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Before

Subcommittee on Strategic Forces
Senate Armed Services Committee
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Thank you for the opportunity to testify before this subcommittee. For about two years I have served as the co-chair of the National Research Council Committee to review the quality of the management and of the science and engineering research at the Department of Energy's National Security Laboratories. Last year I was honored to appear before this subcommittee to testify on the first report of that study committee, which reviewed the management of the laboratories. A second report dealing with the quality of science and engineering is currently nearing completion and delivery to this committee. My testimony today, however, represents my personal views which are not necessarily those of the National Research Council nor have they been reviewed by the NRC.

The three National Nuclear Security Administration (NNSA) National Security Laboratories—Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), and Sandia National Laboratories (SNL)—are a major component of the U.S. government's laboratory complex and of the national science and technology base. These laboratories are large, diverse, highly respected institutions with broad programs in basic sciences, applied sciences, technology development and engineering; and they are home to world-class staffs and facilities. Under a recent interagency agreement among the Department of Energy, the Department of Defense, the Department of Homeland Security, and the intelligence community, these laboratories are evolving to serve the needs of the broad national security community. Despite this broadening of substance and support, these laboratories remain the unique locus of science and engineering (S&E) for the U.S. nuclear weapons program, including, most significantly, the science-based stockpile stewardship program and the S&E basis for analyzing and understanding nuclear weapon developments of other nations and non-state actors.

The National Research Council (NRC) was asked by Congress to assess the quality of S&E and of the management of S&E at these three laboratories. On February

15, 2012, the NRC released a report on the quality of the S&E management[1]. A second report—currently in preparation--will address the quality of S&E. In order to conduct this assessment of quality of S&E, the NRC assembled a committee of distinguished scientists and engineers. Some members of this committee also served on the committee that produced the management report, but most did not.

Assessing the quality of S&E in a meaningful way within the context of the primary nuclear weapons mission of the laboratories requires taking a broad perspective, both in substance and in time. Referring to criteria developed by the NRC Laboratory Assessments Board and to other sources, the committee chose to define the quality of S&E as the capability of the laboratories to perform the necessary tasks to execute the laboratories' missions both at present and in the future: Are the laboratory mission needs being addressed today? Is there a compelling plan for the future? Are the laboratories recruiting and training the next generation of staff? Are the tools and facilities at the cutting edge and adequate to meet mission needs? Is the working environment sufficient to attract and retain high quality staff?

The Nation faces major S&E challenges that extend well into the future. The country has an aging nuclear weapons stockpile, with many of the weapons being decades old. The last nuclear weapons test was conducted before the United States declared a unilateral moratorium on testing in 1992.[2] Because it is no longer possible to test a complete weapon, understanding of the safety and reliability of the nuclear weapons stockpile must be inferred from relevant S&E knowledge. Furthermore, the country faces threats from the development of improvised nuclear weapons (i.e., terrorist nuclear weapons) and nuclear weapons designed by nations seeking to become nuclear powers (such as Iran and North Korea). Understanding and evaluating the threat from such developments—including those that are based on novel design approaches rather than on designs that the United States or its allies have been able to study first-hand—is

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[1] Managing for High-Quality Science and Engineering at the NNSA National Security Laboratories
Committee to Review the Quality of the Management and of the Science and Engineering Research at the Department of Energy's National Security Laboratories – Phase I, February 15, 2012.

[2] 50 USC 2530. In addition, the U.S. has signed, but not ratified, the 1996 Comprehensive Test Ban Treaty (CTBT), and is therefore committed under the Vienna Convention on the Law of Treaties to refrain from actions that would defeat the object or purpose of the CTBT pending entry into force.

of vital importance. Even though we have more than a half-century of experience with nuclear weapons, the need to understand their S&E in detail is likely more compelling today than it has ever been.

An all-encompassing detailed assessment of the quality of S&E at the three NNSA laboratories is a complex task requiring resources far beyond those available to this committee. Instead, we chose to sample a set of activities that are part of the core mission of the laboratories. This assessment is a snapshot of the present with an eye to the future. The committee identified four basic pillars of stockpile stewardship and non-proliferation analysis: (1) the weapons science base; (2) modeling and simulation, which provides a capability to integrate theory, experimental data, and system design; (3) weapons design; and (4) system engineering and understanding of the effects of aging on system performance. The study committee organized itself into four teams, each of which focused on one of these areas.

The challenge facing the nuclear weapon design community in the coming decades is the certification of the performance of weapons that have aged and in some cases have not been tested in the underground test program. Aging—the changes over time in materials and component systems of nuclear weapons—may affect the performance of the weapon. In the absence of the ability to test an aged weapon, an understanding is required of what the aging effects are and how those would affect weapon performance. Life Extension Programs (LEPs) are motivated by aging and by evolving requirements to improve safety, reliability, and other performance characteristics. LEPs now underway sometimes require the incorporation of components that are not identical to those in the original weapon because the exact material is not available, possibly because its manufacturing process has evolved. Predicting the performance of weapons systems whose components are not exactly the same as they were when tested decades ago requires precise S&E knowledge. A strong, systems engineering function is the core integrating activity for the results of high-quality scientific research, development, engineering, and manufacturing. Examples of the importance of high-quality systems engineering are the recent W-76 LEP[3] and the B-61

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[3] The first delivery of refurbished warheads to the Navy was in 2009. Production is to be completed no later than 2021.

LEP currently underway.

Computer modeling and simulation is the key tool for integrating all the knowledge and information about the safety and reliability of a weapons system. For the present, the modeling and simulation capability provides important and effective tools to certify the performance and safety of the stockpile. The quality of the research staff and the availability of underground test data allow models of key physical processes to be fine-tuned to actual data.

The quality of S&E at the laboratories today—across all four of the pillars it examined and across all three laboratories—appears to be at a sufficiently high level to allow the laboratories to effectively certify the safety and reliability of the stockpile. Moreover, in many areas S&E is of very high quality judged in the wider context. Nothing observed would suggest that the S&E underpinning the stockpile stewardship and non-proliferation missions are currently compromised. S&E quality in these four areas of fundamental importance is currently very healthy and vibrant.

In recent years much has been said about the aging work force that maintains the weapons stockpile. Significant progress has taken place in the laboratories and the NNSA to recruit a new generation of weapons designers, scientists, and engineers. The enthusiasm, morale, and capability of the new recruits is impressive. Efforts are being made at all the laboratories to transition information from experienced members of staff to the next generation that will have never seen a weapons test.

Despite these encouraging trends, deterioration of the work environment for scientists and engineers can limit the nation's ability to benefit fully from the laboratories' potential. Looking across the four pillars of stockpile stewardship and non-proliferation examined in this study, several major themes emerge. These themes are to varying degrees common to each of the pillars. These themes in most cases concern aspects of capabilities—impediments to performing experimental work, balance among experimental facilities, facilities and infrastructure, strategic planning and workforce allocation, communications, and workforce issues. Maintenance of the stockpile is a long-term effort extending at the very least decades into the future. While planning for that future should be possible, S&E professionals at the laboratories are frustrated with inconsistent funding from year to year, which leads to inefficiencies, waste, and in some cases a discouraged work force. Many S&E professionals reported having to piece together support from multiple programs. The laboratories appear to be losing some mid-level managers who desire a more stable work environment.

Looking at the longer term, uncertainties in the stockpile certification process will tend to grow unless steady progress is made against S&E challenges. The laboratories recognize the need for new physics-based models to replace some current key models that are based on empirical data from nuclear tests. The new models will have to account for weapons aging due to changes in materials and their properties; this requires cutting edge S&E results. New data will have to be acquired from experiments other than disallowed testing, but the cost of performing the necessary experiments is escalating dramatically. This is a major concern and must be addressed.

Scientists and engineers (and managers) in all pillar areas expressed concern about impediments to performing experimental work. There appears to be a consensus that the amount of experimental work has declined and continues to decline. Laboratory staff cited increasing costs and increasing operational restrictions and controls on experimental work. Necessary experiments are very costly and can require multiple approval steps. This is especially true for experiments using radioactive or otherwise hazardous materials, which are often the key materials in nuclear warheads. For high-explosive-driven hydrodynamics experiments (Hydro Shots), a key part of the primary design and certification process, the time scales involved are months to years, and the costs run into the millions of dollars. If these trends continue and escalate, they could contribute to driving costs to the point where the experiments will not be affordable. Factors driving experimental costs include: the loss of trust, excessive duplicative oversight, formality of operations, and a culture of audit and risk avoidance across the NNSA enterprise without balance from risk/benefit analysis. A number of such factors were discussed in the first report from this study[4], including the loss of trust, excessive duplicative oversight, formality of operations, a culture of audit and risk avoidance across the NNSA enterprise without taking advantage of risk/benefit analyses. All experimental activities have inherent risk, which must be balanced against the benefits that derive from conducting the experiments if reasonable decisions are to be made. It is in the nation's

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[4] See Phase 1 report Chapter IV, pp.22-27

best interest to stabilize the conditions for safe, secure, cost-effective mission success. The risks inherent in doing an experiment need to be brought into balance with the benefits of doing the experiment and the associated risks of not doing the experiment. This needs to be done on a logically sound basis in order to guide important decisions and resource allocations. While no one is advocating irresponsible behavior, the critical need for experimental work must be weighed against the mounting disincentives facing it. Small incremental increases in safety in the conduct of experiments may, for example, require a disproportionate increase in cost. All experimental activities have inherent risk, and successful organizations manage that risk in a manner that allows the work to be performed cost effectively with proper regard for safety. It must be recognized that not carrying out the needed experiments imposes a risk to the ability of the NNSA laboratories to build the capabilities for stockpile certification down the road, which could increase the risk to national security.

The laboratories maintain and operate world-leading major facilities—such as DARHT[5], NIF[6], Z[7], and petascale[8] computing centers. These major facilities are vital to the execution of the laboratories' mission. Smaller facilities are also crucial for executing this mission, and they are an important component of the work environment that attracts new talent and retains experienced staff. Examples of such smaller facilities include: specialized capabilities for the production of nuclear weapons components such as neutron generators; facilities that enable processing and experimentation with plutonium, especially to evaluate its long-term aging; and capabilities for developing radiation hardened microelectronic components, photonic related components, and beryllium parts fabrication. The rising costs of building and operating large signature facilities can threaten the continued support of such vital smaller facilities, particularly in periods of greatly constrained budgets. Moreover, because signature facilities have greater public and political visibility and can be seen as being inextricably bound up with a laboratory's fate, there can be understandable pressure on management to sacrifice other capabilities

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[5] The Dual Axis Radiographic Hydro-Test facility (DARHT) at LANL

[6] The National Ignition Facility at LLLNL

[7] Z Pulsed Power Facility at SNL, also known as the Z machine or the Z pinch facility

[8] Computing facilities capable of performance in excess of one petaflop, i.e. one quadrillion floating point operations per second.

in order to ensure the continuing support of major facilities

The quality of infrastructure is uneven, ranging from world-leading to unsatisfactory. At one extreme, the NIF at LLNL is a world-leading facility of impressive design and engineering. At the other extreme, at the same laboratory (and at the others as well) there are facilities that are considered to be of poor quality, including some at which scientists and engineers report having to perform basic housekeeping functions in order to be able to conduct their work. Examples of old and poor quality facilities include the explosives test facilities at Los Alamos. Many important facilities and other infrastructure are deteriorating, including buildings that house important, expensive, and advanced equipment.[9] This situation can erode morale and the ability of the laboratories to recruit the best young people. Funding difficulties resulting from Federal budget uncertainties clearly make it very difficult to address this issue. Nevertheless, continued careful monitoring by NNSA and Lab management is essential in order to set appropriate priorities for facility improvement.

Computer modeling and simulation is an important component of the weapons program, In the absence of underground testing, the integrated modeling codes (IMCs) provide the only mechanism for assessing the effect on the whole weapon of differences in materials and manufacturing processes relative to those used in the original design. Thus, as these differences increase and underground test data becomes a decreasingly reliable method for calibrating the codes, the requirements for fidelity of physical models and accuracy of the numerical methods in the IMCs will increase in order for them to play their required role in the stockpile certification process. At the same time, the architectures of the processors from which high-performance computers are constructed are undergoing disruptive changes, which will lead to a need for a major software redesign of the IMCs. Finally, the IMC development teams and the developers of supporting software have simultaneously seen the resources available to them decrease (the size of the code teams are down by a third relative to the late 1990's), while their missions have increased from the support of stockpile stewardship to include a number of other areas, such as counterproliferation and life-extension programs.

All three laboratories maintain highly qualified, productive work forces. Statistics

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[9] This matter was discussed in the phase 1 report.

for recruitment—such as acceptance rates and the graduate schools from which postdocs and other early career staff are recruited—are impressive and have remained constant over recent years. Attrition rates are low and relatively steady. The study committee met with many people who are enthusiastic and apparently pleased with being at their laboratories. However, there appear to be some reasons for concern. For example, numerous, and widespread, complaints were expressed about deteriorating conditions at the labs. As recounted in the report of the first phase of this study, these complaints focused primarily on infrastructure and a perceived increasing burden of rules, regulations, operational formality, constraints and restrictions, and administrative burdens. Furthermore while there have not been significant negative changes in recruitment and retention, some of this continued success may be due to the state of the economy since 2008; an improving economy may produce better opportunities outside the laboratories. In some disciplines, it appears that mid-level managers have been leaving for a more stable work environment.

NNSA and the laboratories should pay close attention to the problem of hiring and retaining a cadre of first-rate, creative, energetic scientists, expert in all aspects of modeling and simulation, ranging from deep understanding of the underlying physics and mathematics to the most advanced ideas in computer architectures, algorithms, and programming methods. There is uncertainty concerning staff's ability to make good use of future high-performance computing systems. Expected disruptive changes in computer architectures will require very high levels of computer science expertise in order to create the software to exploit the new capabilities. There is particular concern in core computer science areas, such as computer architecture, systems software, programming models, tools and the algorithms used in these systems. While there are some outstanding individuals in these areas within the labs, there were also signs of difficulty in recruiting and retention. Among laboratory scientists and engineers, these researchers are the most mobile, because they can easily find challenging and lucrative employment in industry—while their work is necessary to the NNSA mission, they have other good options. These researchers and engineers appear less likely to come to the labs and more likely to leave mid-career than those working in other disciplines.

Maintaining a quality workforce in the face of budget uncertainty and competition from other employers will be very difficult. An atmosphere nurturing broad scientific investigation and intellectual excellence, along with the ability to pay salaries that are competitive with industry are the keys to maintaining the laboratories' M&S capabilities.

A supportive and nurturing work environment fosters the ability of highly creative scientists and engineers to do their work while encouraging the retention of senior staff and the recruitment of young staff. The work environment at the laboratories, however, appears to be deteriorating and is at risk of further deterioration[10]. Early-career people at the laboratories expressed concern about time accounting restrictions that seem to limit their working on new ideas at home or on weekends. Some observe that excessive fractionation of their chargeable time among several tasks reduces productivity and efficiency. Inconsistent and unpredictable funding was also cited, along with conflicts between short term project demands and sustained scientific progress[11]. Scientists in National Security Laboratories are isolated from the broader world of science due to classification and the nature of their work. Recently imposed restrictions on traveling to conferences adds to this isolation, limiting career development, access to the latest scientific advances, and the ability of scientists and engineers to bring the full range of relevant science to bear on their work at the laboratories.

Final integration of the advances and understanding in weapons simulation, analyses, design and materials sciences and technology is a critical activity for the science-based stockpile stewardship program. The integration activities fall under the general areas of systems engineering. Systems engineering is also important in the LEP, in which the importance of training the next generation of scientists and engineers cannot be overemphasized. Special projects often help bring the established and the new systems engineering personnel together to assure the health and vitality of systems engineering expertise into the future.

In early 2012 (January to May), the three laboratories fulfilled a request from NNSA to conduct a 120 day study to evaluate alternatives for warheads to be deployed in

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[10] See phase 1 report, chapters IV and V.

[11] This matter was also addressed in the phase 1 report—see, for example, p.17. That report noted that the four agency agreement on national security laboratory governance was an important step in fixing this. In the past, task orders from agencies other than the Department of Energy were often designed to exploit lab staff and infrastructure to obtain a specific product without investing in the development of staff or facilities.

multiple reentry vehicle systems, and to inform NNSA on potential options for future life extension programs (LEPs). The "120-day study"[12]—which considered advanced options for the nuclear physics package and various approaches on how to configure the stockpile using existing components and systems with an emphasis on raising the levels of safety, reliability, and security—provided an example of how a team was created consisting of a few experienced designers, several mid-career designers, and a large number of near entry level designers who were given the opportunity to develop timely and workable design solutions within customer constraints. By bringing together scientists and engineers from these different career stages, it provided a mechanism for transmitting information and experience in a productive manner, and helped develop useful practices. The 120-day study is an example of a best operational practice that demonstrates the high quality of the systems engineering capabilities within the complex.

In conclusion, the Laboratories retain a core of talented and dedicated scientists and engineers who have accepted the responsibilities of the stockpile stewardship program and related activities. Constant vigilance will be required to assure that the work environment enables this work force to perform at a high professional level in order to execute their important mission.

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[12] January 10, 2012 NNSA officially requested that LANL, LLNL, and SNL perform a 120 day study to evaluate alternative warhead designs and to inform NNSA on potential options for future life extensive programs.