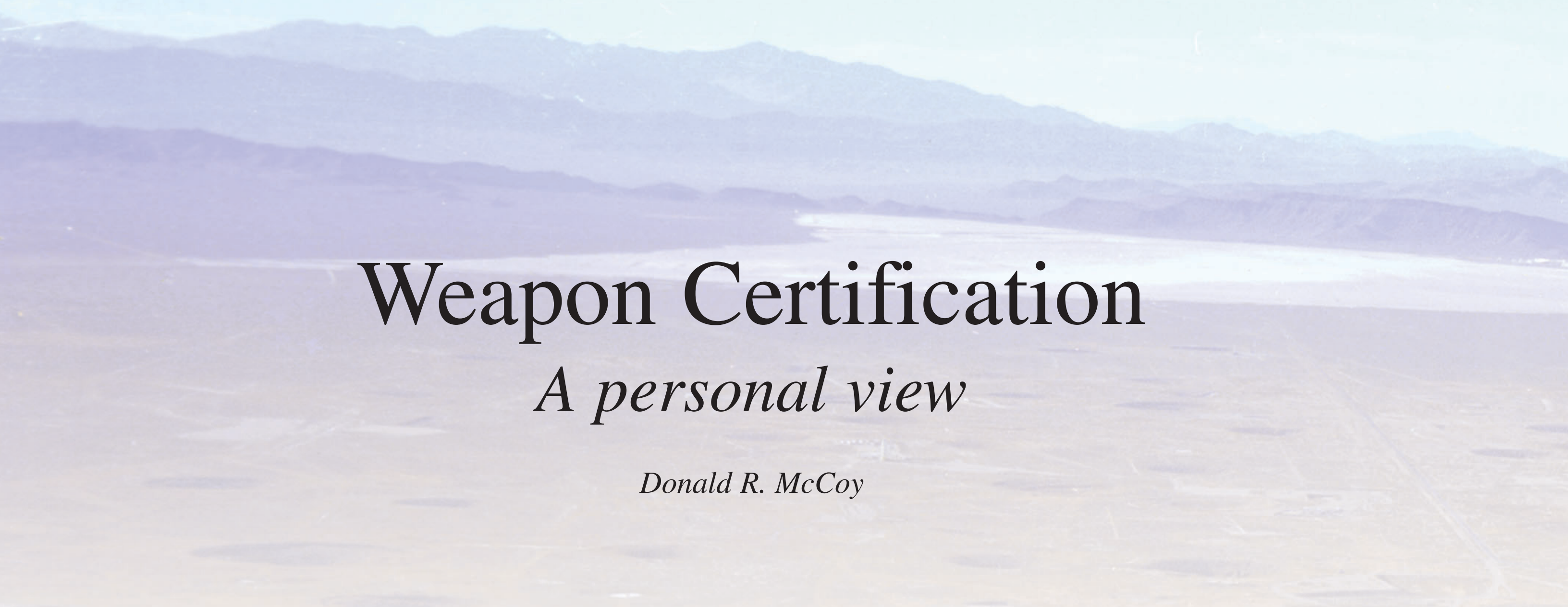

Weapon Certification

A personal view

Donald R. McCoy

Historically, before the September 1992 moratorium on nuclear testing, a nuclear weapon would be placed into the stockpile only after it had undergone several hydrodynamic and nuclear tests over a period of years. Computer simulation codes were used to set weapon design parameters and to estimate both the energy generated by the weapon and the weapon's design margins. Weapons designers knew that the simulation codes were not predictive and gave the wrong answer for weapons safety and performance. To convert simulation code results into predictions of nuclear tests, they would use scaling factors based on nuclear test results. Those nuclear test results would attest to or refute the weapons designers' understanding and judgment of weapons safety and performance. Simulation codes, however, were used to certify yields of weapons placed in the stockpile when the yields were higher than the limit of 150 kilotons established by the Threshold Test Ban Treaty (TTBT). Simulation codes were also used to determine weapon design margins and uncertainties and thus ensure that weapon yields certified for nuclear testing at the Nevada Test Site (NTS) did not exceed the TTBT limit.

Modernization of weapon delivery systems required that new, robustly manufactured designs enter the stockpile on a regular basis. The schedule for weapon development, testing, and production was driven by the planned deployment of Department of Defense (DoD) delivery systems. Today, we certify nuclear weapons performance and safety without additional nuclear testing but with new tools and capabilities provided by the Stockpile Stewardship Program established in 1993.

The Past

I joined Los Alamos under a postdoctoral appointment in the Theoretical Division in 1980 to conduct research in numerical solutions for neutron transport problems with applications to nuclear reactor design and operations. I came to Los Alamos because the Laboratory had the fastest and most capable computers in the world. I enjoyed using this capability to develop improved numerical methods and to publish several papers. I joined the weapons program in the Diagnostic Physics Group in late 1982. The group was responsible for predicting diagnostic measurements for nuclear tests and interpreting the measurements after a test. Nuclear tests were supported by a multidisciplinary team of scientists and engineers from many Laboratory groups and divisions. The weapon development and test program was planned on a multiyear schedule and was highly visible inside and outside the Laboratory. Delaying a nuclear test would bring your name and your supervisor's name to the attention of the Laboratory director, so the team of scientists and engineers felt enormous pressure to meet the planned nuclear-test schedule. The teams supporting nuclear tests were the only organizational unit I have seen at the Laboratory that were stronger and more focused than groups in line organizations. In the early 1980s, Los Alamos and Lawrence Livermore National Laboratories and the Defense Nuclear Agency were conducting 15 nuclear tests per year at a rough cost of $30 to $40 million dollars for each nuclear test.

I was assigned to my first nuclear test, code-named Tortugas, in early 1983. Los Alamos named nuclear tests after towns or places in New Mexico in the early to mid 1980s and towns or places in Texas in the late 1980s and in the 1990s. As far as I know, I am the only weapons scientist that got to work on a nuclear test code-named after the county in which he was born—Bexar County, Texas. I was responsible for predicting the diagnostic measurements that would be fielded on this nuclear test. I learned how to run the simulation codes that predicted the signals measured by the diagnostics on a nuclear test. The timing involved—nanoseconds—and the magnitudes of neutrons, gamma rays, and x-rays were very different from the ones I had seen in the nuclear reactor business. In the 1980s, most recording of nuclear test diagnostics was done with oscilloscopes. In order to provide the nanosecond time response required for the diagnostic measurements, the oscilloscopes had only limited dynamic range for recording and were set for nominal predicted current, one-half the predicted current, and twice the predicted current. The challenge in making these predictions was not limited to running simulation codes in order to predict diagnostic signals. I also had to ask myself if I could believe the results knowing, as I did, that the weapons simulation codes I used as a source term gave the wrong answers.

I remember traveling to the Nevada Test Site for the first time in 1983 to provide the predicted currents to the Physics Division experimentalists. I had learned that it takes nine months to a year to design the numerous measurements for a nuclear-test diagnostic rack (for a description of those measurements and the rack, see the article "How Archival Test Data Contribute to Certification" on page 38), set up the detectors in the rack, and set up and test the recording equipment in the aboveground trailers. The experimentalists took me aside and told me, "If your predictions are a factor-of-2 incorrect, high or low, we don't produce useful data. If this happens, we will take you to the nearest subsidence crater and beat you up and leave you." I suddenly realized that I wasn't performing theoretical research in my new job.

Stringent test schedules combined with simulation codes that were not predictive forced me and everyone else in the nuclear testing program to manage risk. Because I couldn't perform all the sensitivity calculations I thought were reasonable in time for each scheduled test, I learned to focus on those sensitivity calculations that would yield a factor-of-2 difference in predicted detector current and worked on smaller sensitivities only if I had time. The weapons designers worked under similar constraints. Fortunately, after eight years of typically three nuclear tests a year, I was never rolled in a subsidence crater—but I did I work with some technical staff who came close. The nuclear test and weapon development programs provided the most enjoyable work experience I have had at the Laboratory by lending a strong sense of mission and value to my job.

How Things Changed

It has been over 10 years since the inception of the stockpile stewardship program, whose mission is to develop the means to maintain confidence in the nuclear weapons stockpile without additional nuclear testing. The main driver for stockpile stewardship was to support the nonproliferation policy of the Clinton administration. At that time, the thinking was that, if the United States did not conduct nuclear tests, other countries would not test and develop nuclear weapons. It turned out that some member countries of the nuclear club continued nuclear weapon development and testing and some nonnuclear countries have since announced intentions to develop nuclear weapon capabilities using nuclear testing.

I applied for a change-of-station position and was fortunate to be accepted to work for the Nuclear Testing Division at the Department of Energy (DOE) Defense Programs Office in 1992 and 1993. As it turned out, 1992 was the last year of U.S. nuclear testing. The Congress passed a bill with the Exon/Hatfield/Mitchell amendment, and in October 1992, President George Bush signed the bill that allowed the United States to continue nuclear testing for three years under the following restrictions: There could be only five tests per year. Four would test safety improvements to existing stockpile weapons, and one would test reliability. The Congress directed the DOE and the DoD to prepare and submit to the Congress, in early 1993, a three-year plan for those last 15 nuclear tests.

The planning was an interesting exercise. The DOE, with the help of its legal staff, interpreted the law precisely as written—nuclear testing was for safety and reliability. The DoD viewed the law as less specific. It hoped to use those last tests to obtain nuclear test data that would improve the predictive capability of our simulation codes and to conduct nuclear tests at the extremes of the weapon design margins. I was a member of the technical staff that, with input from the Los Alamos and Livermore, proposed several three-year plans and presented each one for discussion and debate among an interagency group chartered by the National Security Council. We proposed so many test schedules that the joke in Washington, D.C., at that time was, "What is the nuclear test schedule of the day?" By the summer of 1993, the DOE and DoD had not settled on a definition of the last 15 nuclear tests, and the Clinton administration extended the nuclear test moratorium indefinitely.

I returned to the Laboratory in late 1993 and continued to participate in the formulation of the U.S. nuclear testing policy. Once the moratorium was extended, the administration pursued the goal of a worldwide comprehensive test ban treaty. The debate shifted to defining exactly what is allowed under a nuclear test ban and what is verifiable under a test ban treaty. An interagency group debated whether hydronuclear experiments—defined by the National Security Council staff as the generation of less than 4 pounds of generated nuclear energy—should be allowed, or whether limited nuclear testing—less than 1 kiloton of energy generated—should be allowed because at that time that yield was thought to be the verification threshold.

The question of limited nuclear testing was addressed by DOE and DoD representatives at a nuclear weapons symposium held in Omaha, Nebraska, in June 1995. The symposium was hosted by Admiral Henry Chiles, then commander in chief of the U.S. Strategic Command. Energy Secretary O'Leary and the nuclear weapons laboratory directors attended the symposium. The laboratories presented the technical benefits of limited testing, and representatives of the nuclear weapons complex plants discussed the required physical-plant infrastructure and capabilities to maintain and refurbish nuclear weapons. The DoD proposed a strategy that implemented the new simulation and experimental capabilities of stockpile stewardship while allowing up to 10 years of limited (less than 1 kiloton of generated energy) nuclear testing to validate the stockpile stewardship capabilities. The DOE proposed a strategy of continued implementation of stockpile stewardship capabilities without conducting limited nuclear testing or hydronuclear experiments.

The outcome of the symposium was a statement from the laboratory directors to the secretary of energy that limited nuclear testing was not needed at that time. The DoD agreed to the DOE's strategy, with the additional safeguard that the laboratory directors would provide the secretaries of energy and defense with an annual assessment of the stockpile and of the need for nuclear testing. The administration announced in August 1995 that the United States would pursue a zero-yield nuclear test ban treaty. At this point, stockpile stewardship was the only option under U.S. policy to maintain confidence in the performance and safety of the nuclear weapons stockpile.

The Present

Using stockpile stewardship tools and capabilities in place of nuclear tests requires a greater predictive simulation capability than was available in the past to certify changes or modifications to the nuclear weapons stockpile and to develop modified weapon designs. A main goal of the present nuclear weapons program is to manage risk across an aging nuclear weapons stockpile by making informed decisions about nuclear weapon design margins and uncertainties and about ways in which those margins and uncertainties change over time. This goal can be accomplished by continuous surveillance, that is, sampling of weapon components in the nuclear weapons stockpile, evaluating and assessing the condition of those weapon components, and establishing the lifetimes of those components. Decisions to replace weapon components, which sometimes cannot be manufactured exactly like the original components, must be based on the best technical assessment and evaluation of the current weapon design margins and uncertainties and on ways to improve the weapon design margins and reduce their associated uncertainties. Los Alamos is currently restoring the nation's capability to manufacture pits. The question to be answered is, "Will a pit manufactured at Los Alamos produce the required nuclear weapons performance that pits manufactured at Rocky Flats used to produce?" In the past, nuclear testing verified that yield. At present, testing is not available. However, I believe the answer to the previous question is "yes," but proving this assertion in the absence of nuclear testing is a difficult technical challenge. An underlying concern that has always been an issue with stockpile stewardship is that certifying nuclear weapons without nuclear testing will not address "unknown" issues that could arise in the nuclear explosion phase of a nuclear weapon's operation. Since this nuclear explosion phase of operation is not accessible without a nuclear test, technical judgment by weapons scientists and engineers will underpin our statements concerning weapon certification.

Quantitative understanding of design margins and uncertainties requires the development of new simulation tools and capabilities because the nuclear explosion phase of a nuclear weapon can no longer be accessed directly. We started the development of these simulation tools and capabilities with the creation of the Accelerated Strategic Computing Initiative (ASCI) program in 1996. We currently have new codes that can run nuclear weapon implosion and explosion problems in three dimensions on terascale computing platforms that could never be simulated in the past. The most difficult elements, verification and validation of these simulation tools and capabilities, are under way.

Certification. The most challenging technical problem to solve for stockpile stewardship is proving or certifying that the results of these simulation tools are believable and can be used to produce meaningful design margins and uncertainties for our aging nuclear weapons or for replacement components that cannot be manufactured exactly like the original ones. That is why we are developing new models that can more accurately capture the details of physical and material behavior. In turn, the new models have led to new experiments in the radiation flow and static and dynamic behavior of materials. The results of these experiments will provide the empirical basis for the models and a means to validate the models.

For the Los Alamos–manufactured pit, we have developed a certification strategy that requires development of weapon simulation baseline models that should match past nuclear test data for both the implosion and explosion phases of experiments (see the article "How Archival Test Data Contribute to Certification" on page 38). These models are built with legacy and Advanced Simulation and Computing (the new ASCI program name) tools and will be used to predict results of subcritical implosion-phase experiments conducted on assemblies whose geometries mimic those of nuclear weapons. These subcritical experiments are planned for the next few years (see the article "The New World of the Nevada Test Site" on page 68).

We will ask such questions as "Which baseline simulation model gives the best prediction for the experiments?" and "Which simulation model gives the smallest uncertainties in the nuclear weapon design margins?" Of course, the hard part in answering these questions is relating implosion experiments to the explosion phase of a nuclear weapon when the only tool available is a simulation model. This certification strategy will be one of the first big tests of the success of the stockpile stewardship program at Los Alamos.

Another challenge in stockpile stewardship has developed over the past 10 years; it was not anticipated when the program started. Originally, there was concern that entry-level weapons scientists and engineers without nuclear weapon development and testing experience would have too much confidence in these new stockpile simulation tools and capabilities. Actually, this concern has not yet materialized. The general view of entry-level staff has held that the current legacy and advanced simulation tools do not have the right, physically based modeling capabilities or are not sufficiently validated. Therefore, when a stockpile issue arises and an assessment and evaluation of the issue are undertaken, no timely resolution of the issue occurs because of the need for a perfect simulation tool with which to address the problem. The technical judgment developed in the old weapon development and testing program, which included management of risks when weapons were certified and tested, does not have an equivalent development of technical judgment in the Stockpile Stewardship Program. That is why managers in the current nuclear weapons program must assume more risk concerning certification than managers had to assume in the past. I believe this situation is a key management challenge to stockpile stewardship.

The new approach to certifying a nuclear weapon is very different from that used in the past and requires new tools and capabilities that are currently under development. Over the next several years, many parts of the nuclear weapons stockpile will be refurbished. That process will require certification of both replacement components manufactured by new methods and modified components. We may also have to certify modified weapon designs. The test for stockpile stewardship will occur during this period, and I am waiting for the answer to the question, " Is stockpile stewardship succeeding or failing?" ■

Donald McCoy is deputy associate director for weapons physics at Los Alamos and is currently responsible for pit manufacturing and certification programmatic activities. Don was program director for nuclear weapons simulation and computing at the Laboratory from 1997 through 2001. He managed a successful program that focused on the development of predictive nuclear weapons simulation tools. He has held various managerial positions in the Nuclear Weapons Program and served on a Department of Energy change-of-station position for the Nuclear Testing Division and the Assistant Secretary for Defense Programs. He joined the Laboratory in 1980 and has experience in simulation code development, nuclear test diagnostics, and nuclear weapon design and certification. Don has received five DOE Awards of Excellence in the Nuclear Weapons Program and a Los Alamos National Laboratory Distinguished Performance Award. He obtained his Ph.D. in nuclear engineering from Northwestern University in 1981. He is a member of the American Nuclear Society.