

Peer Review and Design Competition in the NNSA National Security Laboratories

The state of research and design for the U.S. nuclear weapons program is fundamentally different today than it was two decades ago. During the Cold War era, formal design competitions between teams at national laboratories were combined with nuclear explosive testing to provide the ultimate validation of weapon design procedures. With the moratorium on nuclear explosive testing that began in 1992, laboratories operating under the National Nuclear Security Administration (NNSA) have by necessity strengthened their technical evaluation, modeling, and peer review processes in order to ensure the safety, security, and effectiveness of the nuclear stockpile. Today, the nuclear landscape that remained largely static for many years following the collapse of the Soviet Union is evolving as other nations move to modernize their stockpiles and pursue new weapon designs. In light of this recent nuclear expansion, it is important for the United States to maintain the skills and capability for innovation that are necessary to understand and mitigate threats from foreign nuclear weapon programs.

At the request of Congress, the NNSA commissioned Peer Review and Design Competition in the NNSA National Security Laboratories, a study by the National Academies of Sciences, Engineering, and Medicine, to evaluate the current state of peer review and design competitions related to nuclear weapons at its national security laboratories. The report finds that while simulations and laboratory analyses are useful for providing feedback, these resources cannot fully substitute for the actual design and fabrication process. Though the peer review programs at NNSA laboratories are extensive and well-managed, current design studies do not exercise the complete skill set required for the next generation of nuclear weapon designers. To provide the hands-on experience needed to maintain a workforce at the forefront of weapon design, the NNSA should consider sponsoring end-to-end design competitions to the extent possible within current national policy and agreements. These competitions should culminate in the construction and assembly of a prototype that would not enter the nuclear stockpile.

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BACKGROUND

The Department of Energy's (DOE's) NNSA is responsible for maintaining the capabilities necessary to sustain a safe, secure, and reliable nuclear weapons stockpile for the nation and its allies. Three laboratories are charged with meeting the NNSA mission. The design of the nuclear explosive package (NEP) falls to teams at Los Alamos National Laboratory (LANL) and Lawrence Livermore National Laboratory (LLNL), while non-nuclear components such as the radar, arming, and firing systems are developed and maintained at Sandia National Laboratories (SNL).

There are two distinct periods in the history of these nuclear weapon laboratories: the Cold War period during which nuclear explosive tests were conducted, and the time since 1992, when the nuclear explosive testing moratorium went into effect and new weapons development ceased. More than 50 formal design competitions were held between the two NEP design laboratories during the Cold War period. These competitions resulted in a better understanding of the relationship between different weapon designs and their consequent performance and reliability. The associated weapons tests that took place prior to the moratorium provided strong evidence of how different design choices affected real-world functionality, and the results were sometimes strikingly different from the best predictions. In contrast, at the end of the Cold War, the United States stabilized and reduced its stockpile and put major emphasis on maintaining the existing stockpile. Since the 1992 moratorium, Department of Defense (DoD) has not asked for any fundamentally new warhead designs, and for a considerable time the Congress limited work on new designs. As some nations begin to develop nuclear capabilities and other nations work to update their current stockpiles, the NNSA laboratories must find new ways to cultivate and maintain a quality workforce at the forefront of the field that can inspire confidence in all stakeholders.

PEER REVIEW

In the absence of explosive testing, peer review has become an increasingly important practice at NNSA facilities as a means of identifying potential problems with weapon designs and reduc-

ing risk to the nuclear deterrent. Overall, peer review processes used by all three laboratories are healthy and robust, with each laboratory conducting around 800 peer reviews of various types each year. Incentives for peer review are abundantly evident, and the leadership at each laboratory understands the benefits. LANL and LLNL, the laboratories responsible for the design of the NEP, have taken a somewhat different approach to peer review than SNL, due in large part to SNL's ability to test non-nuclear components and systems. LANL and LLNL rely on vigorous, deep-dive reviews by true, competitive peers and other subject matter experts from inside and outside the weapons complex. Peer review at SNL is driven by the need to assure cost-effective performance of stockpile hardware under all anticipated conditions and by budget pressures to reduce the number of expensive tests.

Even though current peer review programs have been largely successful, all three laboratories have opportunities to improve their processes. For example, with the exception of major reviews associated with the Annual Assessment Report or Life Extension Programs, neither LLNL nor LANL has developed guidance to determine in general when a review is needed, how the review is to be conducted, who should participate in the review, or how to address review findings.

RECOMMENDATION: LANL and LLNL should ensure they have a short, written guidance for a graded approach to peer review, the rigor of which is appropriate to the stage of work and the range of technical activities being reviewed.

In addition, based on presentations and discussions during a visit to SNL, the committee believes the laboratory could make greater use of outside experts in its peer review.

RECOMMENDATION: SNL should strengthen and broaden its use of outside experts on its peer review teams, as articulated in written guidance that Sandia recently finalized.

Current assessment processes such as the Independent Nuclear Weapons Assessment Process (INWAP) have increased confidence in the safety and reliability of stockpile weapons and illustrate

the value of having independent teams tackle common problems using different approaches and methods.

RECOMMENDATION: LANL and LLNL should continue to maintain independent design capabilities, using different approaches and methods, to enable independent peer review of critical technical issues. SNL should likewise carry out, for high-priority issues, competitive designs with independent teams that use different approaches, followed by peer reviews of components, subsystems, and full systems.

DESIGN COMPETITION

Design competitions, and the subsequent testing of components, systems, and subsystems (to the extent possible within national policy and agreements), are critical to developing the next generation of nuclear weapons designers with expertise that goes beyond analysis and modeling. The fraction of the NEP laboratories' science and engineering personnel with hands-on experience in nuclear weapons design and nuclear explosive testing continues to decrease and will reach zero in the next decade or so. Once this experience is lost, it will be difficult to re-establish and could limit the nation's strategic options.

Looking to the future, maintaining nuclear weapon design skills at the NEP laboratories as well as production skills within the NNSA is essential for three reasons:

1. Maintaining a credible nuclear deterrent workforce that is capable of designing and building weapons to meet evolving threats
2. Understanding the status and direction of foreign nuclear weapon programs, and thus strengthening the non-proliferation regime
3. Determining the best and most cost-effective approaches to resolving problems that arise during stockpile weapon surveillance and life extension programs

While the peer review process at the NNSA laboratories is well-managed and effective, the state of design competition is not robust. There have

been no full NEP design competitions since the 1992 nuclear explosive testing moratorium. A full design competition integrates the complete end-to-end design process including the production of an engineering prototype, a step that provides essential feedback about the practicality of a design. Recent design studies have been good analysis and modeling exercises, but they did not result in the actual fabrication of components and systems. Assembly and non-nuclear testing is essential to fully assessing the credibility of a given design and to exercising the complete skill set that is required to maintain an effective nuclear deterrent. While the need to continually replace aging or obsolete non-nuclear components in stockpile weapons and the large life-extension programs for the W76 and B61 have exercised designers' skills at SNL, these exercises do not stimulate the full creativity and innovation that result from a true "blank slate" design competition that includes constructing a prototype. To avoid losing a capability that could be essential for responding to evolving threats, the NNSA complex needs a means of exercising the full suite of nuclear weapon design, development, and engineering capabilities on an on-going basis.

RECOMMENDATION: In order to exercise the full set of design skills necessary for an effective nuclear deterrent, the NNSA should develop and propose the first in what the committee envisions as a series of design competitions that include engineering, building, and non-nuclear testing of a prototype. The non-nuclear components produced by Sandia should be integrated into the design and fabrication of the prototype. This should be done with the clear understanding that this prototype would not enter the stockpile.

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