

**THE NATIONAL NUCLEAR SECURITY ADMINISTRATION'S BUDGET  
REQUEST FOR FY 2002**

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**OPENING REMARKS**

Mr. Chairman and members of the committee, thank you for the opportunity to appear before you. I am the Director of the Lawrence Livermore National Laboratory (LLNL). Livermore is committed to maintaining confidence in the U.S. nuclear weapons stockpile as a principal participant in the nation's Stockpile Stewardship Program. The Laboratory also contributes to vital national programs to reduce the growing threat posed by the proliferation of weapons of mass destruction.

My testimony discusses Livermore's accomplishments in the National Nuclear Administration (NNSA) programs as well as the technical and programmatic challenges we face. But first, I want to thank the Congress for your strong support of the Stockpile Stewardship Program and our threat reduction activities. I believe we are making exceptional technical progress so far. Looking ahead, a strongly supported and sustained Stockpile Stewardship Program is clearly needed to ensure that this nation can maintain the safety, security, and reliability of the stockpile over the long term. Likewise strong and sustained support is needed for our activities in threat reduction—that is, nonproliferation, counterproliferation, and counterterrorism activities. Threat reduction is the “other side of the national security coin” to deterrence and stockpile stewardship. Scientific and technological superiority is the bedrock of both sides of the coin. The contribution of science and technology to stockpile stewardship is well understood. However, the role of science and technology in nonproliferation and threat reduction is not as well articulated and I hope that my remarks today provide a better understanding of this critical element of our national security work.

**INTRODUCTION**

On April 10, 2001, General John Gordon, head of the National Nuclear Security Administration (NNSA), and Admiral Richard Mies, commander in-chief of U.S. Strategic Command, were at Livermore to celebrate the certification of the refurbished W87 ICBM warhead. Speaking as the “customer,” Admiral Mies called the occasion an “historic event” and “the first real test of stockpile stewardship.” The W87 Life-Extension Program was a challenge to all elements of the Stockpile Stewardship Program. Devising the engineering improvements to the warhead, going into production in a less than fully

functional weapons complex, and certifying the performance of the refurbished warheads without nuclear tests were all major accomplishments. It is an important early success story, but in the words of General Gordon, “we still have a long ways to go.” More challenging technical issues are on the horizon as the needs to refurbish other weapon systems emerge.

Weapon refurbishment decisions and actions bring into play the spectrum of capabilities that we are striving to attain through the Stockpile Stewardship Program. First, to recognize and evaluate aging problems (and other defects) in weapons and devise remedies, we must understand in detail the science and technology that governs all aspects of nuclear weapons. We are making progress, but we need even better investigative tools. Second, the nuclear weapons production complex must be able to remanufacture parts and refurbish weapons as needed. Currently the complex is far from fully functional. Third, we must be able to certify with confidence the performance of the refurbished warheads as well as the other weapons in the stockpile. That requires expert judgment and application of the experimental and computational tools that we also use to improve our fundamental understanding of nuclear weapons. Finally, acquisition of this spectrum of capabilities is time urgent to meet existing requirements for weapon refurbishment and to deal with other weapon performance issues that might arise.

As a consequence, a principal goal of the Stockpile Stewardship Program has been to expeditiously put in place a set of vastly improved scientific tools and modern manufacturing capabilities: 100-teraops supercomputers; advanced radiography capabilities to take three-dimensional images of imploding mock primaries; a high-energy-density research facility, the National Ignition Facility, to study the thermonuclear physics of primaries and secondaries; and efficient, flexible manufacturing facilities. These investments are very demanding of resources. Other demands on the program have added stress. To date direct support of the stockpile has required more attention and resources than we initially anticipated to meet Department of Defense requirements. In addition, investments are needed to meet new security requirements and to recapitalize the nuclear weapons complex. Finally, yet other demands may arise out of the Presidentially mandated reviews of the U.S. military in the 21st century and in particular, the role of nuclear weapons and force requirements. When the ongoing national security reviews are completed and the full scope of our requirements is clear, we may need to readdress whether the proposed budget will be sufficient to carry out all necessary programmatic activities.

Livermore has major responsibilities within the Stockpile Stewardship Program, and the Laboratory’s successes in 2000—as well as the challenges that lie ahead—provide a snapshot of the overall program. I have mentioned the certification of the W87 warhead, refurbished through a life-extension program, as one outstanding accomplishment. Lawrence Livermore and Sandia/California are starting a life-extension program for the W80 cruise missile warhead, designed by Los Alamos. The effort builds upon a modern baseline understanding of the W80 and its performance, which was developed cooperatively by the New Mexico and California laboratories to support a formal DoD/DOE study in 2000 to define refurbishment options. Meeting the directed date for

the first production unit (FY 2006), will greatly stress the resources requested in FY 2002 for this life-extension effort

Lawrence Livermore is also responsible for a number of state-of-the-art experimental and computer facilities—in operation and in development—that are essential for stockpile stewardship. Construction of the National Ignition Facility (NIF) at Livermore is now more than 50% complete. I am pleased to report that progress has been excellent on all technical fronts. The new baseline for the NIF project was developed by a restructured project management team that includes many of the Laboratory's most outstanding people including especially those with large-project experience. They worked with experts from U.S. industry to develop the plans, and private industry has a very prominent role in completion of the project. General Gordon provided certification of the NIF project to Congress on April 6, 2001. Construction is proceeding well with "First Laser Light" scheduled for FY 2004 and project completion with all lasers in FY 2008. Work is currently proceeding on a schedule that is constrained by the annual budget, not by what is now technically possible.

The Accelerated Strategic Computing Initiative (ASCI) is central to many of the success stories of the Stockpile Stewardship Program. Last summer, we took delivery from IBM of ASCI White, the world's most powerful computer, capable of 12.3 teraops (trillion operations per second). This machine and ASCI Blue Pacific (4 traops) are being used to support stockpile stewardship through a variety of applications. For example, at the end of 1999, we conducted the first-ever three-dimensional simulation of a nuclear primary explosion, which is an important program milestone, and we are close to completing a simulation of a nuclear weapons secondary. We are earmarked to take delivery of our next ASCI computer in FY 2004, a machine that will be capable of 60 to 100 teraops. The Terascale Simulation Facility (TSF) is needed to house it. Funding in FY 2002 is required to make the building available and fully equipped to accept an ASCI-scale system in 2004.

During their visit to the Laboratory, General Gordon and Admiral Mies also recognized the success of our Counterproliferation Analysis and Planning System (CAPS). They both cited CAPS as a "great partnership" among the DoD, the NNSA and the Laboratory that "shows we can successfully operate in the interagency environment." A dynamic partnership between Livermore and the military commands, CAPS is now part of the counterproliferation planning process for the U.S. Strategic Command, Special Operations Command, and other regional military commands. CAPS exemplifies how the idea of a researcher can be developed by a multidisciplinary team into prototype, which is then picked up by a major sponsor to become a product that has significant impact on national security.

Despite these notable accomplishments in CAPS and many of our other threat reduction programs, a number of these programs are facing major funding cuts. The future of some of these activities will depend on high-level reassessments currently underway by the Administration. Others will depend on establishment of a better understanding of their importance in the overall threat reduction strategy and our confidence in overcoming the sheer difficulty of the technical challenges they entail.

Of greatest concern are the nonproliferation and verification research and development (R&D) programs. These programs provide the science and technology base for the U.S. agencies with operational responsibility for characterizing foreign weapons programs and detecting proliferation-related activities, for detecting and mitigating the use of weapons of mass destruction (WMD) against U.S. civilians, and for negotiating and monitoring compliance with arms-reduction and other agreements. Because the threat is continually evolving, as adversaries employ more sophisticated denial and deception and as more detailed treaties are negotiated, we must continually push the technical state of the art to develop new capabilities. The importance of these programs has been recognized by the Congress in the last two years, when it markedly increased funding for these activities above the President's request. For FY 2002, however, this budget line is slated for a 25% cut in operating funds, which will have a significant impact on delivery of the capabilities that are being developed by these programs.

The cooperative U.S.–Russian programs have been extensively reviewed by various panels and committees. Almost without exception, the reviews concur as to the valuable work being done by these programs—securing at-risk Soviet-legacy nuclear material, disposing of excess highly enriched uranium and plutonium, and assisting in the downsizing of the Russian weapons complex through civilian job creation for displaced weapons workers. The reviews also concur as to the enormity of the undertaking, the difficulty of working with the Russian bureaucracy, and the need for continued involvement. We have made important progress in these program areas; however, it has been nearly ten years since the first Russian programs were initiated, and it is certainly appropriate to reassess the programs against current needs and U.S. national security objectives. In the meantime it is important to avoid disrupting high priority programs. One such Livermore program currently at risk is our work with the Russian Navy to enhance the protection and control of fresh nuclear fuel for their nuclear powered vessels. This work involves direct interactions with Minatom and the Russian Ministry of Defense, an activity that would have been inconceivable during the Cold War.

I am concerned that funding cuts proposed for FY 2002 will result in not only the termination of critical threat reduction projects but also the loss of essential personnel. Livermore faces this possibility most particularly in proliferation detection, WMD response, and plutonium disposition. We need to retain this cadre of people who have both the necessary technical expertise and the on-the-ground experience with these specialized programs, people whose experience base is irreplaceable.

## **THE STOCKPILE STEWARDSHIP PROGRAM**

The Stockpile Stewardship Program is designed to ensure the safety and reliability of the U.S. nuclear weapons stockpile required to meet national security needs of the 21st century. Confidence in the safety and reliability of the weapons is to be maintained through an ongoing and integrated process of stockpile surveillance, assessment and certification, and refurbishment. Stockpile stewardship is a principal mission of the National Nuclear Security Administration (NNSA). NNSA began operation in March 2000.

General John Gordon, Administrator of NNSA, recently announced organizational changes to enhance NNSA's performance in core mission areas. The changes realign and separate programmatic and operational functions within the agency. The organizational and other positive changes adopted by General Gordon will clarify lines of communication and authority, which should improve overall efficiency and performance. Execution of the Stockpile Stewardship Program remains the primary responsibility of the NNSA Deputy Administrator for Defense Programs (NNSA/DP).

The changes being made at NNSA will facilitate long-range planning and the preparation of a comprehensive five-year budget, which are critically important. The Stockpile Stewardship Program faces many competing demands for available resources. Difficult trade-off decisions will have to be made. NNSA must balance evolving requirements for directed stockpile work, the need for vigorous campaigns to prepare stockpile stewards for the more challenging issues that will arise as weapons continue to age, and required investments in research and production facilities and people.

We will greatly benefit from enhanced five-year planning because it will establish future expectations at each of the laboratories and production facilities, which greatly helps in resource, workforce, and facility planning. Also important to our activities will be the results of the high-level review under way of the role of nuclear weapons and nuclear force requirements, part of the Administration's broader review of the U.S. military in the 21st century. Lawrence Livermore's expertise in many nuclear-weapons issues is a national resource to contribute to these deliberations. As discussed below, enhanced five-year budget planning and the outcome of high-level reviews are also important for the future of our Laboratory's nonproliferation and arms control programs.

### **Integrated Program Management and Execution**

Integrated program management and execution is critical to the success of the Stockpile Stewardship Program. The three major program elements—surveillance, assessment and certification, and refurbishment—are tightly interconnected. So are the activities of the three laboratories, the production plants, and the Nevada Test Site. Livermore has many close partnerships and working relationships with other sites in the weapons complex. As one of the two nuclear design laboratories, we have particularly important formal certification responsibilities. The Laboratory also operates a number of unique, state-of-the-art experimental and computer facilities that are essential for both assessment of stockpile performance and certification of refurbishment actions.

The Stockpile Stewardship Program is formally managed by NNSA/DP through three overarching sets of activities: Directed Stockpile Work, Campaigns, and Readiness in Technical Base and Facilities. NNSA/DP uses this breakout to make evident program integration, establish more clearly program goals and budget priorities, and help to identify program risks if there are budget shortfalls. The integrated program activities include:

- **Directed Stockpile Work.** Directed Stockpile Work supports the readiness of weapons and includes activities to meet current stockpile requirements. The effort includes weapon maintenance, comprehensive surveillance, weapon baselining, assessment and certification, supporting research and development, and scheduled weapon refurbishments. It also includes other stockpile commitments, such as dismantlement and information archiving.
- **Campaigns.** Campaigns are directed at making the scientific and technological advances necessary to assess and certify weapon performance now and over the long-term. They develop and maintain specific critical capabilities that are needed to sustain a viable nuclear deterrent. Each campaign has milestones and specific end-dates designed to focus advanced basic and applied science, computing, and engineering efforts on well-defined deliverables related to the stockpile. The current set of eighteen campaigns provide a planning framework for the program's research and development activities.
- **Readiness in Technical Base and Facilities.** "Readiness in Technical Base and Facilities" ensures that necessary investments are made in people and their supporting infrastructure. Readiness includes the fixed costs and the investments of the Stockpile Stewardship Program, and it aims to ensure the presence of: (1) high-quality, motivated people in the program with the needed skills and training; (2) a well-maintained, modern infrastructure—to support the activities of these people—that is operated in a safe, secure, and environmentally responsible manner; and (3) special experimental and computational facilities that must be developed and brought on line for stewardship to be successful in the long term.

A rigorous planning process has been established to clearly define programmatic milestones to be achieved within each of these program areas. The Stockpile Stewardship Program is now defined by a series of five-year plans, one for each program element, describing goals and objectives. The five-year plans, which were developed with participation by the laboratories, plants, and the test site, are accompanied by annual implementation plans with detailed milestones.

## **ACCOMPLISHMENTS AND CHALLENGES IN DIRECTED STOCKPILE WORK**

Livermore is the design laboratory for four weapon systems in the stockpile: the W87 and W62 ICBM warheads, the B83 bomb, and the W84 cruise missile warhead. They are expected to remain in the stockpile well past their originally anticipated lifetimes; the W62 already has. Significant effort is being expended on weapons surveillance and baselining,

on assessing the weapons' performance, and on maintenance and selective refurbishment. We are just completing a major effort to extend the stockpile life of the W87 warhead, and Livermore and Sandia/California have been assigned the responsibility for the engineering development work to refurbish the W80, a Los Alamos-designed weapon.

### **Stockpile Surveillance and Baselineing**

Our stockpile surveillance efforts focus on Livermore designs in the stockpile and on understanding the effect of aging on weapons in the stockpile. Aging is important because it affects the physical characteristics of materials, and we must determine how these changes impact weapon safety and performance. With a better understanding of aging, our stockpile surveillance can be more predictive, making possible systematic refurbishment and preventative maintenance activities to correct developing problems.

As we gather more data and gain experience, we review and upgrade our surveillance programs—refining sampling plans, measuring additional attributes, introducing new diagnostic tools, and improving analysis methods. We are also taking on responsibility for surveillance of pits from Livermore-designed weapons in the stockpile to better balance the workload. These activities had been conducted at Los Alamos.

In addition, we are improving the sensors and techniques used to inspect all stockpiled weapons. These efforts, developed in the Enhanced Surveillance Campaign, contribute to surveillance activities that are part of Directed Stockpile Work. For example, Livermore has completed development of a solid phase micro-extraction diagnostic to detect and characterize the presence of minute quantities of chemicals in warheads. The system is now deployed at Pantex. We are also completing development of high-resolution x-ray tomography for imaging weapon pits, and deployment at Pantex is in progress. Furthermore, development continues of high-energy neutron radiography for nondestructively detecting small voids and structural defects in weapon systems. Working with Y-12, AlliedSignal, and Savannah River, we are also pursuing micro-sensors for evaluation of materials degradation and corrosion in weapon systems.

### **Stockpile Performance Assessments**

Annual certification of the stockpile is fully reliant on the laboratories' assessment capabilities. Demonstration-based assessments also underpin Livermore's W87 stockpile life extension work (discussed below) and our contributions to W76 Dual Revalidation and the Submarine Launched Ballistic Missile (SLBM) Warhead Protection Program. Assessments of the performance of stockpiled weapons and modification actions must be demonstration based—that is, grounded on existing nuclear test data, component-level experiments and demonstration, and simulations using detailed, validated computer models. To the extent possible, non-nuclear experiments are used to assess weapon component performance. Together with past nuclear test results, they also are used to validate computer simulations. Once validated to the extent possible, weapon physics simulations guide expert judgment about integral stockpile issues at this time.

**Annual Stockpile Certification.** Formal review processes for certification of weapon safety and reliability in the absence of nuclear testing have been established as part of the Stockpile Stewardship Program. It is essential that judgments and decisions made by the stockpile stewards are credible among themselves, to DoD and others in the nuclear weapons community, and to the Administration and Congress. In April 2000, the Secretaries of Energy and Defense certified to the President that the U.S. nuclear stockpile is safe and reliable and that no nuclear tests are needed at this time.

Annual certification is based on the technical evaluations made by the NNSA laboratories and on advice from the laboratory Directors, the commander-in-chief of U.S. Strategic Command, and the Nuclear Weapons Council. To prepare for annual certification, our Laboratory collects and analyzes all available information about each stockpile weapon system, including physics, engineering, and chemistry and materials science data. This work is subjected to rigorous, in-depth review by managers and scientists throughout the program.

**W76 Dual Revalidation.** The W76 Dual Revalidation Program was a four-year-long intensive effort to reaffirm the soundness of the W76 SLBM using two independent teams—the Original Design Team (Los Alamos and Sandia/New Mexico) and the Independent Review Team (Livermore and Sandia/California). The W76 Project Officers Group (POG) managed and coordinated the process. The California W76 team submitted its final report in March 2000. Among its accomplishments, Livermore conducted the first-ever hydrodynamic test of the late-time implosion history of the W76 primary, and we performed an extensive series of engineering tests to examine mechanical response and possible component aging phenomena. Nuclear design calculations with the newest codes have provided a re-evaluation of the system performance margins. The results of the dual revalidation provide the basis for planning the W76 life-extension program.

### **Stockpile Maintenance and Refurbishment**

Each year, the Nuclear Weapons Stockpile Plan sets the requirement to maintain a safe and reliable nuclear weapons stockpile, and it specifies the number of weapons of each type to be in the stockpile. Among other responsibilities, the DoD establishes military requirements, which are incorporated into the plan. These requirements drive the Directed Stockpile Work workload for DOE, particularly in the resource-intensive area of refurbishment activities and life-extension programs. The W87 life-extension program is in its production phase and activities are planned for the W76 and the W80 systems.

**The W87 Life Extension Program.** Earlier this month, Admiral Richard Mies (commander-in-chief of U.S. Strategic Command) and General Gordon visited Livermore to celebrate certification of the life-extension refurbishment of the W87 ICBM warhead. They signed the Final Weapon Development Report. This first completed certification of the engineering design and production processes for a life-extension program (LEP) is a groundbreaking milestone for the Stockpile Stewardship Program. It demonstrates the laboratories and the production facilities working together to overcome physics, engineering, and manufacturing challenges to meet DoD requirements without conducting a nuclear test. Assessment of nuclear performance is based on computer simulation, past



nuclear tests, and new above-ground experiments that addressed specific physics questions raised by the engineering alterations and computer simulations.

The objective of the W87 LEP was to enhance the structural integrity of the warhead so that it may remain part of the enduring stockpile beyond the year 2025 and will meet anticipated future requirements for the system. The W87 warhead/Mk21 re-entry vehicle (RV) is a candidate for a single RV option for the Minuteman III ICBM. The development activities have included extensive flight testing, ground testing, and physics and engineering analysis. High-fidelity flight tests, incorporating the latest technological advances in onboard diagnostic instrumentation and telemetry, provide added confidence in the reliability of the design modifications. The first production unit was completed at the Pantex Plant in February 1999, and the final production unit is scheduled for 2003.

**Life Extension of the W80.** Under the direction of the Nuclear Weapons Council, the W80 POG is pursuing a LEP for the W80 cruise missile warhead, which was developed by Los Alamos and Sandia/New Mexico. A formal study that defined refurbishment options and their feasibility (known as a 6.2 study) was completed in 2000. Livermore and Sandia/California participated as an Interlaboratory Peer Review team. In this role, the California team evaluated proposed modifications to the warhead for feasibility, aging effects on the modifications, impact to the DOE complex, and production issues. Working closely together, the New Mexico and California teams established a modern baseline understanding of the W80 and its performance.

The W80 POG has selected a final refurbishment option for the LEP, and NNSA has assigned the associated engineering development task to Livermore and Sandia/California. This assignment better balances the workload among the laboratories and provides a vehicle for the Laboratory to develop the skills of the next generation of stockpile stewards. The California laboratories will also be the design agencies for certifying the safety and reliability of the refurbished warheads, the W80 Mods 2 and 3. Los Alamos and Sandia/New Mexico will continue to be responsible for certification of the W80 Mods 0 and 1. Meeting the currently directed date for the first production unit (FY 2006), would require \$30 million for Lawrence Livermore in FY 2002 that is not in the President's budget.

## **ACCOMPLISHMENTS AND CHALLENGES IN STOCKPILE STEWARDSHIP CAMPAIGNS**

As I have earlier described, stockpile stewardship campaigns are focused, technically challenging, multifunctional efforts that address critical capabilities that will be needed to achieve certification of stockpiled weapons as more challenging issues arise. Eight campaigns are aimed at providing the scientific understanding needed to certify the nuclear weapons stockpile and to support required weapon modernization in life extension programs. Three additional campaigns focus on weapon engineering. They provide specific tools, capabilities, and components in support of weapon maintenance, modernization, and refurbishment, as well as certification of weapon systems. The final seven campaigns support readiness by focusing on sustaining the manufacturing base

within the weapons complex. The campaigns are multilaboratory, and examples of Livermore's major contributions are highlighted below.

### **Experiments, Theory, and Modeling to Better Understand Plutonium**

One of the major success stories of the Stockpile Stewardship Program is the significant improvement we are making in understanding the properties of plutonium. This is a very important issue—we need to understand aging in plutonium and the effect of aging-related changes on the performance of an imploding pit of a stockpiled weapon. The required capacity of the production complex depends on the anticipated lifetime of plutonium pits in the stockpile. An accurate assessment is necessary. If we underestimate the lifetime of pits, we may overinvest in facilities to remanufacture plutonium parts. If we overestimate the lifetime of pits, the nation could find itself critically short of capacity for plutonium operations when it is vitally needed.

**Laboratory Experiments and Modeling.** Available information indicates that plutonium used in pit applications is stable; however, we must assess the effects of long-term aging. Plutonium's properties are among the most complex of all the elements. To study the subtleties of plutonium, we have combined advances in theoretical modeling with the use of sophisticated experiments. For example, we are using old pits and accelerated-aging alloys to determine the lifetime of pits. Accelerated-aging samples are plutonium alloys with a mixture of isotopes to increase the rate of self-irradiation damage so that the material "ages" faster.

Data from our materials, engineering, and dynamic experiments show, so far, that pits are stable. Livermore has conducted important experiments on old pits using advanced materials characterization tools such as our Transmission Electron Microscope, the most powerful such instrument in the NNSA complex. Using the Transmission Electron Microscope, we have discovered nanoscale ( $10^{-9}$  inch) bubbles that are likely filled with helium in the microstructure of aged plutonium. The plutonium appears to be accommodating the helium, which is created through self-irradiation, in a stable form. The presence of these bubbles was predicted theoretically using computer simulations of the radiation damage process.

**Experiments at the Nevada Test Site.** Livermore is conducting sub-critical experiments at the Nevada Test Site to investigate the properties of plutonium shocked and accelerated by high explosives. Matter can be ejected from the free surface of materials that undergo shock. The experiments characterize ejecta, which is thought to affect the performance of primaries in weapons. Performance is being studied as a function of plutonium age as well as surface finish and manufacturing technique. Results will affect estimates of pit lifetime and decisions about future production of replacement pits, and improve our fundamental understanding of performance.

Unlike our first three subcritical experiments, tests in the current Oboe series are performed inside individual confinement vessels. Six of the eight planned Oboe experiments have been completed, four of them in 2000. By using small expendable vessels, up to 12 separate experiments can now be conducted in the same underground

test chamber—the zero room—over several years. Following the test, after the chamber is determined to be contamination-free personnel are allowed to enter the zero room to retrieve films and data. The use of the vessels for subcritical experiments is resulting in significant cost reduction and improved data return. In the past, each subcritical experiment followed a complex schedule and time-consuming preparations, and after each test, the zero room, with all its diagnostic equipment, was permanently contaminated and could not be reused.

In addition, we are bringing into operation the Joint Actinide Shock Physics Experimental Research (JASPER) Facility at the Nevada Test Site, a two-stage gas gun for performing shock tests on special nuclear materials. JASPER experiments, which are planned to start in FY 2001, will complement other experimental and modeling activities by providing scientists more precise equation-of-state data at extreme conditions than can be obtained from other types of experiments.

### **Modeling and Experiments to Probe Primary Performance**

**The Contained Firing Facility/Flash X-Ray Facility.** Hydrodynamics testing is the most valuable experimental tool we have for diagnosing device performance issues for primaries in stockpiled weapons. Through hydrodynamics experiments conducted at Livermore's Site 300 and the Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT) at Los Alamos, weapon scientists are able to characterize the energy delivered from the high explosives to a mock pit, the response of the pit to hydrodynamic shocks, and the resulting distribution of pit materials when they are highly compressed. These three pieces of information are critical for baselining weapons, certifying stockpile performance, and validating hydrodynamics simulation codes.

Over the past decade, we have made tremendous advances in the development of diagnostics capabilities and experimental techniques used in hydrodynamic testing. We are now able to gather far more revealing data from hydrodynamic tests than was possible when we developed the weapons that are now in the stockpile. In 1998, we carried out the first "core punch" experiments, in which scientists use high-energy radiography to record a digital image of the detailed shape of the gas cavity inside a pit when it is highly compressed. We examined two important stockpile primary devices: the W76 SLBM warhead and the B83 strategic bomb.

The Flash X-Ray Facility was shut down in 1999 and work began on an upgrade that will contain the debris created by explosive testing. Construction of the Contained Firing Facility is now finished, and the facility is undergoing qualification testing to assure its ability to contain debris from experiments that use up to 60 kilograms of high explosives. When hydrodynamic testing resumes in late 2001, Livermore will be able to conduct these critically important experiments in an even more environmentally-benign manner.

**Three-Dimensional Simulation of a Nuclear Primary Explosion.** Our hydrodynamic testing of mock primaries is complemented with a vigorous simulation program that achieved a remarkable milestone in December 1999. The first-ever three-dimensional simulation of a nuclear weapon primary explosion was completed using the ASCI Blue

Pacific computer at Livermore. Demonstrating the ability to simulate the explosion of a primary in three dimensions is a major milestone in the Stockpile Stewardship Program and an important step forward in the full-system modeling of weapon performance. Three-dimensional simulation is critically important because phenomena during a nuclear explosion are in many cases not symmetric due to aging and manufacturing variations.

The complex computer model that was used, called a “burn code,” employs tens of millions of zones—hundreds of times more than a comparable two-dimensional simulation. The work was completed through an intense, sustained effort that involved weapons code developers and computer support personnel. It required innovative three-dimensional algorithms able to represent the relevant physical processes and run efficiently on the machine’s parallel architecture. The simulation ran a total of 492 hours of computer time on 1024 processors and used 640,000 megabytes of memory on the Blue Pacific computer. During the calculation, six million megabytes of data were written in a total of 50,000 graphics files. Analyzing and preparing the data for visualization again requires the parallel processing capability of Blue Pacific. This post-processing is enabling weapon scientists to get a more accurate and detailed picture of the primary explosion process as it occurs.

**Modeling and Experiments of High-Explosive Detonation.** By linking two previously separate physics models, Livermore scientists now have a much better capability to simulate the detonation of high explosives (HE). One of the codes, CHEETAH (which is linked the ARES hydrodynamics code), models the chemical kinetics and thermodynamics involved in a detonation. In the resultant simulation, as ARES determines the motion of the materials, CHEETAH provides at each time step the state of chemical reactions and equation-of-state data for the relevant intermediate and final reaction products, which affects subsequent hydrodynamic performance.

We are also obtaining improved equation-of-state data for the materials produced by HE detonation, such as carbon dioxide. Better data increases the accuracy of simulation models. Researchers used Livermore’s diamond anvil cell to study carbon dioxide at extreme conditions (millions of Earth atmospheres). They created two forms of solid carbon dioxide that were never before seen in the laboratory (CO<sub>2</sub>-IV and CO<sub>2</sub>-V). What is especially interesting about CO<sub>2</sub>-V is that it shows nonlinear optical behavior, which may eventually lead to a new class of generating materials for high-power lasers.

### **High-Energy-Density Weapon Physics (HEDP) Calculations and Experiments**

To determine the performance of thermonuclear weapons, we need to accurately model how various types of radiation interact with their surroundings. The fundamental physical processes are particularly complex in the dynamic high-energy-density conditions present during the functioning of a weapon. Materials behave very differently at star-like pressures and temperatures. Modeling performance is made even more difficult by the fact that many of the issues we need to consider are inherently three dimensional. Weapons have been designed as one- or two-dimensional objects but they age three dimensionally. Furthermore, problems that could arise in weapons (e.g., cracks or other irregularities) are also typically three dimensional. High-fidelity three-dimensional modeling demands the

computing power that ASCI promises to deliver. It also demands experimental capabilities that can be used to generate data to validate the models.

**High-Energy-Density Physics Experiments.** When the Nova laser ceased operations at Livermore in 1999, we began using the Omega laser at the University of Rochester and the Z machine at Sandia to conduct high energy-density experiments. These facilities are able to approach the high energy densities produced in nuclear detonations, albeit only momentarily and in only very small volumes. Hence, they are useful for generating data and validating simulation codes near—but not at—weapon-physics conditions. The National Ignition Facility (NIF) will provide much greater capability to perform these types of experiments—it is capable of delivering nearly 60 times the energy of the Omega laser. Livermore researchers have been carefully examining the many possible types of experiments that can be conducted on NIF in support of stockpile stewardship. They presented an extensive set of materials at a High-Energy-Density Physics (HEDP) Workshop held at Sandia/California on January 30-February 2, 2001. The presentations showed that extraordinary progress has been made toward developing quantitative metrics for stockpile assessment and certification and in defining a detailed experimental weapons-physics program to be conducted at HEDP facilities. Although the certification approaches of the national laboratories differ, they all require an enhanced understanding of HEDP weapon behavior as an essential component of the Stockpile Stewardship Program.

**High-Energy-Density Physics Modeling.** As mentioned, Livermore researchers achieved a major milestone in late 1999 with the first-ever three-dimensional simulation of a nuclear-weapon primary explosion. The next step in the full-system modeling of weapon performance is a three-dimensional simulation of the thermonuclear burn of a weapon secondary. Work is currently in progress at the Laboratory using the ASCI White supercomputer. In addition to the codes developed to simulate nuclear weapon performance, the Laboratory has developed the code HYDRA, which was used in 2000 to simulate in three dimensions the performance of targets that might be used in the National Ignition Facility to achieve ignition and thermonuclear burn. The simulations were run on 1,680 processors of the ASCI Blue Pacific computer using a mesh of more than 16 million zones. HYDRA has also modeled the results of hydrodynamic instability experiments performed on our Nova laser and the University of Rochester's Omega laser.

## **ACCOMPLISHMENTS AND CHALLENGES IN TECHNICAL BASE AND FACILITIES**

Assessments of weapon performance and certification of weapon refurbishments must be based on scientific and engineering demonstration to be credible. In the absence of nuclear testing, we rely on data from past nuclear tests as a benchmark, component-level experiments and demonstration, and advanced simulations for an integrated assessment of weapon performance and safety. This approach has enabled us to successfully certify the W87 life-extension refurbishment and address stockpile issues that have emerged to date. However, as the stockpile ages, we anticipate that more difficult issues will arise.

These needs—to be able to assess and certify both weapon performance and refurbishment actions—drive the Stockpile Stewardship Program’s investments in much more capable experimental facilities, such as the National Ignition Facility (NIF), the Dual Axis Radiographic Hydrodynamic Test Facility and even more advanced hydro-test capabilities, and greatly enhanced numerical simulation tools developed through the Accelerated Strategic Computing Initiative (ASCI). We are not progressing as quickly as we could to acquire these greater capabilities because of competing needs for Stockpile Stewardship Program resources that must be balanced. The program must meet requirements for Directed Stockpile Work (e.g., life-extension programs) and pursue vigorous Campaigns. In addition, the nuclear weapons complex is in need of infrastructure recapitalization to support all of these activities. Program success requires both efficient, flexible, and modern manufacturing facilities and a work environment at the laboratories and production facilities that makes it possible to attract and retain an exceptional staff. Here, the discussion focuses on two areas where much more capable research facilities are required—NIF and ASCI—and on the need for infrastructure reinvestment. Workforce issues will be discussed later.

### **The National Ignition Facility**

Construction is under way at Livermore of the National Ignition Facility (NIF), a major research facility housing a 192-beam laser and associated experimental capabilities. NIF will be the world’s largest laser, delivering 60 times more energy than the Omega laser at the University of Rochester (and the previous NOVA Laser at Lawrence Livermore), currently the largest laser in the Inertial Confinement Fusion (ICF) program. NIF will provide 1.8 Megajoules of ultraviolet laser energy that can be used to compress and heat a small capsule filled with deuterium and tritium to conditions at which thermonuclear fusion occurs. NIF is a cornerstone and essential element of the Stockpile Stewardship Program. It will also provide scientific and technical information that may eventually lead to practical fusion energy production.

The baseline plan and schedule for NIF is included in General Gordon’s certification of the NIF project, provided to Congress on April 6, 2001. He concluded that “The NIF Project should continue along the approved 192-beam baseline at a Total Project and Related Cost of \$3,448 million and project completion at the end of FY 2008. The goal for the NIF is to achieve ignition in the laboratory.” With this certification, the full \$199 million appropriated by Congress for FY 2001 has been made available for execution of the NIF project. The FY 2002 budget provides \$245 million for continued NIF construction. The pace of construction is now constrained by available annual funding in the overall NNSA/DP budget, and the project could be completed significantly earlier at a lower total cost if more funding were available in the near term.

**The Importance of NIF to Stockpile Stewardship.** NIF is vital to the success of stockpile stewardship. It will be the only facility capable of well-diagnosed experiments to examine thermonuclear ignition and burn and to study the high-energy-density properties of primaries and secondaries in nuclear weapons. We need the facility for experimental study of key issues related to the effect of aging on weapons and for certification of the performance of refurbished weapons. In addition, NIF experiments provide the only

available means for advancing critical elements of the underlying science of nuclear weapons. NIF experiments will provide necessary data for sophisticated computer simulation models being developed for stockpile stewardship, and the models themselves need to be tested in the physical conditions that only the NIF can provide. Finally, NIF will help to attract and train the exceptional scientific and technical talent that is required to sustain the Stockpile Stewardship Program over the long term.

The findings of NNSA/DP's High-Energy-Density Physics (HEDP) Workshop, held January 30–February 2, 2001, reconfirmed NIF's essential role in the Stockpile Stewardship Program and recommended that NIF be completed to its full 192-beam configuration on its baseline schedule. The Workshop Panel included representatives from DOE, NNSA, DoD, the three NNSA laboratories, and Argonne National Laboratory. They reviewed presentations by experts in weapons design, HEDP, and Inertial Confinement Fusion (ICF) from the three laboratories that discussed options for NIF deployment, other HEDP facilities that can complement NIF, and Stockpile Stewardship Program needs for HEDP and weapons experiments/calculations for future stockpile certification.

**NIF Project Technical Progress and Accomplishments.** The NIF project is more than 50% complete. Major progress continues to be made and at a rapid pace. The NIF conventional facilities are 97% done, with completion expected in September 2001.

- Over 1000 tons of special equipment has been installed in the two laser bays, which are now operating under cleanroom protocols. Jacobs Facilities, Inc. (JFI) is responsible for the integration, installation, and commissioning of all beampath infrastructure systems, which form the exoskeleton of the NIF laser. Awarded the NIF project's Integration Management and Installation contract in August 2000, JFI brings significant expertise in clean construction practices to the project. By January 2001, JFI had mobilized their personnel for an early start to installation of laser bay beampath enclosures.
- The Optics Assembly Building (OAB), which contains an 8000 sq. ft. Class 100 cleanroom facility, is in operation cleaning parts to be used in the assembly of NIF. In February 2001 the Project completed acceptance testing of the first OAB workstation for assembly of the line-replaceable units (LRUs)—modular components that comprise the special laser, target, and optical equipment. Over the next year, the other LRU workstations will be installed, tested, and commissioned. This is a key activity in our preparation for building the NIF.

In addition, progress is outstanding on all technological fronts. A few examples are cited:

- With the development of technology to quickly grow optical-quality crystals for NIF, now we can grow in less than 2 months a 300-kilogram crystal that is used to convert laser light from infrared to the ultraviolet color optimized for the target physics experiments. The Laboratory together with an industrial supplier, Cleveland Crystals, have produced 56% of the crystals required for NIF.
- With development of technologies to continuously pour laser glass, Hoya Corporation and Schott Glass Technologies, suppliers of high-quality laser amplifier glass, are meeting all of NIF's technical specifications and have now produced roughly 75% of the 150 tons of laser glass (about 2400 out of 3000 slabs) required for NIF.
- We applied adaptive optics technology to develop deformable mirrors that allows NIF to maintain a very high quality laser beam even after passing through two meters of glass.
- Finally, we have developed an annealing process to increase the damage threshold for the ultraviolet optical elements in NIF and to meet the operational cost requirements of the NIF. We are now working to implement this process in a production setting.

**NIF Project Rebaseline and Certification.** In his certification of the NIF project, General Gordon concluded that “the NIF project team is capable of managing the project so as to assure a high probability of successful execution.” His certification is dependent on final resolution of a five-year budget plan for NNSA, but as stated in his report, “Funding for the National Ignition Facility will be included in this plan.” The certification follows a series of events and actions taken by the Laboratory, DOE and NNSA, and Congress since the summer of 1999 when we began to restructure the NIF project and develop a new baseline.

General Gordon's certification report reflects the very hard work of and outstanding progress made by the revamped NIF project management team. The team includes many of the Laboratory's most outstanding people and staff with large-project experience, who were brought into the project from other Livermore programs and from outside the Laboratory. To develop the rebaseline plans, the NIF project team combined their collective experience with experts from U.S. industry in extremely large projects that require cleanroom conditions—Jacobs Facilities, Inc., Lockheed Missiles and Space, Intel Corporation, Hewlett-Packard, and others such as United States Navy Strategic Systems. In addition, U.S. industry has a significantly larger role in completion of the project than previously planned with over 99% of the cost of procurement now contracted to private industry.

A series of actions by DOE and Congress preceded General Gordon's certification of NIF. On June 1, 2000, Secretary of Energy Richardson provided to Congress his interim report laying out the Department's path forward for NIF. He stated, “The path forward I have selected is based on the following conclusions/results from a very detailed review process. ...The project is technically sound and based upon good engineering design.



There are no known technical showstoppers remaining for project completion.” The review process included the work of a specially appointed Laser System Task Force of the Secretary of Energy Advisory Board (SEAB), chaired by Dr. John McTague, which issued an interim report on NIF in May and a final report in November 2000.

In September 2000, Secretary Richardson submitted to Congress a DOE-approved rebaselined cost and schedule for the NIF along with his certification of the project. Prior to the Secretary’s submittal, reviews were held following the recommendation of the SEAB Laser System Task Force. One was a thorough, intrusive examination of the NIF project patterned after the highly respected “Lehman” reviews carried out on large high energy-physics and nuclear physics construction projects within the DOE Office of Science. Concurrently, Burns and Roe Enterprises, Inc. conducted a separate Independent Cost Review of the project.

In accordance with the Conference Bill (H.R. 5408, Section 3140 of the FY 2001 Authorization Bill), Congress provided \$130 million immediately for the project, with \$69 million of NIF construction funds held by the NNSA until certification of the project by the NNSA Administrator. To support this certification, NNSA/DP held two additional reviews of the NIF Project. The first, the High-Energy-Density Physics Workshop, is discussed above. The second was the DP Status Review of the NIF Project, held February 27-March 2, 2001. Then on April 6, 2001, General Gordon certified the NIF project, citing the High-Energy-Density Physics Study Report, the Defense Programs NIF status reviews and the Defense Programs Future Years Budget Plan for the Stockpile Stewardship Program.

### **The Accelerated Strategic Computing Initiative**

The Accelerated Strategic Computing Initiative (ASCI) is greatly advancing our ability to computationally simulate the performance of an aging stockpile and to certify the details of refurbishment projects. To make the needed major advances in weapons science and engineering simulation codes, Livermore, Los Alamos, and Sandia national laboratories are obtaining from U.S. industry dramatic increases in computer performance and information management. The ASCI program is integrating the development of computer platforms, simulation applications, and data management technologies. It will take a string of successive investments to achieve ASCI’s long-term goals.

Livermore’s partnership with IBM has been highly successful. We took delivery of ASCI Blue Pacific in FY 1998 and then ASCI White in FY 2000. Both machines exceeded their performance requirements and are being used to support stockpile stewardship through a variety of applications, some of which I have discussed. The important next step in ASCI at Livermore is a supercomputer capable of 60 to 100 teraops (trillion operations per second). It is planned for FY 2004, and to keep plans on schedule, funding is needed in FY 2002 for construction of the Terascale Simulation Facility.

**ASCI White Provides 12.3-teraops.** The Laboratory is home to the world’s most powerful supercomputer, the IBM ASCI White machine, which is capable of 12.3

teraops. It is the latest step in ASCI's ambitious efforts to rapidly advance the state-of-the-art in computers, computational models, and data management tools needed to simulate the performance of nuclear weapons. In Summer 2000, ASCI White was delivered to Livermore on schedule from IBM's research center in Poughkeepsie, New York, in 28 large moving vans. We worked very closely with IBM to successfully install the machine and bring it up and running with our very complex simulation codes.

ASCI White is based on the next-generation IBM processor, node, and switch technology. It consists of 512 nodes, each with 16 processors. Exceeding its contractual performance requirement of 10 teraops, the machine is about a factor of three faster than Livermore's Blue Pacific computer, which was used to perform the first ever 3D simulation of the full functioning of a nuclear weapon primary. It is roughly 100,000 times more powerful than a typical desktop computer and requires about the equivalent of two basketball courts of floorspace. The machine also provides over 8 trillion bytes (terabytes) of main memory and about 110 terabytes of global disk space. Calculations are under way to use ASCI White to simulate the performance of the secondary of a nuclear weapon.

**Simulation Modeling and the Problem-Solving Environment.** ASCI is more than powerful computers; it is the development of advanced simulation techniques as well as data management and visualization tools. Three Gordon Bell Awards, two in 1999 and one in 2000, exemplify the outstanding simulation development capabilities at Livermore and a growing base of expertise in using the machines. Most notable was the 1999 Gordon Bell Award for best performance in supercomputing. A team led by Livermore researchers, with collaborators at the University of Minnesota and IBM, solved a supercomputer problem directly relevant to weapons physics issues and with broad applications including supernova evolution, combustion physics, and supersonic vehicle propulsion and dynamics. In addition, we are making significant progress in the development of very-high-performance data visualization capabilities. Two Assessment Theaters that provide wall-size, extremely high resolution images are now available at Livermore. They are helping weapon scientists to comprehend the vast amount of data the ASCI computers generate, and they enable visualization researchers to experiment with capabilities that are among the best in the world.

**Beyond ASCI White and the Terascale Simulation Facility.** The next supercomputer at Livermore after ASCI White will move us much closer to ASCI's goal of full-scale simulation of weapons performance based on first-principles physics models without resorting to simplified models. The threshold for that capability is 100 teraops, and reaching the goal quickly is vital to success in stockpile stewardship. Plans call for ASCI "Q" (30 teraops) to be operational at Los Alamos in 2002, a 20-teraops machine at Sandia in 2003, and a 60- to 100-teraops machine for Livermore in 2004. At the onset of the Stockpile Stewardship Program, ASCI set as a goal to achieve 100 teraops by 2004. The machine at Livermore will be as close to 100 teraops as can be afforded within budget limitations.

The 60- to 100-teraops machine will be very large, and we need the Terascale Simulation Facility (TSF) to house it. Plans for this \$89 million facility have been developed and a Conceptual Design Report has been approved. Title I design is scheduled

to be complete in May 2001. The TSF will consist of a two-story computing facility with power and space to accommodate a 100-teraops-class system; assessment areas and networking control areas necessary for direction and assimilation of data; and a four-story office structure for staff to manage and utilize the simulation environment. Essentially all of the planned funding for the TSF has been reallocated in prior years by NNSA/DP to meet other pressing programmatic needs; hence, \$32 million is needed in FY 2002. With timely funding, about 24,000 square feet of the machine room (of the 48,000 square feet planned) would be available and fully equipped to accept an ASCI-scale system in 2004. It is important that plans for the 60- to 100-teraops machine not slip.

The two machine rooms in TSF will guarantee our capability to site any system required by the program. The TSF will function more like an experimental facility than a computer center by supporting very close cooperation between staff and analysts. Round the clock support for major runs, restart capability for huge simulations, and on-the-fly trouble shooting will support a mode of operations where “runs” will be viewed as “shots,” requiring intense support to succeed. In addition, the TSF will feature the Advanced Simulation Laboratory for the development of visualization capabilities, and it will house the consolidated Networking Operations Center for Livermore’s supercomputer systems.

### **Infrastructure Recapitalization**

Stockpile stewardship requires major investments in new facilities and capabilities to make it possible for scientists and engineers to much more thoroughly understand the performance of nuclear weapons. As discussed above, at Livermore these investments include construction of NIF and acquisition of ASCI supercomputers and the TSF. The Stockpile Stewardship Program will not succeed without the new-facility investments that are being made at the NNSA laboratories. Scheduled programmatic work at the laboratories and the plants has also placed exceedingly high demands on provided funding. The cumulative effect of necessary continuing attention to the highest and most immediate priorities over the course of the Stockpile Stewardship Program has been shortage of funds to recapitalize NNSA’s underlying infrastructure. As a result, we are providing input and support to NNSA’s Facilities and Infrastructure Recapitalization Plan.

Over the years, Livermore has depended on having special facilities and equipment in an accommodating work environment to attract and retain an exceptional staff. Sustaining the quality of our workforce is a particularly challenging task in view of the high demand in the private sector for skilled people. The task is made more difficult by the continued aging of our facilities without major reinvestment. At Livermore, only 60% of our employees currently reside in permanent space, and 70% of the temporary office space (trailers and modular buildings) is nearing or beyond end of service life. Overall, 14% of Livermore’s office and laboratory space is in need of major rehabilitation and nearly 30% of the space is in need of minor rehabilitation. Such working conditions are not conducive to retaining and attracting the exceptional workforce that we need to accomplish our mission.

Older facilities typically are more expensive to maintain and usually have higher costs associated with safe and healthy operations. Our overall maintenance backlog is about \$330 million if funded with programmatic dollars. Other than funding for line-item construction of major new facilities, since the mid-1990s our infrastructure reinvestments have been in the range of \$25 to 50 million per year in programmatic dollars for a site with a plant replacement value of \$3.1 billion. We need additional funding to reduce the backlog and/or construct replacement facilities.

Reduction of the maintenance backlog is not the only issue we face. Obsolescent equipment needs to be replaced. For example, the Laboratory struggles to keep pace with rapid advances in telecommunications capabilities, which are critically needed to efficiently and securely use our supercomputers and to upgrade our business operations. In addition, we have legacy facilities from long-discontinued programs as well as unusable or unsafe laboratory space that must be decommissioned, decontaminated (where necessary), and demolished. Our legacy facilities and other excess marginal space require considerable up-front investments to rectify. We also have to invest so that buildings at Livermore meet present-day seismic safety codes and the latest, more demanding safety criteria.

## **REDUCING THE THREATS POSED BY THE PROLIFERATION OF WEAPONS OF MASS DESTRUCTION**

The proliferation and potential use of nuclear, chemical, and biological weapons (collectively referred to as weapons of mass destruction, or WMD) threatens the security of this nation. Continuing economic and political instability in Russia jeopardizes that country's ability to secure its legacy nuclear materials. At least 20 countries, some of them hostile to the U.S., are suspected of or known to be developing WMD. The incipient nuclear arms race between India and Pakistan has grave implications for security in that volatile region. There is no indication that years of intrusive inspections and global censure have halted Iraq's WMD ambitions, and Iran is actively building up its nuclear program. The potential availability of WMD materials and know-how makes terrorist acquisition of such weapons frighteningly possible.

### **Livermore's Threat Reduction Program**

Livermore is applying its nuclear expertise, developed through past work in nuclear weapon development and testing and its continuing stockpile stewardship responsibilities, to the challenge of nuclear threat reduction—that is, nonproliferation, counterproliferation, and counterterrorism. Because the threat of proliferation is not restricted to nuclear weapons, we are also drawing on the Laboratory's broad capabilities in the biological and chemical sciences to develop the technologies, analysis, and expertise needed to deal with the proliferation of chemical and biological weapons.

Scientific and technological superiority is the foundation of national security. Advanced science and technology enable the nation's military capabilities and lie at the heart of the Stockpile Stewardship Program. In the threat reduction arena, proliferation detection and intelligence collection depend on successive generations of advanced

technology to overcome denial and deception and to interpret fragmentary clues amid enormous and expanding volumes of technical data and other information. The strength of international treaties and agreements is based, in large part, on technical capabilities for monitoring compliance.

The central role of science and technology in the Stockpile Stewardship Program is well understood. However, the equally critical role of R&D in nonproliferation and threat reduction has not been articulated with sufficient clarity, as evidenced by the significant cuts in FY 2002 funding proposed for this work. Below I describe the critical problems of threat reduction that require advanced science and technology solutions, highlight Livermore's activities and achievements in these areas, and note the effect of the proposed budget cuts.

### **R&D for Threat Reduction**

Scientific and technical capabilities are essential for four "grand challenges" of threat reduction: proliferation detection, response to WMD terrorism, worldwide monitoring for nuclear explosions, and protection and control of nuclear weapons and nuclear material. The main sponsor of our work in these areas is NNSA's Office of Defense Nuclear Nonproliferation and its Nonproliferation and Verification Research and Development (R&D) Program. This program provides the technological base for the U.S. agencies with operational responsibility for characterizing foreign weapons programs and detecting proliferation-related activities, for detecting and mitigating the use of weapons of mass destruction against U.S. civilians, and for negotiating and monitoring compliance with arms reduction and other agreements. Because the threat is continually evolving, we must continually push the technical state of the art. I am concerned that the \$57 million cut in operating funds proposed for this FY 2002 budget line (a drop of roughly 25%), will have a major impact on the program's ability to deliver badly needed new capabilities for proliferation detection and domestic response to WMD terrorism.

**Proliferation Detection.** The discovery of Iraq's extensive clandestine WMD programs following the 1991 Gulf War demonstrated with chilling clarity the difficulty of detecting proliferation-related activities. This experience also illustrated the need to back up agreements with effective monitoring technology, for despite the fact that Iraq had signed the Nuclear Non-Proliferation Treaty and was subject to IAEA inspections, it managed to completely hide its WMD activities. After the dissolution of the Soviet Union (later in 1991), DOE's Nonproliferation and Verification R&D Program was tasked and funded to develop improved proliferation detection capabilities to meet this critical national security need in the more complicated multipolar world.

The goal of this work is to develop technical means by which signatures associated with the development, production, and testing of weapons of mass destruction can be detected and quantified. Characterization of these signatures will provide clues that, together with other sources of information, can be used to infer the nature of suspicious activities. Because of the technical difficulty of achieving the required proliferation detection capabilities, the optimal approach is not readily apparent. Therefore, a number of different avenues must be investigated and the state of the art advanced in many technical

disciplines in order to turn proliferation detection concepts into functioning, field-worthy systems.

In this area more than any other, success requires a long-term focus and sustained effort. Indeed the proliferation detection challenge is increasing. Adversaries continue to acquire more advanced technology for their WMD programs, and they improve their denial and deception techniques as they learn about our detection capabilities.

At Livermore, we take an end-to-end approach to proliferation detection. Our technology developers work hand in hand with signatures experts, all-source intelligence analysts, and the people who develop advanced data-exploitation techniques. This systems-level approach allows us to develop technologies that meet real-world needs, functioning in demanding deployment environments and delivering information that can be readily exploited and used with confidence as the basis for nonproliferation policy and counterproliferation response.

We have developed both passive and active technologies. These technologies have been transitioned from laboratory concepts into prototype fieldable systems and their operational feasibility in complex industrial environments has been demonstrated. The next step would be to work with operational agencies to integrate these detection technologies into their future technical capabilities. However, the funding cuts proposed for FY 2002 will force the termination of Livermore's entire remote sensing effort.

**Domestic Response to WMD Terrorism.** Events such as the World Trade Center and African embassy bombings, the Tokyo subway nerve-gas attack, and a growing number of bioterrorism scares have galvanized U.S. efforts to combat terrorist use of chemical and biological weapons, particularly attacks against civilian targets. The Chemical and Biological National Security Program (CBNP) was initiated by DOE in FY 1997 to develop new technologies for improved response in the event of a chemical or biological terrorist attack.

At Livermore, our CBNP has grown significantly in the past four years. It was initiated as a Laboratory Directed R&D Strategic Initiative in 1996 and has evolved from those roots. Today we have thriving efforts in all four of the national program areas—biological foundations, biodetection, modeling and prediction, and decontamination—with leadership responsibilities in biodetection and modeling and prediction. We have developed the first truly portable, battery-powered, handheld polymerase chain reaction instrument, the Handheld Advanced Nucleic Acid Analyzer (HANAA). The instrument is capable of testing four different samples for two different DNA sequences and reporting the results in less than ten minutes. This year, HANAA entered real-world beta testing, where it is being used by FDA inspectors to detect pathogenic bacteria in imported seafood, health workers to analyze blood samples for drug-resistant strains of malaria in rural Africa, and emergency response personnel as a detection and diagnostic tool in the event of a domestic bioterrorism incident. HANAA technology has also been licensed to a commercial partner.

To provide biodefense for special events (e.g., governmental assemblies, dignitary visits, major sporting events), Livermore and Los Alamos are jointly developing the Biological Aerosol Sentry and Information System (BASIS). This system is designed specifically for the “detect to treat” mission—detecting a bioterrorism incident within a few hours of attack, early enough for public health agencies to mount an effective medical response. BASIS uses a network of distributed sampling units located in and around potential target sites. Each sampling unit continuously collects, stores, and time-registers aerosol samples. The samples are retrieved and brought to a field laboratory for analysis. If bioagent is detected, authorities are notified and provided with information as to agent type, time and location of “hot” samples, estimated aerosol concentrations, hazard zones, and medical case load estimates. To ensure that BASIS supports real-world operational needs, it is being developed in close cooperation with the public health agencies (federal, state, and local) responsible for emergency response and medical operations in the event of a bioattack. It was successfully field tested at Salt Lake City in March 2001 and is planned to be ready for deployment in 2002

**Nuclear Explosion Monitoring.** Livermore has provided seismic research expertise in support of nuclear explosion monitoring for more than 40 years. The U.S. needs to be able to detect, locate, and identify nuclear explosions of any yield, anywhere in the world, under a wide range of possible evasion scenarios. Worldwide monitoring at the required level of sensitivity requires, in turn, a detailed understanding of the propagation of signals (radionuclide, optical, electromagnetic, seismic, acoustic) that differentiate a nuclear explosion from the enormous number of background nonnuclear events like mining explosions, earthquakes, and lightning strikes.

Livermore’s contribution to the current program is the development of ground-based nuclear explosion monitoring capabilities in regions of concern (e.g., Middle East, North Africa, Russia, Korea peninsula). We develop databases, methodologies, algorithms, software, and hardware systems for the Air Force Technical Applications Center (AFTAC) for their use in collecting and interpreting seismic, acoustic, and radionuclide data. A critical deliverable is the Knowledge Base which provides regional propagation path corrections to the event processing algorithms in AFTAC’s analysis pipeline. This Knowledge Base is expanded and enhanced as new monitoring stations come on line and are calibrated and as new data and interpretations become available. This past year, we delivered to AFTAC parameter sets covering the Middle East and Southwest Asia. The focus of our current work is on the European Arctic, including the test site at Novaya Zemlya.

**Verification and Transparency.** The nuclear science and radiation detection technology base resident at Livermore and the NNSA nuclear complex is key to agreements with Russia to reduce the danger from nuclear weapons. During the past decade, the U.S. and Russia have engaged in negotiations on such issues as shutting down plutonium-producing reactors, monitoring nuclear stockpiles, and mutual inspections of material declared excess to defense needs. The sticking point in all of these negotiations is the need to measure attributes of classified objects while preventing the disclosure of sensitive weapons design information.

At Livermore, we conduct R&D to develop novel radiation detection instrumentation, data interpretation algorithms, information barriers, and monitoring procedures for use by U.S., Russian, and IAEA inspection personnel. A prototype detection system, employing our information barrier and autonomous shutter, was successfully demonstrated to Russian technical and security personnel at the Fissile Material Transparency Technology Demonstration, held in August 2000 at Los Alamos. Such demonstrations play an essential role in negotiations, building confidence among the various parties and educating negotiators as to what monitoring technology can and cannot do.

### **Cooperative U.S.--Russian Programs**

Cooperative U.S.–Russian programs overseen by NNSA consist of an integrated set of activities to secure at-risk nuclear material in Russia, dispose of excess highly enriched uranium and plutonium, and assist in downsizing the Russian nuclear weapons complex. These programs draw on the technical capabilities of the Laboratories in areas such as verification and transparency. The programs have been extensively reviewed by various panels and committees and continue to receive significant attention. Here I would like to highlight some of the accomplishments and issues of these cooperative programs.

**Material Protection, Control, and Accounting.** For the MPC&A Program, Livermore specializes in vulnerability assessment, gamma spectroscopy, access control and security system integration, and information systems. We lead the MPC&A project teams for the Federal Information System, various Russian Navy projects, Chelyabinsk-70, Sverdlovsk-44, Bochvar Institute, and Krasnoyarsk-45 and provide project support for an additional seven site teams. Of the various DOE laboratories involved in the MPC&A program, Livermore is unique in its role with the Russian nuclear navy and nuclear-powered icebreaker fleet. Since the work began in 1997, MPC&A upgrades for the four nuclear refueling ships have been completed and commissioned, two in 1997 and two more in 2000.

The work at the Russian Navy facilities has been some of the most successful of the MPC&A program. Success is attributable to the combination of a highly focused user (the Russian Navy), an excellent subcontractor and system integrator (the Kurchatov Institute), and a highly trained team of NNSA and national laboratory personnel that has built an excellent working relationship with the Russian personnel, facilitating efficient problem solving and rapid system implementation. The success of this approach has resulted in an agreement between NNSA and the Russian Navy to expand MPC&A cooperation to include nuclear weapon storage sites. Work at a number of these sites is underway and meeting with the same success as previous activities with the Russian Navy, however, the funding for this work is being cut by nearly \$40 million in FY 2002 (a reduction of 50%), slowing these very important risk-reduction efforts.

**Plutonium Disposition.** Program direction for the disposition of U.S. and Russian surplus plutonium is undergoing review by the National Security Council. Both the U.S. and Russia have agreed to dispose of 34 metric tons of plutonium, but the path forward is complex technically, politically and economically. The U.S. has adopted a dual track



approach in its plutonium disposition program that includes fabrication of mixed uranium/plutonium oxide (MOX) fuel to burn plutonium in nuclear reactors and immobilization of impure plutonium in a ceramic matrix for long-term geological disposition. Livermore has led the national plutonium immobilization program, which is responsible for disposing of 13 metric tons of impure plutonium that otherwise might end up as orphan material. This past year, we completed testing of the can-in-canister and finished the conceptual design report for the plutonium immobilization facility in preparation for the full facility design. We also completed testing of two highly-automated plutonium lines with plutonium surrogates and were scheduled to start testing the lines with plutonium this summer. The first line uses hydrogen in a hydride/oxidation process (HYDOX) to transform plutonium from a metal to an oxide powder. The ceramification line then combines the plutonium oxide with ceramic precursors to form, after cold pressing and high temperature sintering, a ceramic suitable for long-term geological disposition in the can-in canister.

This month we were directed to suspend our immobilization activities, while maintaining the ability to restart at a later date, in response to FY 2002 budget guidance and pending the results of the review mentioned earlier. I fully support a review of both the objectives of the program and its implementation costs. However, the difficulty of stopping and restarting such a complex developmental activity should not be underestimated.

### **Downsizing the Russian Nuclear Weapon Complex**

Downsizing the Russian nuclear complex is a high-priority U.S. national security goal. However, such downsizing will eliminate the jobs of thousands of Russian weapons workers. To accelerate the downsizing process, the U.S. and Russia have launched a cooperative program to create self-sustaining civilian jobs for displaced workers in the closed nuclear cities of Sarov, Snezhinsk, and Zheleznogorsk.

Livermore leads the NNSA team working with Snezhinsk and its various civilian entities to develop commercial enterprises. In November 2000, the Strella Open Computer Center for commercial software development and scientific computations was commissioned. Former Ambassador Ronald Lehman, Director of the Center for Global Security Research at Lawrence Livermore National Laboratory, led the U.S. delegation for the official dedication.

We are also leading a medical technology development project with the Avangard Electromechanical Plant (the equivalent of Pantex) at Sarov. In March 2000, contracts were signed by Livermore, the Avangard Foundation (the commercial element of the Avangard Electromechanical Plant at Sarov), and Fresenius Medical Care (the world's largest provider of products to individuals with chronic kidney failure with six production facilities in the U.S.) for the development of a manufacturing center at Sarov for dialysis machines and related products. In June, fences were moved to place the buildings needed for this facility outside of Avangard's high-security area. Eventually, this project will employ hundreds of former weapons workers in the production of dialysis equipment and

treatment kits. This project represents a major milestone in U.S. government efforts to engage a Russian serial production facility.

### **New Secure Compartmented Information Facility**

I am very pleased that the second year of funding for Livermore's new secure compartmented information facility (SCIF) is included in the FY 2002 budget proposal. We have provided technical and analytical support to the U.S. Intelligence Community since the late 1950's. The Laboratory currently supports and collaborates with an extensive set of Intelligence Community agencies, including DOE's Office of Intelligence, the Defense Intelligence agency, The National Security agency, and the Central Intelligence Agency. Technology, together with the increasingly complex national security landscape, is changing the nature of intelligence work. Hardcopy report and film imagery are rapidly giving way to massive digital files, which require high-bandwidth connectivity and modern communications and computing systems to exploit, interpret, and disseminate.

The new SCIF will enable us to take advantage of this digital revolution in the intelligence business, enhancing our contribution to the Intelligence Community. The new SCIF will also allow us to accommodate our expanding programmatic needs for SCIF space. Let me note that the \$13 million provided in FY 2002 is the minimum required to maintain the project's schedule and cost. Assuming that funding is provided as requested, Livermore's new SCIF will be completed by early 2004 at a total cost of \$24.6 million.

### **INSTITUTIONAL ISSUES**

**Laboratory Operations.** Safety and security are prime considerations at the Laboratory, and both have received considerable management attention. In 2000, we implemented DOE's operational concept, Integrated Safety Management (ISM) and strengthened our commitment to safety in the workplace. Security at the NNSA laboratories was in the headlines in 1999 and 2000, two very stressful years. We have taken strong positive action on security and counterintelligence issues, whether they were anticipated or identified by us or were brought to our attention by others. Substantial progress has been made in many areas. We worked expeditiously to address all issues that arose in self-evaluations or resulted from inspections by the DOE Office of Security Evaluations (OSE). As an outgrowth of these efforts, we are now rated Satisfactory (Green) by DOE/OSE.

Cyber security receives continuing attention because the rapid advance of technology constantly opens up new possible types of threats. We have addressed identified potential weaknesses in the security of some of our unclassified computer systems and we are proceeding to implement our cyber security strategy. Security improvements to keep pace with evolving perceived threats come at a cost, and in the absence of new funds, implementation of mandated upgrades have often been at the expense of other high priority programmatic work.

**Laboratory Personnel.** Our national security programs are no more and no less than the people that comprise them. Over the years, exceptional scientists and engineers have been attracted to the Laboratory by the opportunity to have access to the world-class facilities,

to pursue technically challenging careers, and to work on projects of national importance. Unfortunately, events over the last two years have had a negative effect on the workplace environment. As noted in the “30-Day Review” of the Stockpile Stewardship Program of December 1999, morale and employee recruitment and retention are being impacted by new security requirements (e.g., restrictions on interactions with foreign nationals), by budget and program uncertainties, and by the reduction of resources that support innovative scientific inquiry. I have made workforce management and improvements in the workplace one of the highest priority issues for the senior management team at Livermore this year.

In some respects the situation seems to be improving—or at least, not getting worse. Two positive developments are the extension of the Management and Operations contract with the University of California (UC) and the restoration by Congress of Laboratory-Directed Research and Development (LDRD) funding to the 6% level. The connection to UC is personally very important to many Laboratory employees and it greatly helps us in recruiting. LDRD funding, which provides scientists the opportunity to conduct innovative research aligned with our core missions is important to the vitality of Livermore and to the talented researchers that we need to attract and retain. We are also very hopeful that the national security reviews being conducted by the Administration will lead to a strong reaffirmation of the importance of the Laboratory’s work in maintaining the U.S. nuclear deterrent through stockpile stewardship and in developing technologies to reduce the threats posed by the proliferation of weapons of mass destruction.

Predictability and stability in the budget would be very beneficial, and NNSA’s five-year budget planning will help in the long run. However, commitment is needed this year to stabilize the budget for critically important nonproliferation research and development activities and cooperative U.S.—Russian programs. Other changes being made at NNSA will clarify lines of communication and authority, which should help improve both overall efficiency and the work environment.

### **SUMMARY REMARKS**

The introduction of my testimony starts with an event—formal certification of the refurbished W87 ICBM, “the first real test of stockpile stewardship.” It is fair to say that “we passed,” but the test was not easy. As weapons continue to age, the tests will get harder and our capabilities to answer questions need to improve—better investigative tools to evaluate problems and certify performance, as well as efficient manufacturing capabilities. Acquisition of these capabilities is time urgent to meet existing requirements for weapon refurbishment and to deal with other weapon performance issues that might arise.

As a consequence, there are many demands for resources for stockpile stewardship, which are putting the program under stress. The full scope of requirements on the Stockpile Stewardship Program will be better defined at the conclusion of ongoing national security reviews of the role of nuclear weapons and force requirements. Then the budget needed to carry out the necessary programmatic activities can be more clearly established.

In the face of the challenges, we have many accomplishments to show for our efforts in addition to certification of the W87 warhead. Construction of the National Ignition Facility (NIF) at Livermore is now more than 50% complete, progress is outstanding on all technical fronts, and General Gordon provided certification of the NIF project and its baseline plans to Congress on April 6, 2001. The Accelerated Strategic Computing Initiative (ASCI) is central to many success stories. Last summer, we took delivery of ASCI White, the world's most powerful computer. This machine and ASCI Blue Pacific are supporting stockpile stewardship through a variety of applications, and we are earmarked to take delivery of our next ASCI computer in FY 2004, a machine that will be capable of 60 to 100 teraops. These successes and others I could cite are evidence that the Stockpile Stewardship Program has greatly benefited from strong Congressional support and the dedicated efforts of the many people in the program. Additional support in FY2002 would help relieve a number of stresses that are arising as the program continues mature and face greater tests.

I also urge your vigorous support for the program proposed by the Office of Defense Nuclear Nonproliferation and for the programs and initiatives of other agencies in the areas of WMD nonproliferation, counterproliferation, and counterterrorism. The enormity of the challenge cannot be overstated. Thousands of tons of nuclear materials are stored under questionable levels of protection at hundreds of sites across the former Soviet Union. The smuggling of nuclear materials is a continuing issue. Countries of concern show increasing evidence of their intention to acquire WMD and the means to deliver those weapons, and the threat of WMD terrorism continues to rear its ugly head.

As with stockpile stewardship, the success of U.S. threat reduction efforts depends on R&D. With greater technical capabilities, the U.S. can better monitor compliance with arms-reduction and other agreements. Intelligence collection and proliferation detection have depended on successive generations of advanced technology to identify and interpret fragmentary clues buried amid enormous amounts of data and to overcome adversaries' increasingly sophisticated denial and deception about their WMD activities.

Finally, I hope the summary presented earlier clarifies both the challenges and the critical contributions Livermore is making to reducing the threat posed by the proliferation of weapons of mass destruction. Sustained support for cutting-edge research and development at current funding levels at least is essential to counter the wide range of WMD threats.