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REPORT IN BRIEF

The Quality of Science and Engineering at the NNSA National Security Laboratories

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The FY2010 Defense Authorization Act mandated that the National Nuclear Security Administration (NNSA) task the National Research Council (NRC) to study the quality and management of science and engineering (S&E) at three National Security Laboratories: Los Alamos National Laboratory (LANL), Sandia National Laboratories (SNL), and Lawrence Livermore National Laboratory (LLNL).

This report, the second in response to that request, assesses the quality of S&E at the laboratories based on the laboratories' capability to perform the tasks necessary to their missions. It also identifies current challenges that will need to be addressed in order to maintain the current high quality of S&E at the laboratories.

Introduction

The three laboratories conduct an extensive and diversified research and engineering program for the NNSA. Additionally, they undertake significant research for other organizations, including the Department of Energy, Department of Defense, Department of Homeland Security, and the intelligence community. A complete and detailed assessment of the quality of S&E at these laboratories is beyond the capabilities of a one-year NRC study. Therefore, to carry out this assessment, the committee first identified four basic pillars that are central to the core mission of the laboratories: (1) weapon design; (2) systems engineering and understanding the effects of aging on system performance; (3) the science base for nuclear weapons; and (4) modeling and simulation. It then examined the capabilities of the laboratories—now and in the future—to perform high-quality work in these areas. In examining these capabilities, the committee assessed the quality of specific S&E activities in each of the four areas and it found that, overall, the current quality of S&E at the NNSA laboratories is very high. In particular, no S&E quality issues were found that would prevent their annual certification of the nation's nuclear stockpile. However, current stresses present challenges to maintaining this high level of S&E quality.

Nuclear Weapons Design

The moratorium on nuclear testing since 1992 presents major challenges to certifying the current nuclear weapons stockpile and to future weapons design. In the absence of the ability to test a complete nuclear weapon, the NNSA national security laboratories shifted to a science-based Stockpile Stewardship Program (SSP). Additionally, the SSP provides vital insight to enable the nation to assess threats from weapons designed elsewhere, such as improvised nuclear weapons and nuclear weapons designed by nations seeking to become nuclear powers.

The central idea of the SSP is to systematically upgrade existing mathematical models of weapons so that they are less dependent on old nuclear test data and instead rely more on improved understanding of fundamental weapons physics. But the improved models still require comparison with experiments, and factors at the laboratories are hindering some experimental work. The committee ascribes these factors to a culture of risk avoidance that has resulted in excessive levels of oversight, which in turn has led to increasing costs and difficulties of conducting necessary experiments. In addition to easing barriers to experiments, continued progress of the SSP will require continued recruitment, training, and retention of highly competent nuclear weapons experts.

Systems Engineering and Aging

The three national security laboratories strongly focus on systems engineering in order to ensure the long-term viability and performance of the nation's nuclear stockpile and future nuclear weapons development. The systems engineering staff is responsible for the integration of high-quality scientific research, development, engineering, and manufacturing efforts of the three laboratories and NNSA production sites. Certification of the performance of aged weapons and new components introduced due to Life Extension Programs (LEPs) is one of the major challenges facing the nuclear weapons design community. A strong systems-engineering system is essential to understanding the effects of aging on weapon components, particularly plutonium, and, from that, the capability to predict weapon performance.

The quality of systems engineering at the three national security laboratories is very high. The laboratories possess a unique base of experts with the skills and expertise to deal with some of the most demanding high-technology systems. In the absence of the ability to conduct full-system testing, the current systems engineering staff expressed concern about the lack of opportunities to exercise their skill sets and the increasing impediments to conducting experimental work. Budgetary uncertainties and an aging workforce could negatively impact future recruitment and maintenance of the institutional knowledge base that has been developed over decades.

A pipeline for a new generation of well-trained weapons designers and systems engineers is essential for continued S&E excellence. Assigning more scientific and programmatic development autonomy and responsibility to the laboratories and implementing knowledge preservation and transfer strategies, such as embodied in a recent "120-day study" at the labs, are potential means of sustaining the human resource base.

The Science Base

The national security laboratories' highly competent staff is able to successfully integrate fundamental science, advanced technology, and engineering activities in order to address the challenges of the nuclear weapons mission and other national security concerns.

Infrastructure issues, budgetary uncertainty, and increasing costs and process burdens associated with conducting relevant experiments, however, present significant challenges to the maintenance of a quality workforce at the laboratory. Due to the specialized nature of their work, and the security surrounding much of it, scientists at the national security laboratories may be isolated from the broader scientific community. Recent government travel restrictions have exacerbated the isolation, further limiting career developmevnt and external collaborations. A nurturing and supportive work environment is essential to high staff morale and thus retention of senior and early-career staff.

While the three laboratories maintain and operate world-leading major facilities such as DARHT, NIF, Z and petascale computing facilities, smaller facilities are also crucial for executing the mission, and they are an important component of the work environment that attracts new talent and retains experienced staff. The rising costs of building and operating large signature facilities could threaten the continued support of vital smaller facilities, particularly in periods of greatly constrained budgets.

Modeling and Simulation

In the absence of underground testing of full weapons systems, computer modeling and simulation (M&S) provides the only method of assessing complete weapons today. Because material properties change over time, and refurbished parts may not be identical with those in weapons tested decades ago, the old test data may not accurately predict the performance of those weapons today . Integrated modeling codes (IMCs) are used to simulate weapons performance from fundamental physical knowledge. These are some of the most complex numerical simulations used anywhere, representing decades of work to provide models that capture interactions between multiple physical processes. The NNSA laboratories also produce scientific codes, some representing the present limits of our understanding of underlying physics and pushing the frontiers of mathematical algorithms. The success of the laboratories' M&S requires deep expertise in applied mathematics, computer science, and a range of physical science disciplines.

While the scope of M&S activities at the laboratories has grown in recent years, many of the computation groups are smaller than a decade ago. Recruitment and retention is an ongoing difficulty because M&S researchers are relatively mobile and can find intellectually stimulating and lucrative work in industry. In the coming years, very high levels of computer science expertise will be needed in order to exploit expected advances in computer architecture. Fostering an environment that nurtures broad scientific inquiry and offering salaries that are competitive with industry are the keys to maintaining the laboratories' M&S capabilities.

Cross-Cutting Themes

The committee identified major themes that cut across the core capabilities. Obtaining experimental data is becoming increasingly difficult due to the culture of risk and audit avoidance. The committee recommends a review of the system for assessing and mitigating safety risks and the development of a risk/benefit analysis that will ensure safe and productive experimental work. The quality of infrastructure at the laboratories is uneven. Unsatisfactory facilities reduce S&E productivity and negatively impact morale. The laboratories need to ensure a balance between larger signature facilities and smaller scientific facilities to ensure the laboratories can fulfill their nuclear weapons and national security missions. Addressing these concerns is essential to maintaining the health and vitality of S&E at the NNSA national security laboratories.

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