House Science, Space & Technology Committee Testimony
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INTRODUCTION

As the Director of Lawrence Livermore National Laboratory (LLNL), I thank the Committee for the opportunity to testify and for the Committee's role in and dedication to ensuring U.S. scientific and technical leadership. As a National Nuclear Security Administration (NNSA) laboratory, LLNL is a proud member of the Department of Energy's network of national labs working to make the world a safer place through science and technology (S&T).

This year, I am also serving as the Chair of the National Laboratory Directors Council, and I'm honored to represent my fellow Department of Energy (DOE) Laboratory Directors here. There are 17 national labs in the DOE system, three of which are overseen by the NNSA: Lawrence Livermore, Los Alamos, and Sandia. Together, these world-class national laboratories are strong contributors and critical enablers of U.S. S&T leadership.

LLNL was established in 1952 to pursue audacious ideas through team science. Last year, LLNL celebrated our 70th Anniversary with the theme "Making the Impossible Possible," a mantra that came to life with the achievement of fusion ignition. I will use this recent success—which has been widely compared to the first flight by the Wright brothers—to illustrate key points I wish to make on federal investments to sustain United States leadership in critical areas of S&T.

KEY POINTS

U.S. leadership in Science and Technology matters.
Staying at the forefront of science and technology (S&T) matters for national security and economic competitiveness, which are at stake in an increasingly competitive and dangerous world. The leadership in S&T that the national labs have demonstrated shows what we are capable of – as with the breakthrough experiment on National Ignition Facility in December. We are challenged to ensure we continue to bring the best new ideas, capabilities, and people to bear on important national security challenges.

Establish national long-term S&T priorities and sustain investments toward meeting goals.
Federal investments in S&T are guided by national policy, such as that articulated in the 2020 National Strategy for Critical and Emerging Technologies (C&ET) and 2022 Updated List of C&ETs. Innovation and the sustained support of Congress are required to attain long-term objectives. The DOE national labs are well positioned to provide innovative solutions to pressing national needs; this is especially true for the NNSA national security laboratories. LLNL has mission responsibilities in Nuclear Deterrence, Threat Preparedness and Response, Climate and Energy Security, and Multi-Domain Deterrence. We execute programs ranging from nuclear weapons, biosecurity, and WMD nonproliferation to cyber and space security, infrastructure reliance and climate change, and advanced conventional weapons technologies.

National laboratories are critical enablers of U.S. S&T leadership. Established to meet the special long-term research and development needs for the nation, the system of DOE national laboratories are leading institutions for scientific innovation. The labs tackle critical scientific challenges and possess unique instruments and facilities. They address large scale, complex R&D challenges with a multi-disciplinary approach, working with academia on basic science collaborations that provide opportunities for student training and with industry to develop innovative solutions in support of national priorities. Federal investments in national labs—to support top-notch staff and outstanding scientific capabilities—have provided the foundation of U.S. S&T leadership since the end of World War II. Continuing these investments is crucial for future U.S. S&T leadership.

Public–private partnerships are critical to ensure U.S. excellence in S&T. The DOE national laboratories partner to leverage expertise and develop innovative solutions to grand scientific challenges. Frequently, several DOE laboratories partner as a synergetic team to apply the unique strengths, expertise and capabilities of each lab to grand challenges. The labs also combine forces and capabilities with industry and academia for national benefit. For example, DOE user facilities provide unique capabilities to academia, which helps accelerate scientific discovery and provides a pipeline to train scientists, some of whom are attracted to join the DOE lab workforce. Collaborations with industry have, for example, led to U.S. predominance in high-performance computing (HPC). It is the effective teaming together of the U.S.'s unique national laboratory system, world leading academic institutions, and industrial prowess that enables America's leadership in critical and emerging technologies. Strong partnerships are key to sustaining this leadership.

FUSION IGNITION AT THE NATIONAL IGNITION FACILITY

On December 5, 2022, the National Ignition Facility (NIF) achieved fusion ignition, which had never before been demonstrated in a laboratory setting. Fusion powers the sun and is critically important to the functioning of the U.S. nuclear deterrent, which is why LLNL developed world leadership capabilities in inertial confinement fusion (ICF) to assure the safety and effectiveness of our nuclear weapons stockpile. NIF's 192 laser beams delivered 2.05 megajoules (MJ) of energy to implode a small pellet of fuel and produced 3.15 MJ of fusion energy. This success is a striking example of what national laboratories are able to achieve in decades-long research efforts with strong national support and drawing the expertise of laboratory staff and a broad community of partners.

NIF is a cornerstone of the NNSA's Stockpile Stewardship Program. The capability NIF now offers to conduct fusion experiments, explore fusion science and high-energy-density (HED) physics, and validate HPC simulations of weapons physics strengthens our capability to sustain and modernize the nation's nuclear deterrent without conducting nuclear explosive testing. Demonstration of fusion ignition is also a giant first step forward on the path of using fusion as a carbon-free, abundant source of energy for humankind.

Innovation and sustained support for long-term national S&T priorities. The achievement of fusion ignition was a 60-year-long journey that would not have been possible without innovations and the sustained support of Congress through setbacks, periods of slow progress, ignition success, and challenges yet to be faced. In 1960, nearly coincidental with the invention of the laser, innovative scientists at Livermore invented the concept of ICF. Computer simulations showed that a symmetric, powerful burst of radiation could implode a miniscule capsule and initiate a small fusion reaction. In the early 1970s, the Atomic Energy Commission approved construction of LLNL's first large multi-beam laser system. ICF was viewed as an ideal, long-term undertaking for a national laboratory, requiring major S&T breakthroughs, enabling exploration of HED conditions to support the weapons program, and offering the potential for fusion power.

The large step to construction of NIF, sixty times more capable than its predecessor, required many innovations and the major commitment of the nation to stop nuclear testing and undertake a science-based stockpile stewardship, including NIF as a key component of the program. Whether NIF would provide enough laser energy to achieve ignition was uncertain. NIF opened for operations in 2009, 12 years after construction began. A series of innovations beginning in 2013 launched significant progress toward the goal and important breakthroughs on many fronts in 2021–2022 led to success.

National laboratories as critical enablers of U.S. S&T leadership. LLNL scientists and engineers designed and managed NIF construction, and the facility is maintained, operated, and continually upgraded by LLNL staff. NIF's design and national award-winning construction project drew on expertise gained in designing, building, and operating earlier laser systems at the Laboratory. An engineering marvel, the gigantic laser system functions with nano-scale precision. NIF incorporated numerous innovative leaps in laser technology that required engineering development in parallel with facility construction. Seven technological "miracles" were required – breakthroughs ranging from precision fabrication of targets to optical switches, deformable mirrors, and glass for high-power lasers. These advances have found application in many endeavors, including adaptive optics for astronomy, pioneering advances in extreme ultraviolet lithography, and high-average-power lasers for scientific discovery.

The nearly 4,000 shots fired at NIF before achieving ignition have provided outstanding support to NNSA's national security mission. As a user facility, NIF experiments have advanced HED science and astrophysics through a Discovery Science program. Laboratory staff and the ICF community have worked together effectively to overcome major hurdles in achieving ignition. Important factors that ultimately led to success include innovations in target design, state-of-the-art diagnostics, simulation modeling aided by artificial intelligence, advancements in target fabrication, and multiple improvements that enabled experiments at higher levels of laser energy and power. These advances accelerate progress in HED science and enhance NIF's vital contributions in its mission areas.

Strong public–private partnerships. One of the most enriching aspects of the pursuit of ignition has been the development of partnerships and collaborations that enabled progress. The ignition success is a testament to the strength of the U.S. research ecosystem, which is founded on world class universities yielding a steady supply of well-trained, innovative talent that brings new ideas and a can-do spirit to the national innovation enterprise. Such impossible accomplishments such as fusion ignition are the result. Thousands of people have contributed to this endeavor, and it took real vision and dedication to succeed. That vision and dedication goes to the core of what national laboratories do.

Building NIF was an unprecedented scientific and engineering challenge, engaging U.S. industry in large construction contracts and procurements that drove many high-technology companies to advance the state of the art. For example, over a four-year period the Laboratory procured $550 million of laser hardware to be used in the assembly and installation of over 6,200 precision optics assemblies. Over the last decade, more than 120 diagnostics were designed, developed, and procured. NIF has benefited from decades of experience and ongoing collaborations with national and international partners. A multi-laboratory diagnostics collaboration called the National Diagnostics Working Group was established in 2013 to develop state-of-the-art diagnostics for all the HED science laboratories funded by NNSA.

This year, building on the ignition success, LLNL launched an institutional initiative in Inertial Fusion Energy (IFE). By leveraging decades of investment by NNSA in ICF and exploiting emerging technologies, this initiative seeks to provide IFE leadership on the national and international stage, develop LLNL technical efforts in areas highly synergistic with the Stockpile Stewardship mission, and importantly, work with the community to support the emerging public and private IFE landscape.

NATIONAL LABORATORIES ADDRESS WIDE-RANGING CHALLENGES

Fusion ignition is a particularly exceptional example of innovative multi-disciplinary research at DOE laboratories making a strong contribution to national security through the innovative advance of S&T. A few other examples—drawing on partnerships in which LLNL participated—illustrate the diverse ways national laboratories make a difference.

Human Genome Project and ATOM. The technology that led to the Human Genome Project—and that has yielded the tools that today allow us to create advanced pharmaceuticals—was developed in the national labs and enabled by public investment sustained over decades. Innovative work at LLNL, Los Alamos, and Lawrence Berkeley national laboratories led DOE to undertake the task of mapping and sequencing the human genome in 1987. DOE noted that the laboratories were particularly well suited for the task because of their demonstrated expertise in managing complex, long-term multidisciplinary tasks. Three years later, the DOE Human Genome Initiative joined with the National Institutes of Health and other laboratories around the world to kick off the Human Genome Project. DOE laboratories mapped three of the 23 chromosomes.

The Laboratory's efforts in bioscience and bioengineering led to the establishment in 2016 of ATOM–Accelerating Therapeutics for Opportunities in Medicine. ATOM is a public–private consortium that was formed under a Consortium Agreement signed by LLNL, GlaxoSmithKline, the National Cancer Institute's Frederick National Laboratory for Cancer Research, and the University of California, San Francisco. The consortium has grown to include Oak Ridge, Argonne, and Brookhaven national laboratories. ATOM is developing a pre-clinical drug design and optimization platform that leads with computation to help shorten the drug discovery timeline.

Advanced Supercomputing. Sustained public investment, driven by national security needs, powered a multi-decade effort that led the U.S. to a place of global leadership in HPC. Supported by DOE's 7-year-long Exascale Project, Oak Ridge National Laboratory is currently home to Frontier, the world's fastest supercomputer, capable of 1.85 exaflops (quintillion operations per second) peak speed. This year, LLNL will take delivery of El Capitan, with peak performance greater than 2 exaflops in the next step of NNSA's Advanced Computing and Simulation (ASC) program. NNSA's investment in HPC has led to more than a million-fold improvement in computing speed since the start of the Stockpile Stewardship Program in 1992. But our nation's HPC leadership is not guaranteed; "We would do well not to give it up" because computing has changed—and is changing—everything we do. Modeling and simulation that can be performed with exascale HPC has pushed science forward in amazing ways. And now, artificial intelligence and machine learning can ingest enormous amounts of data and dramatically enhance our ability to make advances in fields ranging from stockpile stewardship to bioscience.

EUVL. In the late 1990s, LLNL, Sandia National Laboratories, and Lawrence Berkeley National Laboratory—the Virtual National Laboratory—developed extreme ultraviolet lithography (EUVL), a breakthrough in chip printing technology that allowed manufacturers to print significantly smaller circuit lines and pack in more processing power. This technology was rooted in LLNL's work on x-ray lasers, specifically the diagnostics that worked in this spectral range. The work was funded by Intel, AMD, and Motorola in a three-year Cooperative Research and Development Agreement (CRADA).
It took almost two decades to incorporate EUVL into semiconductor manufacturing and produce chips that went into commercial smartphones. In 2016, LLNL partnered with ASML Holding NV to advance EUV light sources toward the manufacturing of next-generation semiconductors. This project leveraged LLNL's expertise in lasers and plasma physics and the ability to perform complex, large-scale modeling and simulation using HPC. The partnership helped ASML produce systems that enabled 7-nm mobile phone chips in 2019 and 5-nm chips in 2020. In 2020, Apple's iPhone 12s became the first mobile phones on the market powered by 5-nanometer (nm) microprocessors, which are manufactured using a transistor-packing EUVL process that can be traced back to the EUV technology by the national laboratories. "Everyone's iPhone has a little bit of LLNL inside."

These accomplishments exemplify how national laboratories' S&T is at the critical core of U.S. competitiveness and drives global leadership. The network of laboratories could not play this role without a world class workforce. Our people are the key to everything. The national laboratories need to be able to continue to hire the best and brightest; people are the indispensable ingredient. In a competitive world, because we are leaders, we will have adversaries that try to steal from us. To maintain our leadership, we must be vigilant, but we cannot shut down collaborations and engagement with the rest of the world. Capabilities matter too: to draw scientists, engineers, and technicians into the national lab system, we must maintain leading edge experimental capabilities, particularly the user facilities that provide high performance computing, fusion experimental platforms, x-ray light sources and other capabilities to drive American science and innovation

INVESTING IN NATIONAL LABORATORIES TO SUSTAIN LEADERSHIP

The national security community has played a crucial role in many of the advances I've described. In both computing and HED science, we are reaping enormous benefits outside of national defense applications, but only because of investments driven by national security priorities.

Public private partnerships have played a significant part in most of the laboratories' S&T successes. But the government's role is crucial: without sustained public investment in student and workforce development, cutting edge research facilities including advanced research user facilities at national labs, and the innovative research enterprise that is the envy of the world, the U.S. would not be a leader in such essential areas as HPC, nor would we have been the first to achieve controlled fusion ignition in a laboratory.

Only with reliable, sustained federal funding can the labs continue to hire, train and keep the people we rely on for national security and innovation leadership. And only with consistent public support can we maintain the world-class facilities that both help us attract our workforce and enable the cutting-edge science that keeps the U.S. in a position of global leadership.