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The Stockpile Stewardship Program

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Introduction

In the 1990s, the U.S. conducted its last nuclear explosive test and halted the production of new nuclear warheads. Thus ended an era in which the U.S. modernized its nuclear weapons stockpile by the steady replacement of aging systems with new systems and in which nuclear testing served as the ultimate arbiter of the safety, reliability, and performance of the nation's nuclear weapons stockpile.

With the decision to cease production of new nuclear warheads and to end nuclear testing, the U.S. now faces the challenge of maintaining its existing nuclear weapons stockpile with other tools and different kinds of tests. To meet this challenge, the Department of Energy has developed the Stockpile Stewardship Program.

Significant progress has been made in the implementation of the Stockpile Stewardship Program. A Record of Decision on the Programmatic Environmental Impact Statement was issued in December 1996, establishing the architecture for the future U.S. weapons complex. An implementation plan for the Stockpile Stewardship Program has been developed and is already in its second annual revision. The first two Annual Certifications of the stockpile have been completed. Many new capabilities and facilities for the Stockpile Stewardship Program are well under way. For example, the Dual Axis Radiographic Hydrodynamic Test Facility is being constructed at Los Alamos, and construction of the National Ignition Facility has begun at Livermore. Industry has begun delivering the advanced computers required for the Accelerated Strategic Computing Initiative, and record-breaking teraflops operation has been demonstrated on the first of them. Life extension programs for the enduring stockpile are being developed, and the dismantlement of U.S. nuclear warheads retired from the stockpile is continuing. We are already applying the principles of stockpile stewardship to a number of stockpile systems, and we are on track to restoring the nation's capability to produce tritium.

In this paper, which has been extracted and edited from a Department of Energy publication(1) that LLNL helped write, we present an overview of the current program and highlight some of the accomplishments and progress made to date.

Program Goals

> *"As part of our national security strategy, the United States must and will retain strategic nuclear forces sufficient to deter any future hostile foreign leadership with access to strategic nuclear forces. In this regard, I consider the maintenance of a safe and reliable nuclear stockpile to be a supreme national interest of the United States."*
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> *"I am assured by the Secretary of Energy and the Directors of our nuclear weapons labs that we can meet the challenge of maintaining our nuclear deterrent under a Comprehensive Test Ban Treaty through a science-based stockpile stewardship program without nuclear testing."*
>
> *President Clinton, August 11, 1995*

The Department of Energy (DOE) program for stockpile stewardship has the fundamental objective of maintaining high confidence in the safety, performance, and reliability of the U.S. nuclear weapons stockpile. However, the conditions under which we must accomplish this objective have changed greatly since the early 1990s. DOE is meeting and will continue to meet that challenge by using nonnuclear experiments and computer simulations in lieu of nuclear testing. The changed conditions include:

- *No nuclear testing.* Without nuclear testing, we no longer have a way to do integrated, direct tests of warhead operation. Without such testing, we have also lost the ultimate measure and demonstration of warhead performance and weapons scientists' competence. Under the CTBT, nuclear testing would be used only as a last resort, requiring invocation of the "supreme national interest" clause, if all other means prove insufficient to resolve a serious stockpile issue.

- *Tritium production.* The U.S. has not produced tritium for warheads since 1988 and will require a new tritium production source possibly as early as 2005. A dual-track approach using commercial light water reactor and accelerator production of tritium is being vigorously pursued.

- *An aging stockpile.* Nuclear warheads are not static objects. Materials change over time (e.g., radioactive decay, embrittlement, corrosion). Some changes do not adversely affect warhead reliability or performance, but others have done so in the past, and some changes and their impacts on reliability, safety, and performance are yet unknown. With the average age of the stockpile older now than it has ever been in the past (including a number of warheads approaching the end of their originally anticipated deployment), it is expected that previously unencountered aging-related problems will arise. To meet this challenge, each stockpiled warhead is undergoing a thorough assessment to determine vulnerabilities and to establish refurbishment schedules that will ensure stockpile life extension

- *An aging cadre of stockpile stewards.* Many of the scientists and engineers with actual weapons design, production, and test experience have already retired, and most of those remaining are within ten years of retirement. A new generation of weapons scientists and engineers must be trained and their competence validated before the current generation leaves the work force. Knowledge preservation programs are under way that include video-recording the experiences of senior designers as well as mentoring of new stockpile stewards, The senior designers are also reviewing archived nuclear weapon test data and showing the future stewards how to interpret and extract useful information previously not needed when nuclear tests were conducted.

- *A smaller, less diverse stockpile.* The nation's stockpile now has fewer warheads and fewer warhead types than any time since the 1960s. Further reductions are expected as we proceed to START II and the next strategic arms reduction treaty. Thus, the stockpile is more susceptible to common-mode failures—for example, defects arising from a refurbishment-fabrication process or material used in several warhead types or failures that affect warheads with similar design features.

- *No requirements for new-design nuclear warhead production.* Without new production programs, warheads will remain in the stockpile well beyond their anticipated lifetimes and beyond the base of experience. Without requirements for new warheads, existing warheads will be refurbished and modified to extend their stockpile lifetimes. To address this challenge, the capability is being maintained to design and fabricate replacement warhead parts, as well as to design (but not produce) replacement warheads for existing stockpiled weapons.

- *A reconfigured production complex.* The production complex of the Cold War years is being downsized and consolidated. The future complex, with its reduced capacity and capability, will not be configured for high-rate production programs. Thus, improved manufacturing processes, including the integration of system design, component design, and process development, will be needed to achieve timely production at a reduced cost. To address this challenge, a Programmatic Environmental Impact Statement was developed that specifies significant reductions in the size of the DOE production complex and the development of an agile, capability-based manufacturing enterprise that will use advanced design and production methods to respond to both normal and contingency requirements.

The focus of the Stockpile Stewardship Program is the U.S. nuclear stockpile. All elements of the program are directed at ensuring the safety, reliability, and performance of this stockpile. We will develop the fundamental understanding needed to ensure our ability to anticipate and fix problems, to deal with future unknowns that affect stockpile safety or reliability, and to be prepared to demonstrate that our assessments and evaluations are accurate and credible.

At the heart of the Stockpile Stewardship Program is the issue of confidence. The program must provide three types of confidence—in the weapons themselves, in the systems and infrastructure that maintain the weapons, and in the judgment of the people who assess the weapons. These three elements of confidence are tightly linked and must be effectively integrated to provide overall confidence in the nation's nuclear deterrent. The ultimate measure of success of the program is to certify that the stockpile remains safe and reliable without nuclear testing. The first two annual certifications of the stockpile have been completed, and both the DOE and the Department of Defense (DoD) have concluded that the stockpile is safe and reliable.

Program Strategies

The goals of the Stockpile Stewardship Program will be achieved through an integrated process of surveillance, assessment, certification, and manufacturing. Today's program is characterized by three integrated strategies, or phases, of stockpile stewardship:

- *Surveillance: predicting and detecting problems.* We must identify defects and aging-related changes before they degrade warhead safety, performance, or reliability. To the extent possible, we must predict — relying on experiments coupled with computer modeling and simulation— the occurrence and impact of changes—both the kinds of changes that have been dealt with previously and changes that have not been encountered before.

- *Assessment: analyzing and evaluating effects of changes on warhead safety and performance.* We must assess the effects of identified and predicted age- and environment-related changes in stockpile warheads to determine whether or not the changes adversely affect safety, performance, or reliability. We must determine if the degradation is severe enough to require the replacement or rebuilding of warhead components or even entire weapons. We must also evaluate new materials, new fabrication techniques, and new manufacturing processes to make sure they are functionally equivalent to the originals.

- *Design and Manufacturing: refurbishing stockpile weapons and certifying new parts, materials, and processes.* We must periodically replace limited-lifetime components (e.g., tritium reservoirs, neutron generators) and rebuild or manufacture parts to replace those that have or will soon experience detrimental aging-related changes. We must also certify that the new components do not introduce defects that degrade warhead safety, performance, or reliability.

A distinguishing feature of the Stockpile Stewardship Program is its integration. Not only are the laboratories and plants working closely together, particularly for surveillance and manufacturing, but the activities themselves are tightly interconnected. In addition, the Department of Energy's laboratories and plants work closely with the Department of Defense and the military services to make sure that the enduring U.S. nuclear stockpile meets its mission requirements.

The stewardship process is continual, with no clear ending of one phase before the beginning of another. Assessment and certification pervade all activities, from surveillance through manufacturing. Likewise, computational modeling and prediction are integral to every activity, from the assessments of aging-related changes, to the design and certification of replacement components, to projections of stockpile life extension.

Predicting and Detecting Problems: the Surveillance Program

Stockpile surveillance has been a major component of the U.S. nuclear weapons program ever since the first weapons were put into the stockpile. Since 1958, approximately 14,000 weapons have been examined and subjected to a variety of nonnuclear laboratory experiments and flight tests. In cases where laboratory tests could not provide conclusive answers, nuclear tests of stockpile warheads or warhead components were conducted.

Problems requiring corrective action have arisen in nuclear and nonnuclear warhead components. All warhead types in the enduring U.S. stockpile have had repairs or retrofits, and several have required repairs to the nuclear package. Without replacing older warheads with new ones, the stockpile will age beyond our experience base. There have never before been large numbers of 30-, 40-, or 50-year-old warheads in the U.S. stockpile. (The typical age of a stockpile warhead has been less than 13 years.) As a result, we expect that previously unencountered changes and problems will arise in the older warheads.

To succeed in this new reality, we need new surveillance methods and enhanced predictive capabilities so that we can detect the full range of problems that may arise in the enduring stockpile. We also need to be able to anticipate and identify aging-related changes and understand the significance of these changes and their effect on warhead safety and performance. Some changes have little or no effect, whereas others can make a major difference.

Defects occur throughout the lifetime of a warhead. Typically in complex manufactured systems, initial defects associated with design or fabrication form a large fraction of all defects found. With a high sampling rate during the early years, these defects can be detected and corrected. During middle age, the defect rate typically declines to a lower but nonzero level. As a system ages and components deteriorate, the defect rate climbs. The U.S. nuclear stockpile has followed the pattern of these first two stages. However, we have essentially no experience with the third stage and must develop the capability to predict when it will be reached.

The goal of enhanced surveillance is to anticipate or detect the precursors and onset of aging-related defects before they jeopardize warhead safety or reliability. Predictive modeling and simulation are central to our ability to assess warhead aging and the effect of potential defects on warhead performance. With sufficient lead time, we can make the necessary redesigns, refurbishments, and recertifications efficiently and cost effectively as we work within the capabilities and capacity of the downsized production complex. The alternative to this approach is a large costly manufacturing complex that can fix problems quickly when they occur.

An Enhanced Surveillance Program has been established to develop the technologies and methods as well as the fundamental understanding of materials properties and physical principles to significantly improve our detection and predictive capabilities. The major activities to be pursued are:

- Testing and researching the age-related behavior of existing stockpile materials, components, and systems, including those from retired warheads.
- Developing improved computational models of materials aging and materials performance.
- Developing and conducting high-fidelity nonnuclear tests to examine the behavior of nearly all actual warhead components in realistic flight environments. (Historically, most flight tests have been performed using only a limited number of warhead components from the stockpile.)
- Developing techniques for advanced analysis of existing surveillance data, including complex numerical models and simulations as well as improved access to and analysis of archived data.
- Developing sensors to detect material failure in stockpile warheads for those mechanisms whose failure times cannot be adequately predicted.

As these enhanced surveillance technologies and methods are prototyped and validated, they will be integrated into the core stockpile surveillance program. Improved predictions of component lifetimes, made possible through the Enhanced Surveillance Program, are key to the strategy for extending indefinitely the life of stockpile warheads.

Analyzing and Evaluating: the Assessment and Certification Program

Data and test results from many sources must be analyzed, assessed, and evaluated before conclusions can be drawn as to the safety, performance, or reliability of stockpile warheads. The Assessment and Certification Processes are designed to:

- Develop an understanding of and an ability to predict the lifetime and aging-related changes that occur in every warhead component.
- Identify and understand those variables, processes, and changes that really matter in terms of warhead safety, performance, and reliability.
- Validate the new experimental and computational tools.
- Validate new manufacturing processes and materials to ensure that rebuilt parts and warheads are functionally equivalent to the originals.
- Develop and demonstrate the judgment of the next generation of weapons scientists and engineers.

The science and engineering of nuclear explosives are extremely complex. There are many parameters and unknowns that greatly influence the performance of nuclear warheads. Some of these have, in the past, been identified only in nuclear test failures. Even when nuclear testing was permitted, we were never able to test nuclear warheads to a statistical certainty. In addition, various testing constraints (e.g., the Threshold Test Ban Treaty) required extrapolations to evaluate full-warhead performance and safety characteristics. The key to accurate extrapolations, then as now, is the expert judgment of our weapons scientists.

Confidence in the accurate judgment of weapons scientists and confidence in the safety and reliability of the U.S. stockpile are closely linked. In the past, a weapon scientist's judgment was developed and validated through nuclear testing and new warhead development. The Stockpile Stewardship Program is developing other means for honing and demonstrating the expert judgment of the next generation of stockpile stewards.

We are accomplishing this through a balanced and integrated program of computational simulation, fundamental scientific research, and nonnuclear experiments. In particular, we are designing experiments that test and expand the boundaries of our understanding. There are many areas of warhead operation that cannot be adequately addressed with the tools and knowledge we currently possess. To close these gaps, the Stockpile Stewardship Program is making significant investments in enhanced computational capabilities and advanced facilities for aboveground experiments.

Of particular concern is the assessment challenge posed by the unrecognized problem—the "unknown unknown." We must have rigorous experimental and computational processes that not only confirm and extend what we know and expect, but also fill in gaps in our current understanding. This ability to fill in the gaps is especially important in those areas where previously we would have used nuclear testing, and where a successful test (that is, one in which the nuclear explosive device worked) would have clearly defined the margins of our concerns. Therefore, we need an aggressive verification and validation process for both our tools and our results.

The Stockpile Stewardship Program provides for demonstration-based assessment and certification of warhead safety and reliability. In the absence of nuclear testing, we must rely on different experiments and tools to obtain data relevant to nuclear warhead performance. We have identified a suite of enhanced capabilities that we believe are needed to fill in the gaps of our knowledge and provide data relevant to various stockpile concerns. Advanced experimental facilities will provide high-fidelity data on the stages of the nuclear explosion—primary implosion, boost, primary-to-secondary coupling, weapon effects, etc. Wherever possible, our goal is to obtain data experimentally by at least two different methods.

Under the Stockpile Stewardship Program, computational modeling and numerical simulation provide the critical integration of theory, existing data and knowledge, new experimental results, and predictions into results that can be verified and validated. Advanced computational capabilities (application codes, computers, and various tools and techniques) are being developed under the Accelerated Strategic Computing Initiative and incorporated into ongoing stockpile computational activities. Numerical simulations will both drive the experimental program and be driven by it. Our goal is to combine past nuclear test data, computational modeling, and new data from advanced experimental facilities to fill in gaps in our current knowledge and extend our scientific understanding in other vital areas.

To assess aging-related changes that occur in nuclear and nonnuclear warhead components, we need complex three-dimensional computational simulations that are beyond our current computational capabilities. Through the Accelerated Strategic Computing Initiative, we are developing enhanced capabilities. For example, increases of more than ten-thousand fold in computational speed, network capacity, and data storage are planned to provide simulations of weapon safety and performance of increased detail and complexity. These efforts are closely linked to experiments to validate new and evolving computer models and provide improved physics data.

These new capabilities will be used in addition to the experimental and computational capabilities developed during the nuclear testing years. However, because these older tools were designed to complement nuclear testing, they are not, in and of themselves, sufficient in the absence of nuclear testing. As new facilities and capabilities come on line and are validated, we will incorporate their data into our assessments. Our goal is to accomplish this transition in less than ten years.

Peer review is a key component of stockpile stewardship. Because assessment and certifications of stockpile safety, reliability, and performance rely so heavily on expert judgment, it is essential that the judgment of our weapons scientists, and the assessment process itself, be vetted and validated. Formal and informal peer interactions take place among the three weapons laboratories. In addition, periodic independent reviews by outside experts help provide confidence in the credibility of the laboratories' assessments and in the process by which the assessments are made.

Refurbishing and Recertifying: the Design and Manufacturing Program

Nuclear warheads are not static objects. They contain radioactive materials that decay and organic materials that decompose with time. Some materials, like tritium, decay rapidly and must be replaced every few years throughout the warhead's lifetime. In addition, radioactive decay produces heat and decay products that cause changes in the radioactive materials themselves and in adjacent materials. For example, plastics and other organic materials change with age and exposure to heat and radiation. Many of the metals used in nuclear warheads are chemically reactive and are damaged by long-term exposure to radiation. As a result, all warhead parts must be considered limited-lifetime components, and all warheads in the enduring stockpile will require periodic refurbishment and remanufacturing.

With an improved understanding of the effects of aging on warhead safety, performance, and reliability, developed through our enhanced surveillance and assessment efforts, we will be able to take a proactive approach to refurbishment. Our goal is to replace or fix components systematically, before aging-related changes jeopardize warhead safety or performance.

We have instituted the Stockpile Life Extension Program (SLEP) to extend the life of a number of stockpile warheads. The SLEP provides the framework for our research and development activities and our production planning. A number of specific life extension programs are being defined for each warhead type, allowing the laboratories, plants, and the DoD to anticipate and plan for future maintenance and refurbishment requirements. The schedule guides stockpile-related research and development – at the laboratories to design and certify replacement components and validate new materials, and at the plants to develop and certify new manufacturing processes.

Ensuring Confidence in the System: Integrated Program Management

The Stockpile Stewardship Program is an integrated set of activities performed by an integrated complex of laboratories and plants. The technical challenges involved, combined with the downsizing of the production complex and the consolidation of activities at the laboratories, create the need for seamless, effective, and efficient program management. Indeed, program management lies at the heart of the new paradigm for stockpile stewardship.

The laboratories and plants are collaborating with each other and with U.S. industry to develop enhanced surveillance, advanced manufacturing and computer simulation and modeling capabilities, and tritium production technologies. Once the technologies and capabilities are developed and validated, integration and collaboration will continue as surveillance results are evaluated, replacement parts and manufacturing processes are designed concurrently, and refurbished warheads and components are certified.

An essential element of maintaining confidence in the stockpile—and in the system that maintains the stockpile—is the informed, vigorous, and skeptical set of interactions that take place among the laboratories, the DOE, and the DoD and its advisory groups. These include:

- *Peer review.* In scientific research, peer interaction and review are essential for maintaining excellence and providing confidence in the quality of the work. In the absence of nuclear testing, the need for peer review in stockpile stewardship and management is greater than ever before. Vital peer interactions take place through integrated and collaborative activities among the laboratories and through formal reviews of independent activities.

- *Dual revalidation.* This formal review process was developed in consultation with the Department of Defense. Teams from Los Alamos and Sandia–Albuquerque and from Livermore and Sandia–California independently evaluate the safety and reliability of each warhead. The teams perform the evaluation, one team with personnel from the laboratories that originally designed the warhead and the second team with personnel from the other laboratories. The teams independently review existing calculations and experiments pertaining to the warhead, evaluate relevant stockpile surveillance results and predictive analyses, and conduct separate programs of experimental and calculational work to investigate issues of concern and improve the baseline of understanding.

- *Stockpile life extension (SLEP).* The Stockpile Life Extension Program addresses the need to extend indefinitely the lifetime of existing warheads. It is designed to balance the concern that aging-related changes will degrade warhead safety or reliability against the concern that stockpile modifications may introduce new uncertainties. Life extension options have been defined for each warhead type in the stockpile. These scheduled refurbishments also provide the opportunity, while the warheads are disassembled, to make modifications to improve safety, reliability, or longevity. All stockpile life extension activities are closely coordinated with the Department of Defense before they are initiated.

- *Annual certification.* The Secretary of Defense and Secretary of Energy formally certify to the President that the U.S. nuclear stockpile is safe and reliable and that no nuclear testing is required. This certification is based on rigorous technical analyses that lead to formal concurrence by the Nuclear weapons Council, the Directors of the three nuclear weapons laboratories, and the Commander in Chief of the U.S. Strategic Command.

Other important interactions take place between the Department of Defense and the Department of Energy on issues related to stockpile safety and security. In addition, the Nuclear Weapons Council (NWC) carries out executive decisions on stockpile actions. The NWC, which is supported by a highly knowledgeable staff of military officers, members of the Office of the Secretary of Defense, and the DOE's Assistant Secretary for Defense Programs, also provides valuable review of DOE's stockpile plans.

Stockpile Stewardship Program Accomplishments

Almost six years have passed since the last U.S. nuclear test and almost seven years since the last new warhead entered the U.S. stockpile. The decision to end nuclear testing and new warhead production significantly changed the way in which the U.S. maintains the safety and reliability of its nuclear weapons stockpile. As the accomplishments highlighted below illustrate, much progress has been made in the development and successful implementation of the Stockpile Stewardship Program.

Program Architecture: the PEIS

Beginning in May 1995, Department of Energy held a series of public meetings as part of the process for preparing the Programmatic Environmental Impact

Statement (PEIS) for the Stockpile Stewardship Program. Meetings were held at each laboratory and plant site and in Washington D.C. The comments, questions, and discussions arising from these meetings provided extremely useful input for refining the program.

The Record of Decision for the PEIS was signed by the Secretary of Energy in December 1996. This document formally defines the architecture of the weapons complex for the Stockpile Stewardship Program. It covers the future capabilities required of the three weapons laboratories, the four plants, and the Nevada Test Site. It calls for construction of several advanced experimental facilities at the laboratories, for downsizing production capabilities in place, and for reestablishing some manufacturing capabilities at the laboratories.

The weapons complex outlined in the PEIS preserves the critical capabilities and assets of the laboratories, plants, and the Nevada Test Site. It is consistent with the reduced U.S. nuclear weapons stockpile under current and projected START options. It also supports the U.S. nuclear weapons policy of "lead plus hedge," as set forth in the most recent Nuclear Posture Review (conducted by the Department of Defense and approved by the President in September 1994). With this complex, the U.S. will be able to maintain a reduced nuclear arsenal while sustaining the capabilities needed to reverse course (in terms of stockpile size, nuclear testing, and new warhead production), should future circumstances so dictate.

Implementation Plan: the Green Book

The laboratories and plants have worked with each other and the Department of Energy to lay out a detailed implementation plan for the Stockpile Stewardship Program. This strategy is discussed in *The Stockpile Stewardship Plan*, often referred to as the Green Book. Specific roles and responsibilities have been defined and unique facilities and capabilities identified. As the program has evolved, the strategy has been revised and modified. With an up-to-date and detailed implementation plan, jointly prepared and agreed to by the plants and laboratories, we will be able to execute the Stockpile Stewardship Program efficiently and cost effectively, without duplication of effort, overlooked responsibilities, or gaps in necessary capabilities.

Administration and Congressional Support: the Budget

As the President has stated,

> *"In order for this program to succeed, both the Administration and the Congress must provide sustained bipartisan support for the stockpile stewardship program over the next decade and beyond. I am committed to working with the Congress to ensure this support."*

The President's 1999 budget request includes a five-year plan that meets this commitment. With such budgetary support, we are proceeding with the design and construction of vital new experimental facilities and with the acquisition of the next-generation supercomputers required for the Stockpile Stewardship Program.

Confidence in the Stockpile: the Annual Certification

A primary responsibility of DOE is to certify the safety and reliability of the nation's nuclear weapons stockpile. Stockpile safety and reliability issues are continually assessed by the Department and the Los Alamos, Livermore, and Sandia Laboratories. As part of the Stockpile Stewardship Program, a formal annual certification process has been established. This process incorporates technical evaluations from DOE and DoD, the Directors of the laboratories, and advice from the Commander in Chief of the Strategic Command and the Nuclear Weapons Council. The certification that the stockpile is safe and reliable rests on the expert judgment of these senior officials. The first two Annual Certifications have been completed. In their letters to the President, the Secretaries of Defense and Energy stated that there was no need to conduct an underground nuclear test to address safety or reliability problems.

New Capabilities

We have made major strides in the development and application of new capabilities for stockpile stewardship. Data and information from these new capabilities will be integrated with data from experiments in existing facilities and from past experiments and nuclear tests. Restoration of tritium production is essential and the development of all the new experimental facilities and capabilities are needed to provide confidence in the safety, reliability, and performance of the U.S. nuclear stockpile, now and in the future. The sum total of all these developments is needed for success.

DARHT, NIF, Subcritical Experiments, and Tritium Production.
Important decisions were reached regarding two vital new experimental facilities, subcritical experiments, and tritium production.

- *DARHT.* The Environmental Impact Statement for the Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility has been completed, and construction is under way at Los Alamos. When completed, DARHT will be the nation's most advanced facility for hydrodynamic experiments. These experiments are essential for validating the implosion performance of nuclear primaries.

- *NIF.* Lawrence Livermore has been selected as the site for the National Ignition Facility (NIF), engineering design work is under way, and ground was broken for construction in May 1997. This immense laser facility will provide a means for weapon physics and weapon effects experiments, and for improving and validating new physics models and computer codes.

- *Subcritical Experiments.* In April 1997, the Secretary of Energy announced a schedule for subcritical experiments, an essential component of the Stockpile Stewardship Program. The first two of these experiments were conducted in 1997. These experiments will provide valuable scientific information about the behavior of nuclear materials during the implosion phase of warhead operation. This information is needed to predict accurately the performance of stockpile warheads as they age.

- *Tritium.* DOE is currently pursuing a dual-track approach for the most promising tritium supply alternatives: 1) to initiate purchase of an existing commercial reactor or irradiation services with an option to purchase the reactor for conversion to a defense facility, and 2) to design, build, and test critical components of an accelerator for tritium production. By late this year, the DOE plans to select one of the tracks as the primary source of tritium. The other alternative, if feasible, would be developed as a backup source. Substantial progress has been made for both alternatives.

Strategic Computing and Simulation Advances: Teraflops Operation. Advanced computational tools to model nuclear weapons performance in three dimensions and with complete physics (that is, with minimal approximations) are being developed through the Accelerated Strategic Computing Initiative (ASCI). In partnership with industry and universities, we are developing the high-performance computing platforms, network connectivity, integrated codes, and problem-solving environment that will enable numerical simulation to provide as much of the integrated understanding of stockpile health as possible in the absence of nuclear testing.

The first installments of the advanced new ASCI computers have been delivered. Our ultimate goal is to develop 100-teraflops computers that can perform one hundred trillion mathematical operations per second. These computers will use thousands of processors, linked together using a technique known as massively parallel processing.

- *ASCI Red.* Intel Corp. and Sandia-Albuquerque are developing the ASCI Red machine. In December 1996, this machine demonstrated record-breaking teraflops operation—one trillion operations per second.

- *ASCI Blue Pacific.* IBM and LLNL are developing the ASCI Blue Pacific machine. The first installment of this machine was delivered in September 1996, and stockpile-related problems were run on it two weeks later.

- *ASCI Blue Mountain.* Silicon Graphics and LANL are developing the ASCI Blue Mountain machine. The initial delivery for this machine was made in late December 1996. In January 1997, a 9-hour test run of a hydrodynamics code was successfully completed.

- *ASCI White.* In February 1998, DOE announced that IBM and LLNL will develop the ASCI White machine. It is scheduled to be demonstrated in March 2000 and delivered to LLNL in June 2000. Its speed will be 10 teraflops, with a memory of 4 terabytes and a disk capacity of 150 terabytes.

Significant progress has been made by all three laboratory–industry teams in developing the problem-solving environment (the operating system, data storage and retrieval, utility and applications codes) needed to support terascale computing. Even at this early stage in their development, advanced weapons simulation codes are providing unprecedented capabilities to our weapons scientists. For example, coupled three-dimensional thermal–chemical–hydrodynamic calculations of warhead safety (for example, a warhead in a fire) are now possible. As a practical matter, some standard weapons-related calculations have been performed 100 times faster than before. Through this initiative, the time it took to run one simulation was reduced from 74 days to 7 hours.

The Academic Strategic Alliances Program was launched in July 1997. Five major U.S. universities—Stanford University, the California Institute of Technology, the University of Chicago, the University of Utah at Salt Lake, and the University of Illinois at Urbana/Champaign—will collaborate with LLNL, LANL, and Sandia on extremely challenging projects that will drive the advancement of large-scale computational modeling. The challenges posed by ASCI—and the potential civilian as well as stewardship applications of the computational advances to be gained—demand the broad collaboration of the national laboratories, academia, and industry. There will be benefits in scientific areas such as turbulence, shock physics, astrophysical thermonuclear flashes, atmospheric modeling, numerical simulation of accidents involving explosives and propellants, and other basic science and civilian applications, in addition to stockpile stewardship.

Meeting the Day-to-Day Needs of the Stockpile

We have continued to maintain the U.S. nuclear weapons stockpile. Problems in the stockpile have arisen in the last five years. Some of these problems are similar to those for which, in the past, we conducted nuclear tests to investigate or resolve. However, using the stockpile stewardship approach, we are drawing on test-related expertise and on emerging new capabilities to evaluate and resolve these problems. We have made major progress in dual revalidation, stockpile life extensions, in developing new processes and production capabilities, and in transferring production from plants that are shut down to those that remain.

Warhead dismantlement

Dismantlement of the Cold War arsenal continues, even as we are developing the enhanced capabilities and facilities needed to support the enduring U.S. stockpile. As a result of START I and separate Presidential decisions, thousands of warheads have been removed from the U.S. stockpile and are slated for dismantlement. More than 1000 warheads were dismantled in 1996, and over 500 warheads in 1997. START II will result in further reductions. In March 1997 at Helsinki, Presidents Clinton and Yeltsin agreed as part of the next START agreement to reduce strategic stockpiles even further to levels of 2000-2500 warheads, as well as to explore measures that would involve transparency of warhead inventories and their destruction.

Conclusion

Under the Stockpile Stewardship Program, our goal is unchanged from previous years—namely, to provide confidence in the safety and reliability of the U.S. nuclear stockpile. Absent nuclear testing, the tools have changed significantly — stockpile confidence will now rely on nonnuclear demonstration-based assessments of warhead safety, reliability, and performance. New experimental and computational capabilities are being developed. With these tools, we will be able to offset the loss of critical expertise that will result from the retirement of our remaining nuclear test- and design-experienced weapon scientists and engineers. In the coming years, we will validate these new tools, integrate the information they provide with the suite of weapons-related data and models, and train the next generation of stockpile stewards. On the basis of progress made to date, we are confident that we will be successful and will be able to maintain the safety, security, and reliability of the enduring U.S. nuclear stockpile, now and in the future.

References

1. "Stockpile Stewardship Program – Overview and Progress", Department of Energy, Office of Defense Programs, October 1997.

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