VALUE OF THE DOE NATIONAL LABORATORIES[1]

NATIONAL LABORATORY DIRECTORS' COUNCIL[2]

OCTOBER 15, 2020

Introduction

The U.S. Department of Energy (DOE) National Laboratories (see table 1) are the crown jewels of the nation's research and development (R&D) ecosystem. Forged during the Manhattan Project of World War II to counter the existential threat facing our country and allies, these initial research sites next pursued the peacetime uses of nuclear power, expanding into the National Laboratory complex we have today that continues to provide rapid advances in science and technology (S&T) aligned to pressing national and world-impacting needs. The seventeen National Laboratories function as an interdependent system with an exceptional set of distinctive capabilities, world-leading staff, and state-of-the art facilities and instrumentation. Together, they have produced a wealth of scientific discoveries and technology innovations in support of DOE's overarching mission of advancing the national, energy, and economic security of the United States,[3] garnering 118 Nobel Prizes and discovering 22 elements on the periodic table along the way. The National Laboratories steward vital scientific and engineering capabilities that are essential to our nation's continued science and technology leadership. Their global impacts include discovering and developing new materials and chemistry to advance energy technologies; advancing the field for synchrotrons, light and neutron sources, particle physics, and materials; helping to map the human genome; and developing passive remediation methods to clean contaminated groundwater while saving energy, time, and billions of dollars. In addition to mission support, these world-leading institutions stand ready to deliver rapid-response S&T to help address natural and man-made threats and disasters, including Fukushima, Deepwater Horizon, Hurricane Katrina, Superstorm Sandy, Puerto Rico earthquake, Ukrainian grid cyber-attack, and now Sars-CoV-2/COVID-19 — just as they have done for more than seven decades.

The National Laboratories design, build, and operate unique scientific instrumentation and facilities to serve tens of thousands of scientists and engineers from academia and industry who are collaborating to solve the most pressing and complex problems of our time. These facilities, which are found nowhere else in the world, support open scientific research as well as classified work. Researchers continually advance the laboratories' state-of-the-art capabilities through the development, deployment, and application of next-generation scientific tools and technologies. These capabilities enable researchers to make fundamental scientific discoveries, support our nation's energy future, and ensure national security. In addition, these capabilities are critical to industry in its development of new materials, improved manufacturing processes, and advanced product testing.

The National Laboratories promote innovation that advances U.S. economic competitiveness and contributes to our future prosperity. They partner with the private sector, especially industry, to integrate fundamental and applied pre-competitive 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 prototypes, and working with industry to move these technologies rapidly into the marketplace, thus creating high-paying jobs. The prowess of the National Laboratories is evidenced by their proven track record in technology transfer and commercialization. In short, the Labs have become key partners in many sectors to U.S. industry.

At the core of the National Laboratories is a first-rate workforce of research scientists, engineers, and support personnel who are entrusted to serve the American people. The National Laboratories embrace the responsibility to steward their people, and as such, they also play a critical role in the nation's science, technology, engineering, and mathematics (STEM) ecosystem. Indeed, as the largest funder of the physical sciences in the United States, steward of the nation's most powerful supercomputers, and with critical mission needs such as securing the nuclear weapons stockpile and developing new and sustainable energy and environmental solutions, the DOE has a vested need to develop talent. Separately and together, the National Laboratories invest in growing the nation's S&T workforce with on-the-job training to undergraduates, graduates, and postdoctoral researchers. Building a talent pipeline has proven to be an invaluable investment that sets the National Laboratories apart from other Federally Funded Research and Development Centers (FFRDCs), and is part of how these laboratories are able to maintain their innovative edge. In addition, DOE directly funds college programs, and individual National Laboratories fund K-12 STEM activities, many with a focus on schools in their local communities.

TABLE 1: NATIONAL LABORATORIES (AS OF OCTOBER 2020)

DOE LABORATORY CONTRACTOR	**LOCATION**
Ames Laboratory Iowa State University of Science & Technology	**Ames, IA**
Argonne National Laboratory (ANL) UChicago Argonne, LLC	**Lemont, IL**
Brookhaven National Laboratory (BNL) Brookhaven Science Associates	**Upton, NY**
Lawrence Berkeley National Laboratory (LBNL) University of California	**Berkeley, CA**
Fermi National Accelerator Laboratory (FNAL) Fermi Research Alliance, LLC	**Batavia, IL**
Idaho National Laboratory (INL) Battelle Energy Alliance, LLC	**Idaho Falls, IA**
Los Alamos National Laboratory (LANL) Triad National Security, LLC	**Los Alamos, NM**
Lawrence Livermore National Laboratory (LLNL) Lawrence Livermore National Security, LLC	**Livermore, CA**
National Energy Technology Laboratory (NETL) Government-owned, government-operated	**Pittsburgh, PA** **Morgantown, WV** **Albany, OR** **Sugar Land, TX** **Anchorage, AK**
National Renewable Energy Laboratory (NREL) Alliance for Sustainable Energy, LLC	**Golden, CO**
Oak Ridge National Laboratory (ORNL) UT-Battelle, LLC	**Oak Ridge, TN**
Pacific Northwest National Laboratory (PNNL) Battelle Memorial Institute	**Richmond, WA**
Princeton Plasma Physics Laboratory (PPPL) Princeton University	**Princeton, NJ**
Sandia National Laboratories (SNL) National Technology and Engineering Solutions of Sandia, LLC	**Albuquerque, NM** **Livermore, CA** **Carlsbad, NM** **Amarillo, TX** **Tonopah, NV** **Kauai, HI**
Savannah River National Laboratory (SRNL) Savannah River Nuclear Solutions, LLC	**Aiken, SC**
SLAC National Accelerator Laboratory Stanford University	**Menlo Park, CA**
Thomas Jefferson National Accelerator Facility (TJNAF) Jefferson Science Associates, LLC	**Newport News, VA**

PART I: Mission and Impact

Today's system of National Laboratories has evolved in response to changing national priorities and needs. Nevertheless, the National Laboratories "remain among the most important institutions in American science and technology."[4] In 2018, Energy Secretary Dan Brouillette (then Deputy Secretary) stated, "Together, the national laboratories are greater than the sum of their parts, creating a world-class scientific complex of unparalleled capability."

DELIVERING SCIENTIFIC DISCOVERY AND INNOVATION

The scale and scope of the National Laboratories enable them to launch "big picture" multidisciplinary investments in large-scale and complex problems, with an emphasis on translating basic science to innovation. They collaborate extensively with universities and industry to develop and deploy scientific and technological solutions that meet national needs. While they emphasize long-term contributions, the National Laboratories are also capable of responding with agility to emerging crises. Specifically, these laboratories:

- Conduct research of the highest caliber in physical, chemical, biological, materials, and computational and information sciences that advances our understanding of the world around us;
- Further U.S. energy independence and leadership in clean energy technologies to ensure the ready availability of clean, reliable, and affordable energy;
- 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 securing the nation's borders; and
- Design, build, and operate distinctive scientific facilities and instrumentation, and make these resources available to the broader research community.

Discoveries and innovations from the National Laboratories have contributed to numerous achievements and improvements related to quality of life, economic competitiveness, and national security. Examples span a wide range of fields:

Fundamental science. National Laboratory researchers have answered fundamental questions about the laws of nature and the cosmos, with discoveries that include the detection of the neutrino, 22 new elements in the periodic table, and the accelerating expansion of the universe. As a result, National Laboratory scientists have won the Nobel Prize 118 times. National Laboratory scientists also publish more than 14,000 papers each year, with 456 designated as "highly cited" since 2019 according to the Web of Science Core Collection.

Sustainable energy. National Laboratories have led the way in the creation of technologies for sustainable energy production and conservation. They have led or contributed to the development of nuclear power, biofuels, thin-film batteries, wind energy technologies, geothermal energy, photovoltaics, electric vehicles, and more efficient windows and appliances that have yielded more than $388B in economic returns on a $12B investment.[5]

Supercomputers. National Laboratories drove the creation and evolution of supercomputing and its application to myriad problems. From the Univacs of the 1950s to the petascale supercomputers in operation today at DOE's Leadership Computing Facilities to emerging exascale and quantum computers, the National Laboratories have helped to maintain U.S. leadership in high-performance computing.

Radioisotopes. National Laboratories initiated large-scale isotope production in the 1940s and continue to provide leadership in nuclear medicine and in isotope development for fundamental science, medical applications, threat reduction, homeland security, industrial applications, and environmental science.

Accelerators. The National Laboratory system boasts a suite of particle accelerators used to study the origins of our universe, investigate the subatomic structure of the world around us, and advance research in medicine, environmental clean-up, and more. In addition, National Laboratory scientists are developing new compact laser plasma accelerators that in the future could transform accelerator-based science of all types and their underlying technologies, including high-repetition-rate lasers.

Biology. National Laboratories bring substantial strength in bioenergy production, carbon biosequestration, environmental contaminants processing, and computational and experimental platforms to generate and test hypotheses. Their approaches include new genomic technologies, computational and data science, advanced bioimaging, and new sensing technologies. This research creates a foundation for targeted manipulations of growth rates, biomass accumulation, resistance to stresses, and the accumulation of desired feedstocks for biofuels and bioproducts in fundamental biology to bioprocessing and bioengineering to address DOE mission needs.

Materials. The National Laboratories 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. The National Laboratories have the expertise and unique facilities to be world leaders in this endeavor.

OPERATING UNIQUE SCIENTIFIC FACILITIES

The scientific facilities at the National Laboratories are operated as a resource for the broader national research community. Many are designated as "national user facilities" and made available at no charge to researchers doing nonproprietary work. In 2019, these facilities served about 40,000 users from academia, industry, and government laboratories, including users from all fifty states and the District of Columbia. Thus, much of the funding provided to the National Laboratories for the operation of these facilities supports research conducted by users who are not DOE or National Laboratory employees, the majority from universities.

The capabilities across the National Laboratory system include advanced light sources, neutron sources, particle accelerators, supercomputers, high-power laser systems, biological characterization tools, high-resolution electron microscopy and imaging techniques, nanoscience laboratories, and test beds for new carbon-free energy concepts, additive manufacturing, energy storage, and energy efficiency in buildings.

These capabilities are housed in highly specialized facilities and run by highly trained technical staffs. Supporting both open scientific research and classified work, they continually advance the state-of-the-art, including through incorporation of artificial intelligence and machine learning techniques. No companies or universities in the United States or abroad have the resources to design, construct, and operate facilities on this scale—or to maintain the large, scientifically diverse research staff needed to support them.

SERVING THE NATIONAL INTEREST

While most of their work is supported by DOE, the National Laboratories represent a national resource for the entire federal government. Their roles in ensuring the safety, security, and reliability of the U.S. nuclear arsenal have provided them with unique capabilities for protecting the nation against high-consequence threats through the effective use of science, technology, and systems solutions. As a result, the National Laboratories have well-established roles in providing R&D support to agencies such as the Department of Homeland Security, the Department of Defense, and the Intelligence Community. The National Laboratories also work with the State Department and the International Atomic Energy Agency on nonproliferation, civilian nuclear power R&D, nuclear waste recycling, and scientific diplomacy.

The National Laboratories also bring their resources to bear on other problems of national importance. Their nuclear capabilities and infrastructure support the deep space missions of the National Aeronautics and Space Administration (NASA). Their expertise in developing and operating leading-edge computational resources has also helped support other federal agencies, including the National Science Foundation, the National Oceanic and Atmospheric Administration, and other agencies. Capabilities developed to support DOE's missions in bioenergy, climate, and the environment are applied to the needs of NASA, the National Institutes of Health, the U.S. Environmental Protection Agency, and the Food and Drug Administration. In each case, the federal agency leveraged the National Laboratories' unique expertise and capabilities rather than duplicating them at great expense.

Finally, the National Laboratories constitute a readily available technical response capability. Many of the agencies listed above have called upon the National Laboratories during national and international emergencies, such that DOE scientists and engineers played key roles in responding to the terrorist attacks on 9/11/2001, the 2009 Christmas Day airline bomb attempt, the BP Deepwater Horizon oil spill in 2010, and the nuclear accident at Fukushima in 2011. More recently, the 17 National Laboratories came together to form the National Virtual Biotechnology Laboratory in 2020, leveraging their deep expertise to address the challenges of the COVID-19 pandemic in areas such as supply chain shortages, the modeling of disease spread and community response, development of new testing protocols, and identification of potential drug candidates. In each of the events outlined above, when the U.S. Government needed immediate impartial technical advice, it turned to the National Laboratories, and these labs 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.

TRAINING THE NEXT GENERATION OF SCIENTISTS AND ENGINEERS

The National Laboratories support the development of the future STEM workforce by making their unique facilities and capabilities available to students and faculty at all levels. They 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 one-day workshops to semester-long appointments to extended-term employment. Altogether, the National Laboratories have engaged more than 450 academic institutions in the United States and Canada.

Productive collaborations between university and National Laboratory researchers also 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 strategic institutes established to focus on new areas of scientific endeavor. Collaborating with National Laboratories provides universities with the ability to conduct science that requires:

- Large, complex facilities and teams trained in their safe and effective operation (e.g., the Advanced Photon Source at Argonne National Laboratory);
- Substantial engineering and instrument development (e.g., the Environmental Molecular Sciences Laboratory at Pacific Northwest National Laboratory); or
- Specialized facilities that are costly to maintain (e.g., the Combustion Research Facility at Sandia National Laboratories).[6]

These collaborations provide opportunities for interdisciplinary research, professional development, and training not found anywhere else.

The National Laboratories subcontract with educational institutions, which not only provides them with an additional avenue for education and training, but also represent a substantial flow of DOE resources to the academic research community. In FY 2014, universities accounted for $97.2M in direct partner funds-in to the National Laboratories through SPPs and CRADAs.

The National Laboratories collectively subcontract over $500M to universities and employ more than 8,500 students, postdocs and faculty. This subcontracted research is in addition to the more than $900M that DOE directly funds the universities through academic research grants. This demonstrates how tightly interwoven the laboratories and universities are within the national research ecosystem and building the next generation of a STEM workforce supported by the DOE.

STRENGTHENING U.S. COMPETITIVENESS

The National Laboratories partner with U.S. industry through a variety of programs and mechanisms to strengthen U.S. economic competitiveness and future prosperity. The National Laboratories have long served as test beds for technology innovation, development, and deployment, which is evidenced by their winning a disproportionately large number of R&D 100 Awards (annually honoring the 100 most innovative S&T developments) and their proven track record in technology transfer and commercialization.

In fact, in response to rising concerns about U.S. innovative capacity, the National Laboratories have stepped up activities to more quickly move research results from the laboratory to the marketplace. From 2018-2020, the National Laboratories partnered with DOE's Office of Technology Transitions on Innovation XLab Summits to expand the commercial impact of these laboratories by highlighting promising technologies from across the complex. These Summits facilitated a two-way exchange of information and ideas between industry, universities, manufacturers, investors, and end-use customers with innovators and experts from the National Laboratories and broader R&D complex. With topics such as energy storage, advanced manufacturing, artificial intelligence, and CarbonX, the National Laboratories have increased the level of engagement from industry in utilizing the unique capabilities at these user facilities.

DOE user facilities support the increasingly popular "open innovation" model in which technologies and expertise are obtained from sources outside a company or institution. For example, General Electric used the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory and the Advanced Photon Source (APS) at Argonne National Laboratory to develop advanced heavy-duty batteries that are now being manufactured at a facility in Schenectady, Connecticut. In FY 2019, 41 Fortune 500 companies took advantage of DOE Office of Science user facilities to conduct research supporting the creation of new products including pharmaceuticals, advanced materials for semiconductors and vehicular batteries, telecommunications satellites, and consumer goods.

MOVING INNOVATION TO THE MARKETPLACE

The National Laboratories deploy capabilities, experts, and intellectual assets to companies, entrepreneurs, and other organizations through their Technology Transfer (T2) missions, helping overcome complex technical challenges, create cutting-edge products and services, achieve greater national security, increase our U.S. global competitiveness, and create cleaner environments to live in. T2 mechanisms include user facility agreements, the licensing of intellectual property (IP), Cooperative R&D Agreements, Strategic Partnerships Projects, and Agreements to Commercialize Technology.

These mechanisms enable the National Laboratories to build on their history of successfully working with industry to transfer technology to the marketplace. In addition to winning 38 of this year's annual R&D 100 awards from *R&D Magazine,* in 2020, the National Laboratories won 8 of the 14 awards for excellence in technology transfer presented by the Federal Laboratory Consortium for Technology Transfer.

The National Laboratories also foster economic development at local, state, and regional levels. Activities include development of science and technology parks, venture capital and assistance networks, entrepreneurial leave programs, technical assistance programs, and participation in economic development organizations.

The innovative spirit and entrepreneurial enthusiasm within the National Laboratories is further evidenced by the large number of patents and licensing agreements that they execute each year. National Laboratory scientists and engineers work closely with industry to ensure that these technology breakthroughs are commercialized. Over the decades, the laboratories have spun out thousands of technologies and hundreds of companies that have enhanced U.S. economic competitiveness and created high-quality jobs. Through partnerships with industry and knowledge sharing, the National Laboratories also enable and contribute to the creation and advancement of such industries as nuclear energy, semiconductors, medical imaging, and solar energy.

In summary, the National Laboratories are invaluable intellectual assets. They have repeatedly demonstrated the ability to anticipate national needs and have delivered high-quality solutions over more than seven decades. Collectively, the National Laboratories:

- Solve important problems in fundamental science, energy, and national security;
- Steward vital scientific and engineering capabilities that are essential to our nation's continued science and technology primacy in a rapidly changing world;
- Design, build, and operate unique scientific instrumentation and facilities that serve tens of thousands of scientists and engineers from academia and industry as they collaborate on solutions to pressing and complex problems; and
- Promote innovation that advances U.S. economic competitiveness and contributes to our future prosperity.

PART II: Stewardship and Management

The National Laboratories are stewarded by the U.S. Department of Energy on behalf of the nation. The underlying stewardship model, which dates to the Manhattan Project (and hence predates the DOE) has proven to be remarkably adaptable. One scholar cites this stewardship model as one of the contributing factors to the National Laboratories' ability to adapt over time to meet changing national needs, specifically with respect to their post-Cold War transition.[7]

IMPORTANCE OF THE GOVERNMENT-OWNED, CONTRACTOR-OPERATED MODEL

To put today's stewardship (and associated management) model in context, it is helpful to recall the early days of the Manhattan Project. Faced with the national imperative to develop an atomic bomb, the U.S. Government turned to academia and industry to quickly identify and organize the necessary scientific and engineering talent. Facilities were established at several locations, some near universities (to leverage talent) and others remote (for security purposes). Although the government originally intended to disband these efforts at the end of the war, it soon realized that the talent and resources it had amassed should be maintained in service of the nation. In the ensuing years, the number of National Laboratories increased, and it was necessary to put in place a more formal management structure. Over time, these facilities became Federally Funded R&D Centers (FFRDCs). They were owned by the government but managed by private contractors (typically academic, industrial, and/or not-for-profit entities).

This government-owned, contractor-operated (GOCO) management model affords maximum flexibility in the management and operation of the National Laboratories. It has held up remarkably well over time, as borne out by numerous studies.[8] In particular, the widely acclaimed quality of the National Laboratories' science and technology is often attributed to the GOCO model. Sixteen of the seventeen DOE National Laboratories are government-owned and contractor-operated.[9] In this model, the government competitively awards a management and operations (M&O) contract to the private sector entity, whether a university, not-for-profit research institute, for-profit company, or some combination thereof. This approach allows the DOE to tap the best management talent in the country to operate the National Laboratories. Table 1 includes M&O contractors for each of the National Laboratories.

All sixteen of the GOCO National Laboratories have been designated as FFRDCs, as are many other entities, including Lincoln Labs, the Jet Propulsion Laboratory, and the Institute for Defense Analyses. FFRDCs maintain capabilities (staff, facilities, and equipment) deemed critical by the federal government and to which it wants assured access. The FFRDC designation codifies a special relationship between the entity and the federal government. In particular, it allows the government to utilize the expertise and resources of the FFRDC in a way that would be inappropriate for non-FFRDCs, including the sharing of information, joint planning, and directed work.

The GOCO model represents a partnership between the government and private sector. The private sector contractor is expected to bring best practices, especially in personnel and research management, to the National Laboratories. This model is most effective when DOE specifies the mission and high-level objectives (the "what") and grants the contractor freedom to determine the best means and methods to achieve them (the "how"). The DOE evaluates contractor performance annually; and superior performance is incented through a variety of mechanisms, including contract term extensions and contract extensions.

The GOCO model affords the government several benefits, including the flexibility needed to manage scientific institutions that must be able to recruit and retain world-class technical talent and adapt quickly to changing national research priorities and S&T advances. The consistent recognition of the National Laboratories as world-leading research institutions, with records of sustained scientific excellence and mission contributions, has often been attributed to these benefits. Similar observations about the quality of GOCO-managed FFRDCs outside of DOE (e.g., Lincoln Labs and the Jet Propulsion Lab) further strengthens the case for the GOCO model.

STEWARDING A WORLD-CLASS SCIENTIFIC AND ENGINEERING WORKFORCE

The National Laboratories collectively employ a world-class workforce of approximately 70,000 people, about half of whom are scientists and engineers, including a large number of PhD researchers. This uniquely talented, scientifically oriented workforce is dedicated to the service of the nation. These dedicated people, along with the unique scientific facilities and instrumentation they maintain and use, comprise an unparalleled intellectual asset that has consistently delivered innovative solutions to address some of the most complex problems for the American people.

Private sector personnel practices, including competitive pay and benefits, allow contractors to recruit and retain the best talent from around the world. The researchers who make up this workforce would otherwise work in academia or industry, thus depriving the nation of the talent needed to address significant S&T challenges. The quality of this workforce is further enhanced through a culture of performance accountability for managers and workers alike. For example, private sector practices employed by contractors regarding succession planning, incentive compensation, recognition, and employee performance management are particularly effective in encouraging collaborative and innovative outcomes. Other important workforce management practices are also maintained and addressed including retention, professional growth, career development, and individual performance management. At the same time, contractors promote a culture of "academic freedom" at the National Laboratories. This culture results in intellectual independence and autonomy that helps ensure that the government obtains unbiased technical advice.

The benefit of this contractor model for workforce management is the agility to reshape and refresh the National Laboratory workforce quickly in response to changing national priorities and fluctuating budgets. For example, the National Laboratories can respond to new opportunities or project terminations with aggressive hiring and/or targeted selective reductions in force. Additionally, private sector personnel practices facilitate flexible workforce acquisition and management including practices such as hiring bonuses, temporary employment arrangements, and work practices to accommodate individual needs. These private sector practices are more complicated and onerous to implement in the civil service. In short, the GOCO model efficiently deploys the right resources against the right priorities at the right time.

LEVERAGING PRIVATE-SECTOR BEST PRACTICES TO BENEFIT THE GOVERNMENT

Contractors who operate National Laboratories for DOE are selected for both their technical expertise and management excellence. As a group, they bring intellectual independence and a high degree of interdisciplinary capability needed to address complex scientific and technical challenges. They also exercise initiative and ingenuity in carrying out their work and have substantial autonomy to apply best private-sector management and business practices in their operations. Moreover, by employing several different contractors, DOE benefits from a diversity of approaches and competition of ideas.

Contractors can bring innovation and best practices from the private sector to day-to-day laboratory operations with greater ease than could the government. Federal practices are designed to evolve slowly over time to accommodate a broad range of interests. In this respect, the private sector is much more agile and creative. The use of alternative financing to modernize facilities and infrastructure is one example where the private sector was able to accomplish an objective with which the federal sector has struggled. Moreover, it was able to do so more quickly and at lesser expense. As a result, modern infrastructure to support federal needs was delivered sooner and at lower cost to the federal government.

National Laboratory contractors use governance practices, contractor oversight, and contractor assurance programs to give DOE confidence that the focus is on mission accomplishment and that appropriate performance standards are maintained. Contractor governance practices include structures that provide clear lines of authority and accountability, access to external expertise, and internal corporate staff and leaders for additional resources. The National Laboratories have defined and implemented transparent contractor assurance programs that enable the government to track and understand laboratory performance. Collaboratively, the National Laboratories and DOE are able to identify notable practices and needed improvements and, in this spirit of continuous improvement, drive efficiency in oversight activities and reduce the need for DOE oversight.

DELIVERING COST-EFFECTIVE R&D TO THE U.S. TAXPAYER

The National Laboratories strive to maximize research productivity, providing a natural incentive for effective and efficient management and operations. Funds conserved through reduced operating costs and management improvement initiatives enable increased research productivity and mission impact through the conduct of additional programmatic work and/or investment in new capabilities, including new staff.

DOE encourages efficiency through its performance evaluation plans. Specifically, DOE challenges National Laboratory management to develop innovative, novel, and cost-effective approaches to operations. An idea demonstrated at one laboratory is then suggested to others, ensuring the promulgation and adoption of best practices throughout the complex. Examples include: integrated management systems; electronic security measures in lieu of a larger protective force; and the leveraging of the corporate parent's buying power through discounts and negotiated agreements (such as travel discounts and software agreements).

The cost of doing business varies across the seventeen National Laboratories. In general, the smaller, single-program laboratories are slightly less expensive due to their simpler structure. Indirect costs are also difficult to compare since each contractor has its own system tailored to the unique characteristics of the laboratory being managed. Despite this diversity in business practices, there are some common attributes. Typically, the costs of benefits, space, utilities, and management are among those added to a researcher's salary. For most of DOE's National Laboratories, the price paid for these support activities is approximately two to three times the cost of a researcher's base salary.[10] (This factor of 2–3 is called the "labor multiplier," and it provides a basis for comparing fully burdened labor costs.)

Comparing the cost of doing business at the National Laboratories with non-DOE laboratories is challenging because of their notable differences. For example, the National Laboratories have major scientific facilities that exist nowhere else in the world and a mission that often requires high-hazard and/or high-security operations. Nevertheless, there are some parallels and conclusions that can be drawn. Consider first not-for-profit research institutes,[11] which have missions and cost-allocation structures that are similar to those of the DOE laboratories. An analysis shows that the labor multiplier averages 3.5, which is substantially higher than the 2.8 average of the National Laboratories. This benchmark comparison demonstrates that the National Laboratories are cost effective when equivalent missions are considered.

Comparing the National Laboratories to universities is more difficult, but a similar conclusion is reached. Universities often lower their costs by employing students (as part of their education and training) and subsidizing faculty research time (by covering many fixed costs at the institutional level). Universities also charge substantially more overhead to non-labor costs than a DOE National Laboratory does,12 lowering the university's burdened labor rate but shifting more overhead cost to non-labor. Further, universities generally allocate their time in percentages over a month, meaning that ancillary activities (which are charged to overhead at the National Laboratories) are effectively direct-charged to the sponsor. If all of this is normalized to the practices at a National Laboratory, one finds that the cost of performing research at a university does not differ that much from a National Laboratory's cost.

In short, DOE's National Laboratory contractors maximize the availability of funding for scientific programs through the use of effective cost management strategies for laboratory operations. The normalized benchmarks suggest that the cost for research performed at these world-class facilities is comparable to, and in some cases lower than, the cost at other major research institutions.

Summary

As Vannevar Bush wrote in his 1945 report, *Science: The Endless Frontier,* "Scientific progress is one essential key to our security as a nation, to our better health, to more jobs, to a higher standard of living, and to our cultural progress."[13] Bush's report led to the modern-day U.S. Department of Energy, whose National Laboratories have been changing and improving the lives of millions of people for nearly 75 years. National Laboratory discoveries have spawned industries, saved lives, generated new products, fired the imagination, and helped to reveal the secrets of the universe. Rooted in the need to serve the public good and support the global community, the National Laboratories' expertise keeps our nation at the forefront of science and technology. Now, as our country—and the planet—face the multiple challenges of producing clean energy and water, mitigating and adapting to climate change, ensuring security, and enhancing human health, the National Laboratories offer the expertise, facilities, and capabilities that can assist us in finding urgently required solutions and in creating the new scientific knowledge essential for a sustainable future.

ENDNOTES

1 The present white paper borrows heavily from several previous National Laboratory Directors' Council (NLDC) documents, especially "The Future of the DOE National Laboratories" (2008, 2012) and "The Value of the DOE National Laboratory System" (2011). The paper also borrows from the NLDC document, "Future Science and Technology Opportunities" (May 2020).

2 The NLDC consists of the directors of all seventeen DOE National Labs.

3 See, for example, "75 Breakthroughs by America's National Laboratories," available at www.energy.gov/downloads/75-breakthroughs-americas-national-laboratories.

4 Peter J. Westwick, 2003, *The National Labs: Science in an American System, 1947–1974,* Harvard University Press, Cambridge, MA, p. 299.

5 U.S. DOE, Aggregate Economic Return on Investment in the U.S. DOE Office of Energy Efficiency and Renewable Energy, https://www.energy.gov/sites/prod/files/2017/11/f46/Aggregate%20ROI%20impact%20for%20EERE%20RD%20-%2010-31-17%20%28002%29%20-%2011-17%20%28optimized%29.pdf, 2017.

6 National Research Council, National Laboratories and Universities: Building New Ways to Work Together–Report of a Workshop, National Academies Press, Washington, D.C., 2005.

7 Peter J. Westwick, 2003, *The National Labs: Science in an American System, 1947–1974,* Harvard University Press, Cambridge, MA, p. 299.

8 These studies, which date to the early 1990s, generally affirm the value and benefits of the GOCO model but have raised concerns about the faithfulness of its implementation.

9 The sole exception is the National Energy Technology Laboratory, which is both government-owned and government-operated.

10 See "Overhead at the DOE National Laboratories," prepared by the National Laboratory Chief Financial Officers (2012), for a detailed discussion of laboratory overhead and cost comparisons; available at www.nationallabs.org.

11 Not-for-profit research institutes include Battelle Memorial Institute, Midwest Research Institute, Research Triangle Institute, Southern Research Institute, Southwest Research Institute, and SRI International.

12 Universities are required by OMB Circular A-21 to use a Modified Total Direct Cost (MTDC) overhead base, which allocates substantial amounts of overhead to non-labor-related costs.

13 Vannevar Bush, 1945, *Science The Endless Frontier: A Report to the President,* by V. Bush, Director of the Office of Scientific Research and Development, July. United States Government Printing Office, Washington; available at https://www.nsf.gov/od/lpa/nsf50/vbush1945.htm#summary.