

three orders of magnitude, said LANL director Charles McMillan. "But that wasn't enough, because we also had to really bring the software we developed up to speed on those new platforms," he recalled. "We had developed a great deal of expertise on Crays when I started. [But] we did not know how to do what we needed to do on the [new] machines. We knew we had to go to 3D, and we had to get all the physics into 3D to do a nuclear calculation."

The SSP ushered in a new peer-review system of validation in which LANL and LLNL check each other's work, said LLNL director William Goldstein. "This has been a critical part of success, and it will continue to be part of sustaining confidence."

Application of the scientific method is key to certifying the performance of the weapons, Goldstein said. That entails "developing hypotheses, theories, models and challenging them with experiments and exercising that loop with the continual application of peer review."

A leap of faith

The success of the program has eliminated one of the objections that many senators had to ratification of the Comprehensive Nuclear-Test-Ban Treaty (CTBT)

in 1999. At the time, the now nearly complete international monitoring system for detecting clandestine underground tests hadn't been initiated (see the article by Matthias Auer and Mark Prior, *PHYSICS TODAY*, September 2014, page 39), so "senators were being asked to take a leap of faith," noted Brian McKeon, principal deputy undersecretary for policy at the Department of Defense. Secretary of State John Kerry, addressing the conference, recalled as a senator listening to SSP skeptics testify that "there was no way possible except through explosive tests" to ensure stockpile performance. "As you might hear on a playground somewhere in America, 'no way' turned into 'way,'" he said.

Nevertheless, the US remains one of eight nations that still must ratify the CTBT in order for it to take effect. And it's unlikely that the treaty today would gain the 67 votes required for passage should the Obama administration resubmit it for ratification. Some senators now want to know why the US has ruled out developing new weapons systems when Russia and China are modernizing their forces, noted former National Security Council staffer Franklin Miller. "Why are we imposing restrictions on ourselves that others aren't?"

As warheads age and their numbers diminish, stewardship challenges remain. "As we reduce the [stockpile] size, it actually means we have to have an even higher confidence in the weapons we retain," said DOE deputy secretary Elizabeth Sherwood-Randall. A program is under way to modify and extend the life of the kiloton-class B-61 bomb (shown on page 31), the oldest and most plentiful weapon in the arsenal. Once complete, the program will permit the retirement of the last megaton-class weapon in the stockpile, the B-83 bomb. (See *PHYSICS TODAY*, December 2013, page 26.) It will also cut the number of nuclear bombs in half, slash by 80% the amount of plutonium and highly enriched uranium in the bomb portion of the stockpile, and lower the bombs' overall destructive power by a similar factor, she said.

Klotz said the NNSA is preparing for the future of the SSP by rebuilding critical infrastructure, continuing to refine weapons diagnostic capabilities, seeking the exascale level in computing performance by 2023 (see *PHYSICS TODAY*, January 2015, page 24), and developing a new generation of scientists and nuclear policy professionals.

David Kramer

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Academies urge new weapons designs

To help maintain the skills of US nuclear weapons designers, the Department of Energy's National Nuclear Security Administration (NNSA) should have Los Alamos and Lawrence Livermore National Laboratories compete to develop new warhead designs, build components, and assemble prototype weapons, says a new report from the National Academies of Sciences, Engineering, and Medicine. Once a mainstay of the US weapons design process, full-scale competitions have not been held since 1992, when a moratorium on nuclear testing began. According to the report, the lack of competitions has meant that the labs have not engineered or fabricated components and systems and thus designers have been unable to exercise their complete skill sets.

The congressionally mandated report, *Peer Review and Design Competition in the NNSA National Security Laboratories*, emphasizes that the competitions should be done with the understanding that final prototypes would not result in new warheads entering the stockpile.

But if the recommendations were followed, such a program may arouse concerns that it could lead to a new weapons system.

That's what happened to the Reliable Replacement Warhead (RRW) program, held in the past decade. That effort began with a design competition between Los Alamos and Lawrence Livermore. Intended to produce modernized weapons without changing the explosive yields or roles of warheads in the current stockpile, the RRW was canceled by Congress in 2008 amid charges that it was unnecessary and would harm US nonproliferation objectives. (See PHYSICS TODAY, June 2007, page 35.)

The new report urges the labs to go further and actually assemble devices that could be tested, though without the nuclear explosive. "In order to adequately exercise their design skills, designers must 'close the loop' and, at the very least, receive feedback from the real world about whether their design is practical and can be manufactured," it says.

Although the competitive peer-review functions that Lawrence Livermore and Los Alamos perform on each other's work are "healthy and robust" for most of their scientific work, the report says, that's not the case with regard to weapons design. Some studies have helped to maintain the labs' competence in the modeling of new weapons designs, but they haven't been validated by engineering and fabrication of new systems.

Dimitri Kusnezov, chief scientist at the NNSA, alluded to the RRW experience when he commented on the report. "The challenge for us as we read the recommendations is, How do you take the best out of this in terms of enhancing peer review and intellectual tensions we require in the laboratories and the [weapons production] plants against the backdrop that the decisions are not entirely ours to make in this space?" he says. "Because the work we do sits at the intersection of science and policy."

The report, written by a committee cochaired by Jill Dahlburg of the US Naval Research Laboratory and Paul Percy of the University of Wisconsin-Madison, warns that the number of science and engineering personnel at Los Alamos and Lawrence Livermore who have "hands-on experience in nuclear weapons design and nuclear explosion testing continues to decrease and will reach zero in the next decade or so. Once this experience is lost, it could limit the nation's strategic options, and it will be difficult to re-establish."

To avoid losing a capability that could be essential for responding to

evolving threats, the report states that "the NNSA complex needs a means of exercising, on a regular and on-going basis, the full suite of nuclear weapon design, development, and engineering capabilities through true design competitions." It says that the more than 50 design competitions that were held during the Cold War led to significant reductions in the size and weight of nuclear warheads and to safety improvements.

Unlike the two nuclear design labs, Sandia National Laboratories is responsible for replacing aging and obsolete nonnuclear components in stockpiled weapons and for carrying out life-extension programs for aging warheads. Those activities have exercised the skills of Sandia's designers, the report says. "However, these exercises do not stimulate the full creativity and innovation that result from a true blank slate design competition that includes engineering and building a prototype."

Kusnezov says he experienced personally "how RRW brought people together in ways that challenged themselves across the complex. I saw the fierceness with which Livermore and Los Alamos were at each other in terms of trying to outdo each other in design and how confident you could be."

The report notes, however, that the manner in which the RRW competition was conducted, with the labs criticizing each other's designs in the setting of a large meeting, "created deep-seated negative feelings on the part of the two . . . laboratories and mistrust of NNSA that still exists."

David Kramer

news notes

Teacher preparedness. Nearly 40% of high school physics teachers teach mostly other subjects. About the same percentage say they are not adequately prepared in some areas. Those and other findings come from a 2012–13 survey conducted by the Statistical Research Center of the American Institute of Physics, which asked 27 000 high school physics teachers from across the US—more than a third of them women—how well prepared they felt for the job.

Teachers were asked to rate themselves as "not adequately," "adequately," or "very adequately" prepared in seven categories: basic physics, other science, application of physics to everyday experience, use of demonstrations, instructional laboratory design, use of computers in physics instruction and labs, and recent developments in physics.

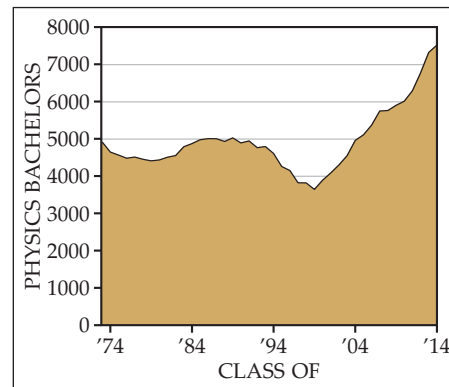
In several categories, a higher proportion of men than women say they are at least adequately prepared. The

largest gender gap was in how prepared teachers felt they are to teach recent developments in physics, with about three out of four male teachers reporting they are adequately or very adequately prepared, compared with roughly three out of five female teachers. But the report stresses that the self-reporting is subjective and that it is "entirely possible that women are objectively just as well prepared as men."

For more details, see the report *High School Physics Teacher Preparation*, available at <https://www.aip.org/statistics/highschool>. An earlier report summarizes objective aspects of teacher preparation (see PHYSICS TODAY, March 2015, page 26).

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Bachelor's trends. The number of physics bachelor's degrees awarded in the US has increased about 5% a year over the past 15 years (see figure). In 2014 some 7526 physics bachelor's degrees were awarded by 743 departments. Of that class, 20% were women, 6% were non-US citizens, and the median age was 22.4 years.



In all, the number of physics bachelor's degrees has more than doubled since 1999. That increase is significantly larger than the roughly 50% rise seen for science, technology, engineering, and mathematics fields and for total US bachelors over that time. More than a third of physics bachelors earned a double major.

The University of Washington leads in the number of physics bachelor's degrees awarded: For the three years 2012 through 2014, it averaged 98 a year. Next was MIT, with 92, followed by the University of California, Berkeley, with 85.

For more data on who is majoring in physics, where, and how physics compares with other fields, see *Physics Bachelor's Degrees*, a recent report by the Statistical Research Center of the American Institute of Physics. The report is available at <https://www.aip.org/statistics/undergraduate>.

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