL's science, technology, and engineering foundations enable its unique mission. The Laboratories' highly specialized research staff is at the forefront of innovation, collaborating with universities and companies and performing multidisciplinary science and engineering research programs with significant impact on U.S. security.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $2, 769M
FY 2015 DOE/NNSA operating costs: $1, 775M
FY 2015 SPP costs (non-DOE/non-NNSA/non-DHS): $939M
FY 2015 SPP as % total Lab operating costs: 33.9%
FY 2015 DHS costs: $55M

Facts

Location:	Albuquerque, NM; Livermore, CA; Tonopah, NV; Amarillo, TX; Carlsbad, NM; Kauai, HI
Type:	Multidisciplinary National Security Laboratory
Year Founded:	1949
Director:	Jill M. Hruby
Contractor:	Sandia Corp., a wholly owned subsidiary of Lockheed Martin Corp.
Responsible Site Office:	Sandia Field Office

Physical Assets

193,483 acres and 1,001 Buildings/trailers (all sites)
7,200,201 GSF in buildings and trailers
(This data includes one (1), 4,781 GSF, GSA leased facility)
Replacement plant value (includes structures): $6,597,385,180
13,942 GSF in 45 excess facilities (22 of these are structures with no GSF)
357,979 GSF in 15 contractor-leased facilities

Human Capital

10,500 full-time equivalent employees (FTEs)
2 joint faculty
213 postdoc total researchers
416 undergraduate students
219 graduate students

Core Capabilities

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

Mission Unique Facilities

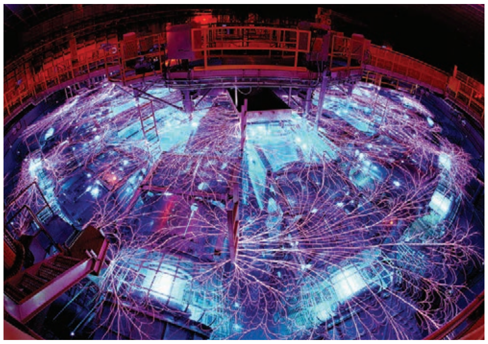
Z Machine
Combustion Research Facility
Microsystems & Engineering Sciences Applications (MESA) Complex

Sandia National Laboratories

Sandia National Laboratories
Accomplishments

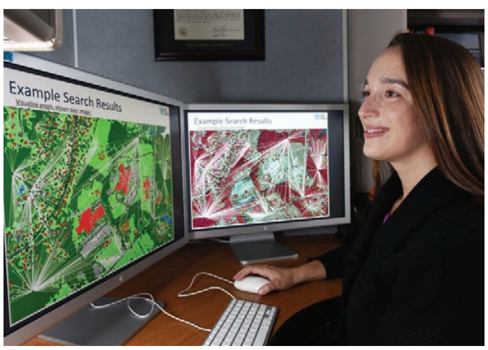
U.S. DEPARTMENT OF ENERGY

Unique Facility
Z Machine Creates Pressures, Temperatures Found Nowhere Else on Earth



SNL's Z machine is the world's most powerful and efficient laboratory radiation source. It uses high magnetic fields associated with high electrical currents to produce high temperatures, high pressures, and powerful x-rays, conditions found nowhere else on earth and crucial to SNL's mission to ensure the reliability and safety of the aging U.S. nuclear stockpile. Z provides the fastest, most accurate, and cheapest method to determine how materials will react under extreme pressures and temperatures, similar to those produced by the detonation of a nuclear weapon. It produces key data used to validate physics models in computer simulations. The Z machine's role in solving the world's energy challenges is directly tied to its potential for fusion.

Research Highlight
PANTHER Aids Analysts Hunting for National Security Needles in Data Haystacks



SNL's Pattern Analytics to Support High-Performance Exploitation and Reasoning (PANTHER) team is developing solutions that will enable national security analysts to work smarter, faster, and more effectively when looking at huge, complex amounts of data in real-time, stressful environments where the consequences might be life or death. Based in research in cognitive science, the team is developing ways to pre-process and analyze huge data sets to make it searchable and more meaningful, and designing software and tools to help those viewing the data glean deeper insights in minutes instead of months. They are rethinking how to compare motion and trajectories and developing software that can represent remote sensor images, couple them with additional information, and make them searchable.

Technology to Market Highlight
Decon Formula Battles Everything from Mold to Meth Labs to Ebola

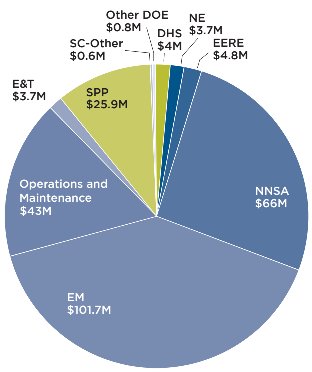
SNL's Decontamination Technology for Chemical and Biological Agents, which won regional and national Federal Laboratory Consortium awards for Excellence in Technology Transfer, contains surfactants that kill 99.99999 percent of bacteria, viruses, and fungi on a surface. Originally used by military and first responders, SNL has licensed the formula to companies that have further developed it to battle toxic mold and decontaminate meth labs, disinfect healthcare facilities and schools, remove pesticides from agricultural packing plants, and fight the Ebola virus in Africa. Seven licensees are manufacturing and distributing products based on the SNL patents, and research efforts continue to discover applications that could lead to more products and licensees.

Savannah River National Laboratory
At a Glance

U.S. DEPARTMENT OF ENERGY

The multiprogram SRNL puts science to work to provide practical, cost-effective solutions for environmental cleanup, nuclear security and clean energy. As the National Laboratory for DOE's Environmental Management program, SRNL applies its expertise across the DOE complex. Its unique facilities include labs for studying the processing and handling of radioactive materials, field demonstration sites for evaluating environmental cleanup technologies, labs for ultrasensitive measurement and analysis of radioactive materials, and the Nation's only radiological crime investigation laboratory.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $254.2M

FY 2015 DOE-EM/NNSA costs: $181.3M

FY 2015 SPP costs (non-DOE/non-DHS): $25.9M

FY 2015 SPP as % total Lab operating costs: 12.3%

FY 2015 DHS costs: $4.0M

Facts

Location:	Aiken, South Carolina
Type:	Multiprogram Laboratory
Year Founded:	1951
Director:	Terry A. Michalske
Contractor:	Savannah River Nuclear Solutions, LLC
Responsible Site Office:	DOE – Savannah River

Physical Assets

39 acres and 54 buildings
829,800 GSF in buildings
Replacement plant value: $1.3B
58,850 GSF in leased facilities

Human Capital

1,000 full-time equivalent employees (FTEs)
20 postdoctoral researchers
45 undergraduate students
2 visiting scientists

Core Capabilities

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

Mission Unique Facilities

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

Accomplishments

Technology to Market Highlight
SRNL Innovation Used to Harvest Medical Isotopes

SRNL's Thermal Cycling Adsorption Process (TCAP) is the best hydrogen isotope separation process in the world. With flexible modularization and process intensification, the process has evolved from a 23-ft tall distillation column to a 2-square-foot mini-TCAP, doubling throughput with one-tenth the footprint and saving hundreds of millions of dollars. SHINE Medical Technologies Inc. licensed the technology and anticipates being able to produce enough molybdenum-99 every year to serve more than two-thirds of U.S. patients, ensuring a stable supply of radioisotopes for a variety of medical diagnostic procedures.

Mission Highlight
Immobilizing High-level Waste through Smart Manufacturing

SRNL has optimized the high-level waste vitrification process using "materials-by-design" and focused laboratory experiments. Tailoring glass-forming chemicals (frit) to the composition of each waste batch has significantly reduced the canister fill time (melt rate) and increased waste loading—the ratio of waste to glass—by 40%. Fewer canisters are filled more quickly and contain more waste, shaving five years off the life of the defense waste processing mission and reducing the cost by $1.5B.

SRNL™ SAVANNAH RIVER NATIONAL LABORATORY

SLAC National Accelerator Laboratory
At a Glance

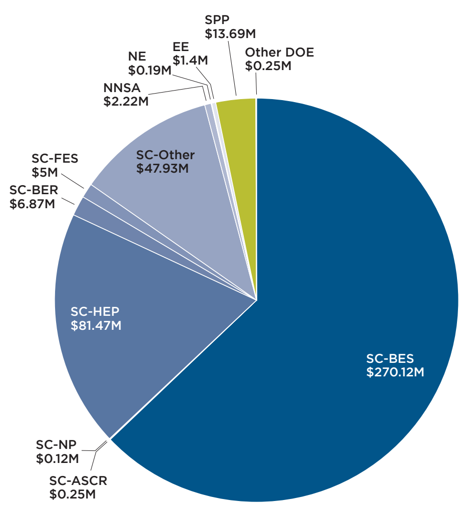
U.S. DEPARTMENT OF ENERGY

SLAC pursues transformative research on some of the most important scientific questions and technology challenges within the mission of the DOE using unique cutting-edge accelerator facilities and world-leading light sources. Founded in 1962 with a 2-mile-long linear accelerator used for revolutionary high energy physics experiments, SLAC has evolved into a multipurpose Laboratory with research programs in materials, chemical, biological and energy science, matter in extreme conditions, cosmology and technology development.

SLAC's mission leverages the Lab's intellectual capital, unique relationship with Stanford University, and location within Silicon Valley to:

- Innovate, develop, and operate world-leading accelerators, light sources and scientific tools;
- Deliver transformative chemical, materials, biological, and fusion energy science enabled by our unique facilities and define their direction;
- Perform use-inspired and translational research in energy; and
- Define and pursue a frontier program in particle physics and cosmology.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $429.6M
FY 2015 DOE costs: $430.2M
FY 2015 SPP costs (non-DOE/non-DHS): $13.7M
FY 2015 SPP as % total Lab operating costs: 3.2%

Facts

Location:	Menlo Park, California
Type:	Multiprogram Laboratory
Year Founded:	1962
Director:	Chi-Chang Kao
Contractor:	Stanford University
Responsible Site Office:	SLAC Site Office

Physical Assets

426 acres and 140 buildings and 35 trailers
1.559 million GSF in buildings
Replacement plant value: $1.459B
2,662 GSF in 2 excess facilities
654 GSF in 1 leased trailer

Human Capital

1,452 full-time equivalent employees (FTEs)
55 faculty
119 postdoctoral researchers
167 graduate students
2,737 facility users
47 visiting scientists

Core Capabilities

Accelerator Science and Technology
Chemical and Molecular Science
Condensed Matter Physics and Materials Science
Large Scale User Facilities/Advanced Instrumentation
Particle Physics
Plasma and Fusion Energy Science

Mission Unique Facilities

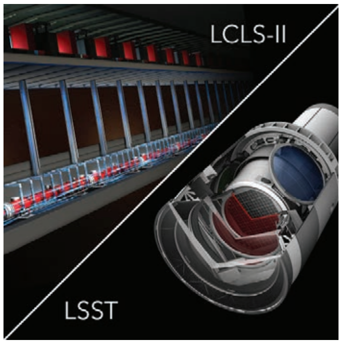
Linac Coherent Light Source (LCLS)
Stanford Synchrotron Radiation Lightsource (SSRL)
Facility for Advanced Accelerator Experimental Tests (FACET)
Instrument Science and Operations Center for the Fermi Gamma-ray Space Telescope (FGST)
Leading the DOE contributions to the construction and operation of the Large Synoptic Survey Telescope (LSST)
Leading the joint DOE-NSF construction of the next generation dark matter experiment Super CDMS
Enriched Xenon Observatory (EXO) at the Waste Isolation Pilot Plant (WIPP)

SLAC NATIONAL ACCELERATOR LABORATORY

SLAC National Accelerator Laboratory
Accomplishments

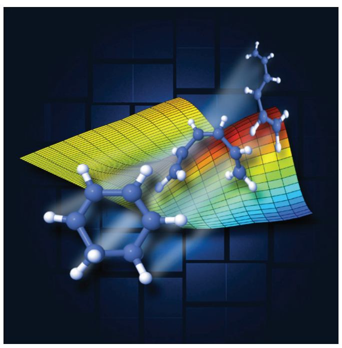
U.S. DEPARTMENT OF ENERGY

Unique Facility
SLAC Leads Major Next-generation Projects for Ultrafast X-ray Science and Cosmology



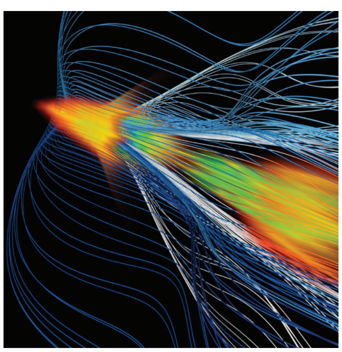
Construction has begun on a major upgrade to the world's brightest x-ray laser, the LCLS. LCLS-II will add a second x-ray laser beam that is 10,000 times brighter and fires 8,000 times faster. The project will greatly increase the power and capacity of the x-ray laser for experiments that sharpen our view of how nature works on the atomic level and on ultrafast timescales. SLAC is also leading construction of the 3.2-gigapixel digital camera (the largest digital camera ever built for ground-based optical astronomy) for the LSST in Chile. LSST will provide a definitive wide-field, ultradeep survey of galaxies for precision measurement of dark energy properties.

Research Highlights
New 'Molecular Movie' Reveals Ultrafast Chemistry in Motion



Scientists for the first time tracked ultrafast structural changes, captured in quadrillionths-of-a-second steps, as ring-shaped gas molecules burst open and unraveled. Researchers using SLAC's x-ray laser compiled the full sequence of steps in this basic ring-opening reaction into computerized animations that provide a "molecular movie" of the structural changes. Ring-shaped molecules are abundant in biochemistry and also form the basis for many drug compounds. The pioneering study marks an important milestone in precisely tracking how gas-phase molecules transform during chemical reactions on the scale of femtoseconds.

Antimatter Catches a Wave at SLAC



Studies at SLAC's FACET (Facility for Advanced Accelerator Experimental Tests) demonstrated a new, efficient way to accelerate positrons, the antimatter opposites of electrons, by having them "surf" waves of hot, ionized gas in a technique known as plasma wakefield acceleration. The method may help boost the energy and shrink the size of future linear particle colliders that probe nature's fundamental building blocks.

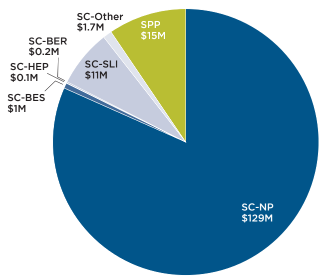
Thomas Jefferson National Accelerator Facility

At a Glance

U.S. DEPARTMENT OF ENERGY

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. The Laboratory is home to the Continuous Electron Beam Accelerator Facility, the first large-scale application of superconducting radiofrequency technology. TJNAF's expertise is enabling an ever-increasing array of applications in the international scientific community, from high-power lasers to advanced particle accelerators.

FY 2015 Funding by Source



FY 2015 Lab operating costs (excluding Recovery Act): $158M

FY 2015 DOE costs: $143M

FY 2015 SPP costs (non-DOE/ non-DHS): $15M

FY 2015 SPP as % total Lab operating costs: 9%

Facts

Location:	Newport News, Virginia
Type:	Single-purpose Laboratory
Year Founded:	1984
Director:	Hugh Montgomery
Contractor:	Jefferson Science Associates, LLC
Responsible Site Office:	Thomas Jefferson Site Office

Physical Assets

169 acres and 70 buildings
876,084 GSF in buildings
Replacement plant value: $397M
74,736 GSF in leased facilities

Human Capital

686 full-time equivalent employees (FTEs)
24 joint faculty
21 postdoctoral researchers
7 undergraduate students
37 graduate students
1,510 facility users
1,346 visiting scientists

Core Capabilities

Accelerator Science and Technology
Large Scale User Facilities/ Advanced Instrumentation
Nuclear Physics

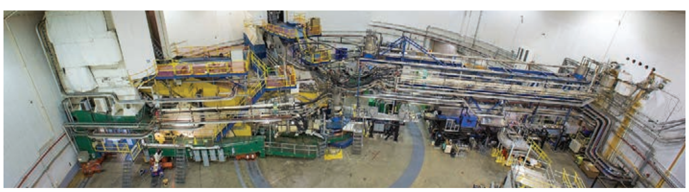
Mission Unique Facilities

Continuous Electron Beam Accelerator Facility

Accomplishments

Research Highlight

Elucidating the Internal Structure of the Proton



In operation since 1995, the CEBAF has been upgraded to triple its original beam energy to 12 GeV and outfitted with new experimental equipment. CEBAF's research program is a unique and essential part of the national and global nuclear physics program, spanning the study of hadronic physics, the physics of complex nuclei, the hadronization of colored constituents, and precision tests of the standard model of particle physics.

Unique Facility

Continuous Electron Beam Accelerator Facility

A robust description of the internal structure and dynamics of protons and neutrons is a fundamental goal of nuclear physics. Key ingredients of this characterization are the elastic electric and magnetic form factors of the proton, which are directly related to the charge and current distributions inside the nucleon. TJNAF experiments discovered that the spatial extension of charge in the proton is surprisingly larger than that of its magnetization.

Jefferson Lab

For additional information visit: www.jlab.org

Appendix E

Acronyms and Abbreviations

Acronyms and Abbreviations

ACT	Agreement for Commercializing Technology
AEC	U.S. Atomic Energy Commission
AGS	Alternating Gradient Synchrotron
AISES	American Indian Science and Engineering Society
Alcator C-Mod (MIT)	Alto Campo Toro fusion reactor (at Massachusetts Institute of Technology)
ALCF	Argonne Leadership Computing Facility
ALS	Advanced Light Source
Ames	Ames Laboratory
ANL	Argonne National Laboratory
APS	Advanced Photon Source
ARM	Atmospheric Radiation Measurement
ARRA	American Recovery and Reinvestment Act
ASC	Advanced Simulation and Computing
ATLAS	Argonne Tandem Linear Accelerator System
B Factory	A machine that produces millions of B mesons and anti-B mesons
BES	Basic Energy Sciences
Bevatron	Billions of eV Synchrotron (a particle accelerator)
BIS	Big Ideas Summit
BNL	Brookhaven National Laboratory
BRC	Bioenergy Research Center
CAS	Contractor Assurance System
CASL	Consortium for Advanced Simulation of Light Water Reactors
CCI	Community College Internship
CD	critical decision
CDF	Collider Detector at Fermilab
CEBAF	Continuous Electron Beam Accelerator Facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFO	Chief Financial Officer

CHCO	Chief Human Capital Officer
CMI	Critical Materials Institute
CRADA	Cooperative Research and Development Agreement
CRENEL	Commission to Review the Effectiveness of the National Energy Laboratories
CRF	Combustion Research Facility
CSSX	Caustic-Side Solvent Extraction
D&D	deactivation and decommissioning
DARHT	Dual Axis Radiographic Hydrodynamic Test Facility
Daya Bay	Daya Bay Reactor Neutrino Experiment
DEAR	Department of Energy Acquisition Regulation
DHS	Department of Homeland Security
DIII-D	A research program to establish the scientific basis for the optimization of the tokamak approach to fusion energy production
DNDO	Domestic Nuclear Detection Office
DNN	Office of Defense Nuclear Nonproliferation
DOD	Department of Defense
DOE	Department of Energy
DWPF	Defense Waste Processing Facility
EADL	Electrochemical Analysis and Diagnostics Laboratory
EBR-1	Experimental Breeder Reactor
ECFWG	Excess Contaminated Facilities Working Group
EERE	Office of Energy Efficiency and Renewable Energy
EFRC	Energy Frontier Research Center
EM	Office of Environmental Management
EMSL	Environmental Molecular Sciences Laboratory
EPA	Environmental Protection Agency
EPSA	Office of Energy Policy and Systems Analysis
ERDA	Energy Research and Development Administration
ERI	earned royalty income
ES&H	environment, safety, and health
ESAAB	Energy Systems Acquisition Advisory Board
ESIF	Energy Systems Integration Facility
ESLG	Energy Sciences Leadership Group
ESNet	Energy Sciences Network
ETC	Energy Technology Center
ETCF	Energy Technology Commercialization Fund
F&A	facilities and administrative
FACE	Free-Air Carbon Dioxide Enrichment
FACET	Facility for Advanced Accelerator Experimental Tests
FAR	Federal Acquisition Regulation
FE	Office of Fossil Energy

FES	Fusion Energy Sciences
FFRDC	federally funded research and development center
FLC	Federal Laboratory Consortium for Technology Transfer
FNAL	Fermi National Accelerator Laboratory (or FermiLab)
FOA	funding opportunity announcement
FTE	full-time equivalent employee
FY	fiscal year
FYNSP	Future Years Nuclear Security Plan
GA	General Atomics
GAIN	Gateway for Accelerated Innovation in Nuclear
GMLC	Grid Modernization Laboratory Consortium
GOCO	government-owned, contractor-operated
GOGO	government-owned and government-operated
GPP	general plant projects
GSF	gross square feet
GSS	government scientific source
HEP	high energy physics
HFBR	High Flux Beam Reactor
HFIR	High Flux Isotope Reactor
HGP	Human Genome Project
HLW	high-level waste
HPC	high performance computing
HRIBF	Holifield Radioactive Ion Beam Facility
ICAM	Identity, Credentials, and Access Management
ICPT	Integrated Contractor Purchasing Team
ICR	institutional cost reporting
IEC	Infrastructure Executive Committee
IEWO	inter entity work order
IMGB	Information Management Governing Board
INEL	Idaho National Engineering Laboratory
INL	Idaho National Laboratory
IP	Intellectual property
IPNS	Intense Pulsed Neutron Source
JC3	Joint Cybersecurity Coordination Center
JCAP	Joint Center for Artificial Photosynthesis
JCESR	Joint Center for Energy Storage Research
JGI	Joint Genome Institute
KAPL	Knolls Atomic Power Laboratory
LAMPF	Los Alamos Meson Physics Facility
LANL	Los Alamos National Laboratory
LANSCE	Los Alamos Neutron Science Center
LBL or LBNL	Lawrence Berkeley National Laboratory
LCLS	Linac Coherent Light Source

LDRD	Laboratory Directed Research and Development
LED	light emitting diode
LHC	Large Hadron Collider
LINAC	Linear Accelerator
LLNL	Lawrence Livermore National Laboratory
LOB	Laboratory Operations Board
LOSA	Laboratory Operations Supervisor Academy
LPC	Laboratory Policy Council
LSST	Large Synoptic Survey Telescope
Lujan	The newest name for the Los Alamos Neutron Science Center (LANSCE), which was formerly LAMPF
M&O	management and operating
MA	Office of Management
MEC	Mission Executive Council
MII	Manufacturing Innovation Institute
MSI	Minority Serving Institutions
MSIPP	Minority Serving Institutions Partnership Program
MTA	Material Transfer Agreement
MYPP	multiyear program plan
NASA	National Aeronautics and Space Administration
NDCX	neutralized drift-compression experiment
NE	Office of Nuclear Energy
NERSC	National Energy Research Scientific Computing Center
NETL	National Energy Technology Laboratory
NFE	nonfederal entity
NGS	next generation solvent
NIF	National Ignition Facility
NIH	National Institutes of Health
NLCCO	National Laboratory Chief Communications Officers
NLCIO	National Laboratory Chief Information Officer
NLDC	National Laboratory Directors' Council
NNMI	National Network for Manufacturing Innovation
NNSA	National Nuclear Security Administration
NOAA	National Oceanic and Atmospheric Administration
NP	nuclear physics
NRC	Nuclear Regulatory Commission
NREL	National Renewable Energy Laboratory
NSBE	National Society of Black Engineers
NSLS	National Synchrotron Light Source
NSLS-II	National Synchrotron Light Source II
NSRC	Nanoscale Science Research Center
NSRL	NASA Space Radiation Laboratory
NSTC	National Science and Technology Council

NSTX	National Spherical Torus Experiment
NSUF	Nuclear Science User Facilities
NuMI-MINOS	Neutrinos at the Main Injector / Main Injector Neutrino Oscillation Search
NWTC	National Wind Technology Center
OCIO	Office of the Chief Information Officer
OE	Office of Electricity Delivery and Energy Reliability
OPC	other people of color
ORNL	Oak Ridge National Laboratory
OTT	Office of Technology Transitions
PEMP	Performance Evaluation and Measurement Program
PEP	Positron Electron Project
PIV	personal identity verification
PMRC	Project Management Risk Committee
PNNL	Pacific Northwest National Laboratory
PPPL	Princeton Plasma Physics Laboratory
PUREX	plutonium and uranium recovery by extraction
QER	Quadrennial Energy Review
QTR	Quadrennial Technology Review
R&D	research and development
RD&D	research, development, and demonstration
RE	rare earth
REDC	Radiochemical Engineering Development Center
RHIC	Relativistic Heavy Ion Collider
RTBF	Readiness in Technical Base and Facilities
S&T	science and technology
SBA	Small Business Administration
SBIR	Small Business Innovation Research
SBV	Small Business Venture or Small Business Vouchers
SC	Office of Science
SCGSR	Office of Science Graduate Student Research
SEAB	Secretary of Energy Advisory Board
SGIG	Smart Grid Investment Grant
SHPE	Society of Hispanic Professional Engineers
SLAC	SLAC National Accelerator Laboratory, formerly known as Stanford Linear Accelerator Center
SLC	SLAC Linear Collider
SLI	Science Laboratories Infrastructure
SNL	Sandia National Laboratories
SNS	Spallation Neutron Source
SPEAR	Stanford Positron Electron Asymmetric Ring
SPP	Strategic Partnership Projects
SRNL	Savanah River National Laboratory

SRS	Savanah River Site
SSMP	Stockpile Stewardship Management Plan
SSRL	Stanford Synchrotron Radiation Light Source
STEM	science, technology, engineering, and mathematics
ST&E	science technology and engineering
STTR	Small business technology transfer
SULI	Science Undergraduate Laboratory Internship
SWE	Society of Women Engineers
SWPF	Solid Waste Processing Facility
TCF	Technology Commercialization Fund
Tevatron	Teraelectronvolt synchrotron
TFTR	Tokamak Fusion Test Reactor
TIR	Technologist in Residence
TJNAF	Thomas Jefferson National Accelerator Facility (or JLab)
TRL	technology readiness level
TTC	Technology Transfer Coordinator
TTEP	Technology Transfer Execution Plan
TTWG	Technology Transfer Working Group
UESC	Utility Energy Service Contract
URM	underrepresented minorities
US/MP	Under Secretary for Management and Performance
US/NS	Under Secretary for Nuclear Security
US/SE	Under Secretary for Science and Energy
VFO	Visiting Faculty Program
WFO	Work for Others
WIPP	Waste Isolation Pilot Plant

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