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# SAFETY AND RELIABILITY OF THE U.S. NUCLEAR DETERRENT

## HEARING

BEFORE THE

SUBCOMMITTEE ON INTERNATIONAL SECURITY, PROLIFERATION, AND FEDERAL SERVICES

OF THE

COMMITTEE ON GOVERNMENTAL AFFAIRS

UNITED STATES SENATE

ONE HUNDRED FIFTH CONGRESS

FIRST SESSION

OCTOBER 27, 1997

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# THE SAFETY AND RELIABILITY OF THE U.S. NUCLEAR DETERRENT

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**MONDAY, OCTOBER 27, 1997**

U.S. SENATE,
SUBCOMMITTEE ON INTERNATIONAL SECURITY,
PROLIFERATION, AND FEDERAL SERVICES,
OF THE COMMITTEE ON GOVERNMENTAL AFFAIRS,
*Washington, DC.*

The Subcommittee met, pursuant to notice, at 2 p.m., in room SD–342, Dirksen Senate Office Building, Hon. Thad Cochran, Chairman of the Subcommittee, presiding.

Present: Senators Cochran, Thompson, Domenici, and Levin.

## OPENING STATEMENT OF SENATOR COCHRAN

Senator COCHRAN. The meeting of our Subcommittee will please come to order. Today, our hearing topic is the safety and reliability of the U.S. nuclear deterrent. This Subcommittee has had a full schedule this year, holding 11 hearings on proliferation, arms control, export controls, ballistic missile defense, and nuclear deterrence, exploring each issue and examining the relationships among these issues.

Our first hearing in February was on the future of nuclear deterrence, and today's hearing, the last for this year, is an outgrowth of that hearing. The witnesses at that first hearing were Dr. Walt Slocombe, General Andrew Goodpaster, and Richard Perle. As expected, there was some disagreement among the witnesses. But there was a convergence of views on a key point, that as long as the United States has nuclear weapons, these weapons must be safe and reliable, without regard to the size of the stockpile. The witnesses agreed that unsafe or unreliable nuclear weapons would undermine the central functions assigned to these weapons in our national security strategy.

For most of the last 52 years, the United States has ensured the safety and reliability of the nuclear stockpile through periodic testing of these weapons. In September 1996, however, President Clinton signed a zero-yield Comprehensive Test Ban Treaty, pledging that the United States would, subject, of course, to the advice and consent of the Senate, bind itself to an international regime that forswears nuclear testing. In signing the CTBT, the President made a political decision to end the testing of America's nuclear weapons, announcing that the United States would attempt, instead, to ensure the safety and reliability of our weapons through a science-based Stockpile Stewardship and Management Program.

The directors of our national labs, Lawrence Livermore, Los Alamos, and Sandia, pledged their best efforts to design and implement such a program. Nevertheless, as Los Alamos Director Hecker has said, "We recognize that there is no substitute for full-systems testing in any complex technological enterprise. This is certainly true for nuclear weapons. A robust nuclear testing program would certainly increase our confidence."

That the senior leadership of these labs accepted the challenge of ensuring the stockpile's safety and reliability through some new method should be given due weight when the Senate considers the Comprehensive Test Ban Treaty. These labs have a record of success and unparalleled scientific and engineering achievement, and the people who have worked at them, beginning with the Manhattan Project, are deserving of America's appreciation.

Even so, this impressive record of success has not been unblemished by failure, so when the lab directors now say they think the Stockpile Stewardship Program will be good enough in a zero-yield environment to ensure the safety and reliability of our nuclear weapons because it is the best program they can develop, the Senate must take their judgment into account. But we must also ask a fundamental question. Is this assurance good enough?

In preparing for this hearing, Subcommittee staff met with senior officials of the three labs and the Department of Energy headquarters. They have all been unfailingly available and helpful in explaining the details of the Stockpile Stewardship Program. The nearly universal desire expressed by these experts has been a preference to delay joining the Comprehensive Test Ban Treaty until the Stockpile Stewardship Program is more mature, until its prospects for success are more likely.

I quote statements that have been made to Subcommittee staff by senior lab and Energy Department officials. "How do we know that we have failed? We do not have an acceptable answer yet." "The Stockpile Stewardship Program might be good enough. We hope it is good enough." Stockpile stewardship is "our best attempt, though it might not be enough." "We do not know if stockpile stewardship is good enough, and we do not know when we will know if it is good enough." "There is no guarantee that stockpile stewardship will work. It is just the best we can do." "I am skeptical of the Stockpile Stewardship Program."

Nobody yet knows if the program will sufficiently offset the loss of nuclear testing, and if so, when we will know it, nor have we a good idea of when we will know if it will not be an adequate replacement for testing. The key question is whether the United States should agree to give up testing when the Stockpile Stewardship Program may never become an acceptable alternative.

We have with us today three witnesses of impressive credentials and experience to assist us in examining the Stockpile Stewardship Program and its relationship to the Comprehensive Test Ban Treaty. Testifying first will be Dr. James Schlesinger, former Secretary of Defense for Presidents Nixon and Ford, former Secretary of Energy for President Carter, former Director of Central Intelligence and Chairman of the Atomic Energy Commission. Our second witness will be Dr. Vic Reis, Assistant Secretary of Energy for Defense Programs. Our final witness will be Dr. Robert Barker, currently the Assistant to the Director of the Lawrence Livermore National Lab. Dr. Barker has designed nuclear weapons and participated in their testing and has served as the Assistant to the Secretary of Defense for Atomic Energy.

Dr. Schlesinger, welcome to our Subcommittee. Before proceeding, though, I want to recognize my distinguished colleague, the Senator from Michigan, Senator Levin, for any comments that he might have.

**OPENING STATEMENT OF SENATOR LEVIN**

Senator LEVIN. Thank you, Mr. Chairman. Let me join you in welcoming all of our witnesses this afternoon.

The subject before us this afternoon, which is the Department of Energy's Stockpile Stewardship and Management Program, is, indeed, a key underpinning of the Comprehensive Test Ban Treaty and it is this program which enabled the President to decide to seek a zero-yield test ban treaty and it is this program which will, hopefully, provide for a safe and reliable deterrent in the future without nuclear weapons testing.

The witnesses this afternoon represent a variety of views on the Stockpile Stewardship Program and on the Comprehensive Test Ban Treaty itself. One of the witnesses that we had hoped to be able to join us, and I had requested you, Mr. Chairman, to extend the invitation on short notice, which you were kind enough to do, was Dr. Tarter. He apparently did not get that invitation in time and was unable to join us. But again, I very much appreciate, Mr. Chairman, your willingness to add him to the list. I would like to get a statement of his for the record, if that would be OK.

Senator COCHRAN. Without objection, we will make a statement from him a part of the record.

Senator LEVIN. Of course, the question we face is whether or not the testing of nuclear weapons is necessary to maintain a safe and reliable nuclear deterrent or will the Stockpile Stewardship Program ensure a safe and reliable stockpile? The top scientific experts with responsibility for the program have confidence that stockpile stewardship will provide the knowledge needed to answer the question in the affirmative, indeed, that Stockpile Stewardship Program will ensure a safe and reliable stockpile.

Are there any guarantees? As in most things in life, there are no guarantees. The question is whether or not there are sufficient safeguards that will be in place, including maintaining the ability to conduct a test, if necessary, so that the reliance which the stewards of the stockpile have on the Stockpile Stewardship Program is well founded.

This program and this test ban treaty have allowed us to take a significant step to reduce the nuclear danger and to reduce the importance of nuclear weapons to global security and to enter into a Nonproliferation Treaty and to have that treaty, be available for others to sign. Those are very important goals, as well, and those goals have been achieved, in part because the stewards of our stockpile have confidence in the Stewardship Program, and that, in turn, has allowed us to enter into the Comprehensive Test Ban agreement which is so significant an achievement in terms of reducing the reliance on nuclear weapons and the possibility of trying to end the proliferation of those weapons in the world.

The issue before us today is a very important one, and as always, Mr. Chairman, you have put your finger on a very significant issue and we look forward to the testimony of our witnesses today.

Senator COCHRAN. Thank you very much, Senator.

Let me also extend a word of welcome to our distinguished Senator from Arizona, Mr. Kyl, who joins us today. He has had an active interest in the subject that we are discussing and also has exchanged communications with the Directors of the Livermore and Los Alamos Labs. We intend to put the questions and answers that Senator Kyl has obtained on this subject at least in an addendum to our hearing record and we appreciate his being here.

Dr. Schlesinger, welcome again. Thank you very much for being here. You may please proceed. We have a copy of your testimony, which we will put in the record in full, and you may proceed to make any comments, summarize it, or read it, whatever pleases you, sir.

**TESTIMONY OF JAMES SCHLESINGER, FORMER DEFENSE SECRETARY, FORMER CHAIRMAN OF THE ATOMIC ENERGY COMMISSION, AND FORMER SECRETARY OF ENERGY**

Mr. SCHLESINGER. Thank you, Mr. Chairman, Senator Levin, and Senator Kyl. I am delighted to be here. I thank you for the invitation. I will attempt to lay out some of the issues that will lie before the Senate as it comes up to the issue of ratification of the CTBT.

Mr. Chairman and Members of the Subcommittee, as the Senate considers the CTBT, it will be obliged to focus on one dominant, ineluctable result of its ratification. Over the decades ahead, confidence in the reliability of our nuclear weapons and in the U.S. deterrent would inevitably decline. The Stockpile Stewardship Program will unquestionable mitigate that decline to some extent. It is hoped that it may mitigate the decline to a substantial extent. But for the moment, that remains only a hope. Mitigation is, of course, not the same as prevention. Over the decades, the erosion of confidence inevitably will be substantial.

A nuclear weapon is a complicated device, especially so the sophisticated weapons in the U.S. stockpile. Its numerous components must function together with split-second timing. There is scant margin for error. Moreover, a nuclear weapon must be able to endure highly stressful environments. On a ballistic missile, for example, a weapon must withstand the shock of sharp acceleration, the sub-zero temperatures of space, heat of reentry, deceleration, and possibly impact. Air-delivered weapons must undergo similar physical stress, though to a lesser degree. Once again, there is little tolerance for miscalculation.

There has never been an adequate statistical basis for establishing weapon reliability, nor have we been able adequately to measure the other phenomenon that I have just mentioned. Inevitably, there has always been a good deal of estimation and educated guesswork in estimating weapon reliability and overall system reliability. A permanent test ban would, of course, amplify those problems.

As a nuclear weapon ages, its individual components are subject to the effects of aging—corrosion, deterioration, and unexpected as well as expected failure. The shelf life of U.S. nuclear weapons was expected to be some 20 years. In the past, the constant process of replacement and testing of new designs gave some assurance that weapons would not be subjected to the effects of aging. But in the future, we shall be vulnerable to the effects of aging because we shall not be able to replace or to test weapons. In a decade or so, we will be beyond the expected shelf life of weapon in the stockpile.

It might be noted that a 1978 report to the Armed Services Committee stated, “The reliability of our nuclear weapons has been assured by the continuous introduction of recently-tested new designs and by a constant turnover of the stockpile made possible by the retirement of old weapons before they have begun to deteriorate.” It may also be noted that for Soviet, and now Russian, weapons, the expected shelf life has been 10 years. Unlike ourselves, the Russians continue to produce some thousands of weapons each year to replace aging weapons in their inventory. By contrast, despite an explicit policy commitment, the United States at this time lacks the capability either to fabricate or to certify new warheads.

The Stockpile Stewardship Program will, among other things, disassemble nuclear weapons selected from the stockpile, subject the components to careful individual scrutiny, looking for signs of corrosion, decay, et cetera. Individual components will be replaced if the judgment is reached that they have failed or are near failure. We will try to make those replacements as identical as possible to the earlier component. A problem exists that individual components go out of production, manufacturers go out of business, materials change, production processes change, certain chemicals previously used in production processes may have been forbidden under new environmental regulations, and so on. The upshot is that we can never be quite certain that these replacement components will work as did their predecessors.

The Department of Energy is to be applauded for its commitment meticulously to examine weapons in the stockpile. I trust that the Congress will not fail to provide the funds for the Stewardship Program. But one must also recognize that the reassurance once available through the testing of weapons, at least to the point of nuclear ignition, is no longer there. In addition, the Stewardship Program will create new facilities intended to reduce our still incomplete knowledge regarding what occurs in a nuclear explosion.

It will also provide funding for further enhancement of computation power. But these new facilities and new enhancements will not be fully available for a decade and then the experimentation and the assessment of the results will require additional years. Moreover, even significantly enhanced computation power would still not be able to simulate a weapon 3-dimensionally. And, of course, unlike a reliable weapon, which can be simulated symmetrically, that is, 2-dimensionally, a weapon undergoing decay decays asymmetrically.

Once again, I trust that the Stewardship Program will be vigorously pursued and will be vigorously supported by the Congress. Nonetheless, it will be many years before the new facilities and new capabilities are in place. It will be more years before the projected experiments can be completed and assessed. If the treaty is ratified, the Stewardship Program would be subjected to the usual budget pressures and to the possible erosion of support by the administration or by the Congress. It will be many, many years before we can assess adequately the degree of success of the Stewardship Program and the degree to which it may mitigate the decline of confidence in the reliability of the stockpile.

We should bear in mind that DOE and laboratory personnel were never asked, what should we do to sustain or to maximize confidence in the reliability of our weapons? To that question, the answer remains obvious, as recently testified by the current directors of the lab. Periodic testing, at least a very low yields, remains desirable. By "very low yields", I mean in the 1 to 2 kiloton range, Mr. Chairman.

Instead, they have been asked the question, given an international commitment to eliminate nuclear testing, how can you best seek to sustain confidence in weapon reliability? To that rather different question, the system has responded with a vigorous program for stewardship, but no one now has either the experience or the knowledge to anticipate the degree of success of the Stewardship Program. When queried, DOE or laboratory officials will indicate that there is a good chance that, through the program, we shall be able to maintain sufficient confidence in the stockpile.

They also know that it will be more than a decade before we can judge how successful the Stewardship Program will have been and they recognize that never before have we depended on weapons as old as those steadily aging weapons in the stockpile. In assuring weapon reliability, there is no substitute for nuclear testing. How imperfect or how satisfactory a substitute the Stewardship Program will prove to be remains to be seen.

For many years, the Congress has received repeated and persistent testimony from officials at the DOE and its predecessor agencies, from laboratory directors and scientists, from the Chiefs, and from the relevant CINCs that nuclear weapons testing was essential.

I have here comments by General Powell, for example, to the question, "Are you prepared to recommend to the President that we continue nuclear testing?" General Powell, "I would recommend to the Secretary and to the President it is a condition that we could not meet," that is, the Russian demand that we cease testing. "I would recommend against it. We need nuclear testing to ensure the safety and security of our nuclear stockpile. As long as one has weapons, you have to know what it is that they will do, so I would recommend continued testing." I have a statement from Admiral Crowe and I have similar statements from six laboratory directors.

The testimony in the past has been clear. Suddenly, that testimony has changed and now we have a somewhat more ambiguous response. Senators will, no doubt, want to satisfy themselves to what extent things have really changed.

We must also contemplate what is implied by the permanent cessation of nuclear testing. As one senior official has confided, none of us can comprehend what that means. Some 36 years ago, President Kennedy decided to resume nuclear testing after the Soviet Union broke the moratorium. Consider what it would mean to have an equal period of 36 years in the future without weapons testing. We would then be dependent upon the judgment of engineers who are being hired today, that is, dependent on the judgment of personnel who will have no personal experience either in designing or in testing nuclear weapons. In place of a learning curve, we would experience an extended unlearning curve. In brief, we are embarked on a voyage into the unknown.

Mr. Chairman, let me now turn away from technical issues to the political and strategic issues. Does a decline in the confidence in the stockpile, to a degree which cannot now be predicted, matter all that much? Quite clearly, in the current circumstances, it matters far less than it would have at the height of the Cold War. The collapse of the Soviet Union and the Warsaw Pact has substantially reduced the dependence of the United States and its allies on nuclear weapons. The challenge of holding a nuclear umbrella over our allies in Western Europe and elsewhere has been substantially alleviated. Moreover, the requirement to initiate the use of nuclear weapons in response to an overwhelming conventional attack has been eliminated, at least for the time being. Indeed, any need for such a nuclear response to a conventional attack has, at least for this period, happily disappeared.

Given these altered circumstances, does a decline in the confidence in the stockpile reliability matter at all? If the United States were just another country and its nuclear posture were designed simply to deter attack on its own territories, such a decline would probably have only limited significance.

The United States is, however, not just another country. Its geopolitical role on the current world scene is unique. It has both acquired and has had thrust upon it international responsibilities. It is still pledged to hold a nuclear umbrella over its NATO allies and Japan. It has a semi-commitment also to hold an umbrella over other states, possibly including those non-nuclear weapons states that have signed the NPT. Its forces are stationed in many countries. Though it itself has abandoned chemical and biological weapons, it has threatened to retaliate with nuclear weapons to such an attack. In the Gulf War, such a threat apparently was sufficient to intimidate Saddam Hussein from employing chemical weapons.

In addition, the United States has a very ambitious foreign policy agenda. At this time, it is engaged in the expansion of NATO. Our most senior officials have additionally indicated that NATO membership should be open to any democratic country in Europe. If, for example, NATO is expanded to include the Baltic States, no conventional defense would be possible. Under such circumstances, if we were to fulfill a commitment to provide protection, we would be driven back to threatening a nuclear response to a conventional attack, a commitment from which we have only escaped recently.

Given the nature of our foreign policy agenda and given the unique geopolitical role of the United States, a decline in the confidence in U.S. nuclear weapons cannot, therefore, be viewed with equanimity.

Over the years, much of the pressure for a complete cessation of nuclear testing has been based upon a belief that such cessation would help to prevent nuclear proliferation. I believe that such a view is exaggerated, at best. The motivation for the so-called rogue nations—Iraq, Iran, Libya, North Korea—to acquire nuclear weapons surely will not be affected by whether or not the United States tests. Similarly, the possession of nuclear capabilities by the so-called nuclear threshold states—India, Pakistan, Israel—depend upon the regional circumstances and are scarcely affected by whether or not the United States tests. Indeed, the incentives might actually point in the opposite direction. If confidence in the reliability of the U.S. nuclear deterrent were to decline, other nations that have been content to rely on American protection might feel impelled to seek their own nuclear protection.

The ambitious nature of the U.S. foreign policy agenda implies that a decline in the confidence in the reliability of U.S. nuclear weapons and in the U.S. nuclear deterrent could not be viewed with equanimity. To be sure, we might be prepared to limit our foreign policy agenda as confidence in the reliability of the stockpile declines. At the moment, however, there is little inclination to move in that direction and even less realization that such a price might have to be paid.

The geopolitical role of the United States remains unique. Cessation of nuclear testing would have consequences and those consequences will grow as the decades pass. As members of the Senate consider ratification of the proposed CTBT and the effectiveness of the Stockpile Stewardship Program to slow down the decline in the confidence in stockpile reliability, they will, I believe, want to carefully examine the risks as well as the benefits of the proposed treaty. Thank you, Mr. Chairman. I will be delighted to respond to any questions.

[The prepared statement and article from the *Wall Street Journal,* submitted by Mr. Schlesinger follows:]

## PREPARED STATEMENT OF MR. SCHLESINGER

### IMPLICATIONS OF A ZERO-YIELD NUCLEAR TEST BAN

Mr. Chairman, Members of the Committee: As the Senate considers the CTBT, it will be obliged to focus on one dominant, ineluctable result of its ratification: over the decades ahead, confidence in the reliability of our nuclear weapons and in the U.S. Deterrent would inevitably decline. The Stockpile Stewardship Program will unquestionably mitigate that decline to some extent. It is hoped that it may mitigate the decline to a substantial extent. But for the moment that remains only a hope. Mitigation is, of course, not the same as prevention. Over the decades, the erosion of confidence inevitably will be substantial.

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It might be noted that a 1978 report to the Armed Services Committee stated: "the reliability of our nuclear weapons . . . has been assured by the continuous introduction of recently tested new designs and by a constant turnover of the stockpile made possible by the retirement of older weapons before they have begun to deteriorate." It may also be noted that for Soviet—and now Russian—weapons, the expected shelf-life has been ten years. Unlike ourselves, the Russians continue to produce some thousands of weapons each year to replace aging weapons in their inventory. By contrast, despite an explicit policy commitment, the United States at this time lacks the capability either to fabricate or certify new warheads.

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Once again, I trust that the Stewardship Program will be vigorously pursued and will be vigorously supported by the Congress. Nonetheless, it will be many years before the new facilities and new capabilities are put in place. It will be more years before the projected experiments can be completed and assessed. If the treaty is ratified, the Stewardship Program would be subjected to the usual budget pressures and to the possible erosion of support by the administration or by the Congress. It will be many, many years before we can assess adequately the degree of success of the Stewardship Program and the degree to which it may mitigate the decline of confidence in the reliability of the stockpile.

We should bear in mind that DOE and laboratory personnel were never asked: what should we do to sustain or to maximize confidence in the reliability of our weapons? To that question the answer remains obvious: periodic testing at least at very low-yield remains desirable. Instead they have been asked a question: given an international commitment to eliminate nuclear testing, how can you best seek to sustain confidence in weapon reliability? To that rather different question the system has responded with a vigorous program for stewardship. But no one now has either the experience or the knowledge to judge the degree of success of the Stewardship Program. When queried, DOD or laboratory officials will indicate that there is "a good chance" that through the program we shall be able to maintain "sufficient" confidence in the stockpile. They also know that it will be more than a decade before we can judge how successful the Stewardship Program will have been, and they recognize that never before have we depended on weapons as old as those steadily aging weapons in the stockpile. In assuring weapon reliability, there is no substitute for nuclear testing. How imperfect a substitute the Stewardship Program will prove to be remains to be seen.

For many years, the Congress has received repeated and persistent testimony from officials at the DOE and its predecessor agencies, from laboratory directors and scientists, from the Chiefs, and from the relevant CINC's that nuclear testing was essential. Suddenly that testimony has changed, and now we have a somewhat ambiguous response. Senators will, no doubt, want to satisfy themselves to what extent things have really changed.

We must also contemplate what is implied by the *permanent cessation* of nuclear testing. As one senior official has confided—one of us can comprehend what that means. Some thirty-six years ago President Kennedy decided to resume nuclear testing after the Soviet Union broke the Moratorium. Consider what it would mean to have an equal period in the future without weapons testing. We would then be dependent upon the judgment of engineers who are being hired today—that is dependent on the judgment of personnel who will have no personal experience either in designing or in testing nuclear weapon. In place of a learning curve, we would experience an *extended unlearning curve.* In brief, we are embarked on a voyage into the unknown.

II.

Mr. Chairman, let me now turn away from technical issues to the political and strategic issues. Does a decline in confidence in the stockpile, to a degree which cannot now be predicted, matter all that much? Quite clearly in the current circumstances, it matters far less than it would have at the height of the Cold War. The collapse of the Soviet Union and the Warsaw Pact has substantially reduced the dependence of the United States (and its allies) on nuclear weapons. The challenge of holding a nuclear umbrella over our allies in Western Europe and elsewhere has been substantially alleviated. Moreover, the requirement to initiate the use of nuclear weapons in response to an overwhelming conventional attack has been eliminated. Indeed, any need for such a nuclear response to a conventional attack has, at least for this period, happily disappeared.

Given these altered circumstances, does a decline in confidence in the stockpile reliability matter at all? If the United States were just another country and its nuclear posture were designed simply to deter attack on its own territories, such a decline would probably have only limited significance.

The United States is, however, not just another country. Its geopolitical role on the current world scene is unique. It has both acquired and has had thrust upon it international responsibilities. It is still pledged to hold a nuclear umbrella over its NATO allies and Japan. It has a semi-commitment also to hold an umbrella over other states, possibly including those non-nuclear weapon states that have signed the NPT. Its forces are stationed in many countries. Though it has abandoned chemical and biological weapons, it has threatened to retaliate with nuclear weapons to such an attack. In the Gulf War such a threat apparently was sufficient to intimidate Saddam Hussein from employing chemical weapons.

In addition, the United Statics has a very ambitious foreign policy agenda. At this time, it is engaged in expansion of NATO. Our most senior officials have additionally indicated that NATO membership should be open to any democratic country in Europe. If, for example, NATO is expanded to include the Baltic states, no conventional defense would be possible. Under such circumstances, if we were to fulfill a commitment to provide protection, we would be driven back to threatening a nuclear response to a conventional attack—a commitment from which we have only escaped recently. Given the nature of our foreign policy agenda and given the unique geopolitical role of the United States, a decline in the confidence in U.S. nuclear weapons cannot therefore be viewed with equanimity.

Over the years, much of the pressure for a complete cessation of nuclear testing has been based upon a belief that such cessation would help to prevent nuclear proliferation. I believe that such a view is exaggerated at best. The motivation for the so-called rogue nations—Iraq, Iran, Libya, North Korea—to acquire nuclear weapons surely will not be affected by whether or not the United States tests. Similarly, the possession of nuclear capabilities by the so-called nuclear threshold states—India, Pakistan, Israel—depend upon regional circumstances and are scarcely affected by whether or not the United States tests. Indeed, the incentives might actually point in the opposite direction. If confidence in the reliability of the U.S. nuclear deterrent were to decline, other nations that have been content to rely on American protection might feel impelled to seek their own nuclear protection.

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The geopolitical role of the United States remains unique. Cessation of nuclear testing would have consequences—and those consequences will grow as the decades pass. As members of the Senate consider ratification of the proposed CTBT, and the effectiveness of the Stockpile Stewardship Program to slow down the decline in the confidence in stockpile reliability, they will, I believe, want to carefully examine the risks as well as the benefits of the proposed treaty.

*Article from The Wall Street Journal, Monday, July 12, 1993*

CLINTON DEFERS A NECESSITY—NUCLEAR TESTING

*By James Schlesinger*

On July 3, President Clinton announced his long-awaited decisions regarding the future of nuclear testing, called for by congressional legislation enacted in 1992. In brief, he decided to continue the nuclear testing moratorium for at least 15 months, to avoid nuclear testing unless some other nation tests, to begin negotiations for a comprehensive test ban starting presumably in 1996, and, apparently, to prohibit subsequent testing with nuclear yield.

Since our national security and foreign policy departments had within recent months recommended unanimously that nuclear testing be resumed (and a presidential decision to do so had been announced to the press), these decisions represented quite a package to be buried on the Fourth of July weekend.

Let us first examine the short-run implications. The most serious is that we have scuttled our most intimate, longtime ally. The U.S. has been committed to allowing the British to test the warheads for their Trident program (for which, incidentally, we are selling them the missiles) at our Nevada test range. Unless some other weapons state bails us out by testing first, the president's decision means that the British program is both delayed and degraded. Quite bluntly, we have treated the British more shabbily than at any time since another weapons doublecross, the Skybolt decision of 1962. British officials have steadily urged the administration to permit their tests to take place, but they have done so quietly, wishing to avoid an embarrassing public rebuff by their major ally.

*Concerns Over Warheads*

This decision will seriously damage our relations with the U.K. On the Continent, the reaction could be even worse. The Germans will recall being similarly embarrassed by the neutron bomb decision of 1977. The French will likely extract some delight in seeing the British (once again) come a cropper in their willingness to rely on the U.S. But overall the reaction will be quite simple: If the Americans despite their "special relationship," are prepared to do this to the British, what kind of support can the rest of Europe expect?

There is another near-term aspect of the decision not to test. Present law permits testing to enhance the safety of the weapons inventory. The president's decision puts us in a paradoxical and potentially distressing position: If we have a serious safety problem, we must wait for some other nation to test before we address that problem. Even now there are safety concerns with the W–88 warhead for the Trident and the W–80 for the air-launched cruise missile.

These are, however, risks that we can tolerate. All in all, the president's decision does little immediate damage to America's own defense posture. But if we turn to the longer run, the consequences are potentially dire. Why this is so requires a brief explanation of the nature of nuclear weapons, and the continued necessity for reliability testing.

A nuclear weapon is a highly complicated device. This is especially so for American weapons, since over the decades we have steadily sought to improve yield-to-weight ratios, safety, security and reliability. Over time, individual components of these weapons will fail or degrade, and will have to be replaced. Acceptable components may become unavailable, as manufacturers shift product lines or go out of business. Over time, materials may be slightly altered. Thus new components or components of slightly different materials must be integrated into weapon designs that were deployed earlier. As this process goes on over the years, a simple question arises: Will this design still work?

That is why reliability testing is essential. As time passes, and as the weapon is retrofitted, we must be absolutely confident that this modified device will still induce the proper nuclear reaction. That is why nonnuclear testing, valuable as it is, is insufficient. It is why talk of a test ban with zero nuclear yield is irresponsible. Testing for reliability may be very low-yield, in the kiloton range, but it remains essential if we are to maintain confidence in stockpile reliability.

All this should be perfectly obvious, if nuclear testing had not become so freighted with symbolism in the years since President Kennedy's atmospheric test ban. Individuals who would not allow their lawnmowers, let alone their automobiles, to go untested for more than a year will argue with apparent seriousness that our nuclear weapons can remain untested in perpetuity and yet remain reliable.

The history, of complex military hardware gives no support to that belief. To cite one example, going into World War II the Navy's torpedoes had not been adequately tested because of insufficient funds. It took two years of war before we fully solved the problem of making our torpedoes effective. At the battle of Midway, the U.S. launched 47 torpedo aircraft, with not a single hit on any Japanese ship. (The Japanese performance at Pearl Harbor was noticeably better.) Had it not been for our dive bombers (and some good luck) the U.S. would have lost the crucial naval battle of the Pacific war.

We can reduce the number of tests to a minimum. We can go to very low-yield testing. But we cannot—unless we are irresponsible—eliminate testing entirely. Especially now that we are reducing the numbers of delivery vehicles and warheads, we cannot afford to allow warhead reliability to erode as well. No longer will there be a sufficient variety of systems to tolerate, say, more than one weapon's reliability problem.

The legislation adopted by Congress in 1992 (and reluctantly signed by President Bush) was based on the premise that we could run a few reliability tests between now and the end of 1996, and those few tests would ensure the reliability of our principal weapons designs in perpetuity. It is a false premise, reflecting a rather cavalier attitude toward stockpile reliability. It will not stand up to scrutiny.

The administration will seek to justify its reversal. First, it will emphasize that a halt in testing is essential to our effort to prevent the spread of nuclear weapons. This seems to suggest that the reason such leaders as Kim II Sung, Saddam Hussein, Moammar Gadhafi, and Hashemi Rafsanjani—as well as prominent nonproliferation treaty holdouts like India and Pakistan—are motivated to acquire nuclear capabilities is that the Americans are testing.

To say the least, this strikes me as a naive reading of the motivations of nuclear aspirants. Suffice it to say, to prevent the further spread of nuclear weapons will require a massive effort on the part of the U.S. and the international community, and we shall get scant assistance by refraining from an occasional low-yield test to sustain our confidence in stockpile reliability. Indeed, those many nations that prefer to be sheltered under the American nuclear umbrella (though they themselves could acquire nuclear capabilities) will scarcely be sustained in their policies if our actions raise doubts about the reliability of our weapons.

Second, we shall hear much in the months ahead about the new safeguards that will be put in place as a substitute for testing: advanced simulation techniques, new computer codes, etc. We shall hear praise for the sophistication of our laboratories that can make testing unnecessary. Yet one conclusion remains ineluctable: In the absence of any nuclear testing, both the estimate of stockpile reliability and the degree of confidence in that estimate will erode over the decades ahead.

Third, we shall hear a great deal about the soundings that were taken in Congress and the negotiations regarding what would be acceptable, before the administration abandoned its initial decision to resume testing. That there were such inquiries is true, but they were primarily with the critics of nuclear testing who sought to emphasize how restrictive the legislation was.

*Ignoring the Critics*

Little attempt was made to listen to those lawyers who insisted that the legislation provided the administration with ample leeway. Little attempt was made to organize support for renewed testing on the Hill. For example, save for the principal sponsor of the legislation, Republicans in the Senate were ignored. In any event, it is the obligation of an administration not simply to defer to prevailing Hill sentiment but to shape attitudes on important matters of national security.

The administration has acknowledged that in this case, at least, it has failed to do so. However, there is some good news in the administration's handling of this issue. In my judgment it will forever preclude this or another administration's obtaining the 67 Senate votes needed to ratify a comprehensive test ban treaty, if that treaty were to preclude low-yield testing for reliability purposes.

Our principal designs are relatively new. For the next half-decade, perhaps for as long as a decade, the decline in the confidence in the stockpile will be relatively modest. If President Clinton does not recognize the connection between continued testing and confidence in the stockpile, one of his successors almost certainly will. Continued testing, if very modest testing, is the price of a reliable deterrent.

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*Mr. Schlesinger is former Defense Secretary, former Chairman of the Atomic Energy Commission, and former Secretary of Energy.*

Senator COCHRAN. Thank you very much, Dr. Schlesinger, for your interesting statement.

Before I came over here, I was at a luncheon and the question came up what I had to do this afternoon. I mentioned to one of my luncheon companions that I would chair a hearing on the subject of the safety and reliability of the U.S. nuclear deterrent and this person said, "Well, do not mess up." That very clearly, I think, sets the tone for this hearing, at least in my mind, that makes this a very serious undertaking. We really do need to know what we are doing and what the consequences of our actions in ratifying this Comprehensive Test Ban agreement will be and whether or not there is in place an acceptable alternative to testing.

Your testimony also, I think, meets the challenge of the seriousness of the activity that we are about, examining the facts, examining the consequences, and so we deeply appreciate your taking time to come here to the hearing today and to present this impressive testimony.

Mr. SCHLESINGER. Thank you, Mr. Chairman.

Senator COCHRAN. You have pointed out, and I said in my statement, others have acknowledged the fact that there are a lot of unknowns about the Stewardship Program. It seems to me that one option for us, and I am curious to know your reaction, is to postpone or phase in the effective dates of any kind of test ban that would tie the hands of the U.S. Do you know whether the administration has undertaken to explore that option with our negotiating partners, whether or not that would be a practical way to see if we do develop an alternative at some time in the future rather than at the front end making a commitment that whether or not we are able to develop an alternative, we are bound by that agreement? What is your reaction to that?

Mr. SCHLESINGER. Well, if the administration were prepared to do that, it would not be shared with me. I think that the administration is committed to proceeding with the CTBT as it has been signed and which the administration itself led in securing the other countries to sign. So I would doubt, at least at this stage, that the administration would be prepared to consider it.

It would have an advantage, not only of reducing the uncertainties involved about the Stockpile Stewardship Program, Mr. Chairman, but it would also allow less opportunity for the normal budget pressures to chip away at the funding of the Stockpile Stewardship Program.

Senator COCHRAN. Up until 1992, the United States made sure that the weapons we had were safe and reliable by conducting periodic tests, and while we did not obtain 100 percent confidence even from these tests, they did provide a level of confidence that was considered to be adequate by policy makers and by other observers throughout the world.

Do you think these tests served the purpose of helping to demonstrate to potential adversaries and observers that the U.S. possessed nuclear weapons that worked and established the credibility necessary for nuclear deterrence, and if so, do you believe that the Stockpile Stewardship Program would demonstrate that same credibility in our nuclear deterrent?

Mr. SCHLESINGER. It would not be a substitute or a perfect substitute for testing. I think that that is universally understood. It might prove to be, Mr. Chairman, too credible—in this respect, that other nations, when we announced the Stockpile Stewardship Program, have said, this is another example of American technological superiority. They are trying to steal a march on us. They will be able to sustain their weapons, and we will be unable to match them. Some of our response, as reflected in the New York Times today, has been to say that we are going to be prepared to share both our computational ability and the information that comes from the Stockpile Stewardship Program with others, and we have had pressures from the French and from the Russians, in particular, with regard to that issue.

So there is a conspiracy theory afoot around the world and the conspiracy theory basically says that this is the Americans pulling a fast one because they have technical advantages over us that we cannot match.

Senator COCHRAN. Do you think that there are any changes or conditions that could be made to ratification of the treaty by the Senate that would make it advisable, then, or in our clear interest, to approve the Comprehensive Test Ban Treaty?

Mr. SCHLESINGER. As I have indicated in my prepared remarks, Mr. Chairman, I am concerned about the permanency of this treaty and I am concerned about zero yield. As some of the Members here may recall, when President Carter dealt with the issue of the CTBT, it was at a time that we were seeking a 10-year treaty and that yields up to 2 kilotons would be permissible. That was about the level that we could verify, down to that level.

If there were a limitation in time so that we do not face the uncertainties for perhaps an infinite period, and if we were permitted to test at very low yields from time to time, I would feel more comfortable with this treaty.

Senator COCHRAN. Thank you. Senator Levin.

Senator LEVIN. Thank you, Mr. Chairman.

One of the references in your testimony is to the position of the Chiefs relative to nuclear testing and it was my understanding that the Chairman of the Joint Chiefs, General Shalikashvili, has supported the decision of the President to sign the Comprehensive Test Ban. Was that not your understanding?

Mr. SCHLESINGER. That is my understanding, Senator. I was referring to prior testimony to the Congress. I said that the testimony has changed. It is now different from what it has been in the past and Senators might want to inquire into the basis for that change.

Senator LEVIN. But it is your understanding, as it is mine, that General Shalikashvili, reflecting the position of the Joint Chiefs, did support the entering into this Comprehensive Test Ban Treaty?

Mr. SCHLESINGER. Yes, sir.

Senator LEVIN. Your last statement, or your last comment in your statement was that we should examine the risks as well as the benefits of the proposed treaty and you outline some of the risks. Could you give us some of the benefits, in your judgment?

Mr. SCHLESINGER. Primarily two, Senator Levin. As you are aware, as everyone is aware, the United States took the lead in acquiring the support of other nations for the CTBT. It leaned very hard on some of those nations, including Russia. At this stage, whether it was wise to have gotten into this initially or not, if the

United States fails to ratify, that raises questions about our credibility, so that one benefit would be to sustain our credibility on a path that we have embarked on.

The other one that I would mention, which is less significant than it was during the Cold War, is that when the United States and the Soviet Union were vying for advantages in the nuclear weapons area, the United States felt that it had a sizeable advantage over the Soviet Union at that time and that a limitation on testing would, in effect, slow down any capacity of the then-Soviet Union to reduce that advantage. I think that there is still something there, though there is less than there was during the Cold War.

Senator LEVIN. Were you a supporter of the permanent extension of the Nonproliferation Treaty?

Mr. SCHLESINGER. Absolutely. Yes, sir.

Senator LEVIN. If, in fact, the participation in the Comprehensive Test Ban was important to gaining the permanent extension of the Nonproliferation Treaty, would that be added as a benefit on your ledger?

Mr. SCHLESINGER. That is an aspect of the first point that I made, but it is a special aspect. Indeed, we, once again, perhaps unwisely, our negotiators did make those kinds of commitments.

Senator LEVIN. Was our decision not to manufacture or remanufacture weapons of the same design that were previously manufactured, which I believe was a decision of President Bush, was that decision driven by the Comprehensive Test Ban, or is that just——

Mr. SCHLESINGER. No. That decision was driven by the so-called Hatfield Amendment.

Senator LEVIN. But that had nothing to do with the Comprehensive Test Ban, that decision. We could change that decision, I presume, if we wanted to, consistent with the Comprehensive Test Ban, is that correct? In other words, we could remanufacture or manufacture weapons the way the Russians do, according to the same design over and over again, consistent with the Comprehensive Test Ban?

Mr. SCHLESINGER. Yes, indeed. There are two aspects of that, first, that we, at this juncture, do not have that capability to remanufacture. Secondly, for the reasons I mentioned in my statement, it is impossible to guarantee that the components that one replaces prior components with are the same or identical and will act in the same way.

Senator LEVIN. But my point is, when you said that we——

Mr. SCHLESINGER. We are not constrained with regard to remanufacture.

Senator LEVIN. And when you said that the Russians are manufacturing or remanufacturing and we are not, that is not anything to do with the Comprehensive Test Ban?

Mr. SCHLESINGER. No. That is correct.

Senator LEVIN. That is for other reasons.

Mr. SCHLESINGER. We shut down our production complex for a variety of reasons, including environmental reasons. Whether that was wise or not is a question. The Russians have chosen to continue to run their production complex.

Senator LEVIN. I just wanted to make the point, we could start that up again if we chose and still be within the Comprehensive Test Ban.

Mr. SCHLESINGER. Within some years, yes.

Senator LEVIN. Now, we have adopted a prohibition in the so-called Hatfield-Exon-Mitchell Act on testing after September 30, 1996. This Act was passed in October 1992, had a 1-year moratorium on testing, and then up to five tests per year for 3 years and then the prohibition after September 30, 1996, unless another country conducted a test. Do you believe that that should be repealed, that Act?

Mr. SCHLESINGER. I think that the Act is an encumbrance, but in the light of the position of the administration and the issue of the CTBT, I do not think that the repeal of that Act at this time will change anything—excuse me, that amendment at this time.

Senator LEVIN. That is all I have. Thank you, Mr. Chairman.

Senator COCHRAN. Senator Domenici, you were the next Senator on the Subcommittee in attendance. You are recognized.

Senator DOMENICI. Thank you, Mr. Chairman.

First, I want to say to you, I am delighted to be here. I hope I can join in more of your hearings. There is probably no treaty on the horizon that is more important than this one.

Dr. Schlesinger, let me just say, I was asking somebody recently if they knew you and they did not know you very well and I proceeded to tell them my views. I hope you know that I think during the last 40, 50 years, you are probably one of the most gifted public servants and advisors to Presidents that we have had in this country. I am just very, very proud of the way you have conducted yourself. Now, whether I end up agreeing with you on the Comprehensive Test Ban Treaty, that matters little.

Let me see if I can do a little bit without using up too much time. At this moment in our nuclear weapons evolution, we are not manufacturing any new bombs and we are not doing any nuclear underground testing. That is both because the moratorium and the President chooses to continue the moratorium, which is up to him, given certain conditions. I assume you would probably say there has been at least one time when he could have said, the moratorium is off.

He has chosen not to, but rather to proceed to try to get countries to sign the Comprehensive Test Ban Treaty. He has had some rather significant good fortune on the CTBT if it means as much as I think it does, although we have some verification questions and we have some questions as to whether we are tied too tightly in terms of trying to get inspection authority to go into foreign countries. We are required to get more than a simple majority, as you know, of the members because, in turn, we get to keep our own mechanisms for surveillance.

But let me say, as far as the safety and reliability of the stockpile in this new mode, which is no new nuclear designs, we all should be aware, should we not, that the Joint Chiefs of Staff passed on this. The condition they imposed on the President was that the directors of our national laboratories, the three that we normally associate with maintaining this stockpile, would have to certify annually that, indeed, the stockpile was reliable, trustworthy, safe, et cetera. Now, they have been doing that, have they not, even without any nuclear tests?

Mr. SCHLESINGER. They have been doing that. They have been required to do that by the established process, yes sir.

Senator DOMENICI. Wait a minute. Your use of the word "required" there would mean that somebody told them to. They have been required or the President does not have a deal with the Joint Chiefs?

Mr. SCHLESINGER. This is a procedure that has gone on for many years. I think that the Chiefs were saying that this procedure must continue into the future. The laboratory directors have been required—not required, have annually certified the stockpile.

Senator DOMENICI. But the point I am making is, they are pretty good people with pretty good advisors, are they not? They and their predecessors have kept America in its nuclear position, I think. The directors of the laboratories and those who advise them probably have kept America in the position of avoiding a nuclear war over all this time. I do not notice any failure or any diminishing of the quality of those directors.

Los Alamos succeeded from one to another recently, and I think anybody in your position looking at John Browne, the recently-appointed new head of Los Alamos, would say he ranks among the three or four best nuclear weapons people in the world. We have a similar situation where the ambassador that negotiated most of our treaties for reduction in nuclear forces as a physicist is head of Sandia. So these people have all agreed, as I understand it, even as of now, that even if we do not have this treaty, we do not have to have any testing and we can maintain our stockpile, is that not correct?

Mr. SCHLESINGER. They have agreed that we need not have testing but that the confidence in the stockpile reliability will decline, and that has been reiterated most recently by Sig Hecker, the Director of Los Alamos.

Senator DOMENICI. And Sig Hecker is the director who apparently, as a leader among the directors, concurred that we could maintain this stockpile with this President when the question was asked of the laboratory directors.

Mr. SCHLESINGER. Well, he is hopeful that we may be able to sustain it.

Senator DOMENICI. OK.

Mr. SCHLESINGER. He is very clear that we now have a lower confidence level.

Senator DOMENICI. I guess I am concerned whether we can reliably maintain the stockpile with what we now have. My little Subcommittee on Energy and Water puts all the money up, so I have to learn a little bit about it. Frankly, I believe that science-based stockpile stewardship is a rather good American approach to trying to maintain those weapons without testing. From what I understand, within about 3 or 4 years, which is not a huge number of years in the life of a nuclear weapon even though they are getting very old, we will have all of the equipment, including sophisticated computers and some new devices to look inside the bombs to see what their status is. It will cost us a lot of money to get that built, but I am told that will make the stockpile pretty reliable. Are you speaking relatively, or are you saying they will be unsafe unless we do testing?

Mr. SCHLESINGER. We do not know. We do not know. Let me assure you that I think that the Stewardship Program is a good American program, as you have put it. We are all hopeful that it will provide information to lessen the decline of confidence in the reliability of that program. But if you take the NIF, for example, it is not scheduled to come into existence until 2003, if memory serves. If that program slips—as has happened before in the history of Department of Energy projects—it will be later than 2003.

Senator DOMENICI. Well, NIF——

Mr. SCHLESINGER. It will take many years before we have the computational power to look inside of a weapon 3-dimensionally.

Senator DOMENICI. The NIF is the National Ignition Facility.

Mr. SCHLESINGER. Yes, sir.

Senator DOMENICI. Anybody looking at the treaty will find out its major initial funding was voted by five Senators here today who voted to put it into effect, because in the energy and water bill, which you all voted for, we put the first installment down, Mr. Chairman, to build this new facility at Livermore. But it is interesting.

Mr. SCHLESINGER. I hope that it does not go the way of the super collider, Senator.

Senator DOMENICI. I do not think it has a chance on the same grounds, but it is interesting. For while you sit here and say, “We will not have that ready within a certain period of time,” there is a very distinguished group of physicists in the nuclear community who said we did not need it anyway. So we have that going, too, and I do not know what you think about that. I did not call you in and ask you. I asked a lot of other people before we said, “Let us go ahead and fund it.

Let me move a little bit in another direction. You expressed some serious concern that the treaty will not prevent rogue states from obtaining nuclear weapons.

Mr. SCHLESINGER. Correct—no, that they will seek to obtain nuclear weapons, that it will not inhibit their seeking to obtain nuclear weapons.

Senator DOMENICI. Right. Do you have any other approach that would inhibit them from seeking to obtain rogue weapons?

Mr. SCHLESINGER. The only other approach, Senator, is physical means.

Senator DOMENICI. And it has nothing to do with whether we have underground testing or not.

Mr. SCHLESINGER. No. The point that I was making is that whether or not we test is irrelevant to their motivations.

Senator DOMENICI. Correct.

Mr. SCHLESINGER. Yes.

Senator DOMENICI. So the underground testing takes on a different coloration than it might have 20 years ago in that these rogue countries, if they would be buying weapons, do not need to test. They would not need testing, these rogue countries, would they, that you are worried about?

Mr. SCHLESINGER. They do not need testing if they are satisfied with large weapons with relatively limited yields. I suspect, as your question implies, that they would be, because they have much less demanding purposes.

Senator DOMENICI. Let me just ask another question, and if I need to submit some questions to you which are more specific, may I do that, Mr. Chairman?

Senator COCHRAN. We would be happy to have you do that.

Senator DOMENICI. Let me just ask, what type of program would you suggest that might satisfy your concerns regarding the situation as it is now? Do you have certain tests you think we ought to be conducting, certain yields, certain——

Mr. SCHLESINGER. Senator, mention was made of the Hatfield Amendment. I would have proceeded with some confidence testing under the latitude of five tests that existed then. That has been cut off now.

In the future, as I think I have indicated, I am not worried about this year or next year or the even next decade. What I am worried about in particular is the permanency of this treaty, which will prevent our testing more or less in perpetuity, even as the confidence in the stockpile declines. So that is my principal concern.

Senator DOMENICI. Mr. Chairman, I might say, it seems to this Senator that one of the issues that we have to be seriously concerned about as we look at this treaty is whether the United States, if we sign it, would continue with the effort to make sure we have and use the technology to be able to determine to the maximum extent whether testing is taking place elsewhere.

Senator COCHRAN. That testing is taking place elsewhere?

Senator DOMENICI. Yes. In order to enforce this treaty, we can use our own national means of ascertaining whether an event occurred that may be a nuclear test. That is up to us. Then there are international systems that give us guideposts and help. What concerns me is we may get into a complacency situation once the treaty is done and not continue such things as sensor programs. Many of them are airborne, as you know; many of them are on satellites, as you know; and we have to maintain the pressure and the resources to keep that going. Some of them are piggy-backed, so the total mission is not all a military function. Some of it is a straight transportation function and the like. I will be working with you and others to see if we can have some kind of a national legislation that assures that we will do everything within our technological powers to maintain our ability to ascertain whether any event is occurring in another country.

Thank you very much.

Senator COCHRAN. Thank you, Senator.

Mr. SCHLESINGER. Could I add one thing there with regard to Senator Domenici's comments?

Senator COCHRAN. Mr. Secretary.

Mr. SCHLESINGER. I expressed some concern that in the future, after hypothetical ratification of the agreement, the Congress or the administration might be less willing to provide the funds for the Stewardship Program. It seems to me that that could be a requirement that is written into that hypothetical ratification at that time, that the support of the agreement by the Congress would lapse if that safeguard is not observed.

Senator COCHRAN. Thank you very much. Senator Thompson, the Chairman of our full Committee on Governmental Affairs.

Chairman THOMPSON. Senator Kyl was here before me.

Senator COCHRAN. He is here to observe. He is not a member of our Subcommittee.

Chairman THOMPSON. Thank you very much, Mr. Chairman. I, too, appreciate the fact that you are having these hearings. It has been something that has been a concern of mine for some time and we are certainly fortunate to have Dr. Schlesinger's views.

I share his recurring theme here of long-term commitment. We are making a long-term commitment, or would be in this treaty, and it is going to require a long-term commitment of us, both in terms of new and additional monies which you expressed some concern about, rightfully so, and new and additional people to operate these laboratories in the future. I do not think we are doing too well nowadays in terms of facing up to long-term problems and things that do not have some immediate benefit to us and this is going to be off the radar screen if it continues to go down the road that it is going now and the treaty is approved.

One of the things that concerns me has to do with the actual management part of the Stewardship Program and the production facilities. You point out some of the problems in connection with maintaining the adequate funding, having new people come in who really never knew anything about the manufacturing of these things or that expertise and so forth after a period of time is going to be lost.

I would be interested in your views, assuming that the Comprehensive Test Ban Treaty is approved, what are the things that we need to do from a production standpoint? As you know, that includes activities such as manufacturing of weapons components and modification of existing warheads and things of that nature, so that if we ever do need these things in the future, they will be there. What are the kinds of things that we have to be mindful of in the future?

I was looking with some concern, as a part of the submission to the Senate for ratification of the treaty, the President proposed six safeguards that the United States should take to maintain our security under this treaty, and they mention the maintenance of nuclear laboratory facilities, which, of course, is important, but there is no mention of production facilities. What are your thoughts about this?

Mr. SCHLESINGER. Of course, the administration, as I mentioned in my testimony, has committed itself to maintain—made a policy commitment "to maintain the capability to design, fabricate, and test nuclear weapons," including fabrication. At the moment, we do not have that capability. It has been a reflection of the closure of Rocky Flats, for which there is no replacement as yet, and will be only a limited replacement in Senator Domenici's State. Y–12 in your own State is closed down. If you look at that display, you will see that those are two critical elements in the capability to fabricate nuclear weapons. We do not have that capability at this time.

Chairman THOMPSON. What are your thoughts about that?

Mr. SCHLESINGER. I was concerned in 1989 when Rocky Flats was closed down. That was before the end of the Cold War. The end of the Cold War substantially alleviated that concern. I am still concerned about the lack of an ability to fabricate warheads, not as Senator Levin indicated, new warheads, but just to remanufacture existing warheads. When we take apart, when we disassemble a warhead, we disassemble parts of it to destruction, so that one must be able to replace those elements. At the moment, we have no capability to replace the primaries.

Chairman THOMPSON. What is it going to take to reachieve that capability?

Mr. SCHLESINGER. The Department—I think that you would have to speak to Secretary Reis on that—the Department has a plan to bring that capability back into existence on a very limited basis at Los Alamos. There is also a plan, I believe, and once again, Secretary Reis would be able to comment more knowledgeably on this, to bring Y–12 back into the capability to contribute to the weapons.

Chairman THOMPSON. We can discuss that with the Department.

Mr. SCHLESINGER. One other aspect, you asked the question, what should we do. We are trying to capture experience, interviews with those who have designed, those who have participated in the manufacture of weapons, put them on videotape so that that experience does not disappear. That is, once again, not a perfect substitute, but it would help 30 years out or 25 years out if we have to go back for national security reasons to producing nuclear weapons, and even possibly producing new nuclear weapons.

Chairman THOMPSON. Thank you very much, Mr. Chairman.

Senator COCHRAN. Thank you, Senator.

Secretary Schlesinger, thank you so much for being here. We appreciate your testimony.

Mr. SCHLESINGER. Thank you, Senator.

Senator LEVIN. May I just ask one more question?

Senator COCHRAN. Senator Levin.

Senator LEVIN. I was a little uncertain about one answer and that has to do with this certification procedure. My understanding was that the certification procedure, which I believe Senator Domenici was referring to, is a new certification procedure. You suggested it had been in place for some time and I am now very uncertain as to whether we are talking about the same certification procedure.

Mr. SCHLESINGER. The laboratories have been required in the past, have habitually certified the stockpile. There may be new wrinkles in the certification procedure. I am not aware of them. Certification, in general, has been a function of the laboratory directors.

Senator LEVIN. Because there was a new certification procedure put in place in August 1995 and that is the one which, I think, we have been referring to here. Thank you.

Senator COCHRAN. Thank you.

Senator DOMENICI. Mr. Chairman.

Senator COCHRAN. Senator Domenici.

Senator DOMENICI. Dr. Schlesinger, before you leave, and Mr. Chairman, for the Subcommittee, you mentioned one thing we might do in enabling legislation, is to make sure that the Stockpile

Stewardship Program is maintained over time. When the treaty was sent up by the administration, Mr. Chairman, they did send up with it a number of proposals and commitments and one is a 5-year plan to maintain the nuclear stockpile stewardship at a level about half-a-billion dollars higher than now for the reasons that have been discussed here. I do not know whether that can ever be enabled without it being an entitlement. But I believe that it will come up regularly in the discussion of the treaty that we have to have the personnel to make sure that we do not suddenly wake up in 15 or 20 years and learn we could not do anything about a deficiency if we found out about it. Thank you.

Senator LEVIN. Mr. Chairman, could I just follow up on the certification question?

Senator COCHRAN. Senator Levin.

Senator LEVIN. We have had two annual certifications now under this new certification procedure. Both reviews have found that the stockpile is safe and reliable. Do you have any basis to disagree with that certification?

Mr. SCHLESINGER. No. As I indicated, I am not concerned about this year or next year or 5 years out. I am concerned about the decades ahead.

Senator LEVIN. Thank you.

Mr. SCHLESINGER. If I might add, with regard to Senator Domenici's comment, no Congress, of course, can bind its successors unless it is a matter of treaty or a matter of law. I believe that the Stewardship Program is a good program, irrespective of whether we give up testing, that we do not know, for example, what goes on inside of a nuclear weapon explosion. This has always been as much a matter of art as science and this will help to diminish our ignorance, and that is welcome even if we were to continue testing.

Senator COCHRAN. Thank you very much, Dr. Schlesinger. Thank you a lot.

Mr. SCHLESINGER. Thank you, Mr. Chairman.

Senator COCHRAN. Our next witness is Dr. Victor Reis, who is Assistant Secretary for Defense Programs in the U.S. Department of Energy, a position he has held since August 1993. Dr. Reis has the responsibility for directing the Department of Energy's Stockpile Stewardship and Management Program. Prior to serving in this capacity, Dr. Reis was the Director of Defense Research and Engineering at the Pentagon, a position he held since late 1991.

Dr. Reis, thank you very much for being here. We appreciate your attendance and willingness to testify before our Subcommittee. You may proceed with your statement.

## TESTIMONY OF VICTOR H. REIS, ASSISTANT SECRETARY OF ENERGY FOR DEFENSE PROGRAMS

Mr. REIS. Thank you very much, Senator. Mr. Chairman, Senator Levin, Senator Thompson, I am particularly pleased to be here with Dr. Schlesinger, who is sort of like the Leonardo da Vinci of public service. I think the only position you did not mention, that he also, I think, was Director of the Bureau of the Budget at one time. Of course, he was never elected to anything, but then, neither have I been. [Laughter.]

Thank you, Mr. Chairman, for the opportunity to testify before you today on the Stockpile Stewardship Program. This program is fundamental to our national security under a Comprehensive Test Ban Treaty. Because this is my first time before this Subcommittee, I would like to begin with a brief history of stockpile stewardship, tell you what it is, give you its current status, and then answer your questions. In addition to my written testimony, I would like to provide the Subcommittee with a recently published overview of the program and, if you wish, submit it for the record.[1]

Senator COCHRAN. We would be happy to have that. We appreciate it very much.

Mr. REIS. The Stockpile Stewardship Program began in July 1993 when President Clinton announced he would continue the moratorium on nuclear weapons testing and seek a Comprehensive Test Ban Treaty for nuclear weapons, a goal that has been sought since President Eisenhower. In August 1995, President Clinton announced his intention to seek a zero-yield Comprehensive Test Ban Treaty. He included as part of his announcement six safeguards that would accompany the treaty. The first of these was that we would conduct a science-based Stockpile Stewardship Program. The Senate START II ratification text in January 1996 also commits the U.S. to a robust Stockpile Stewardship Program.

President Clinton signed the CTBT in September 1996, and on September 22 of this year, he submitted it to the Senate for approval. As part of the submission, the administration committed to fund stockpile stewardship at about the $4.5 billion level in fiscal year 1999 and to use the fiscal year 1999 as a baseline for future funding. This does not include funding for construction of a new tritium production source. Thus, stockpile stewardship, which is essential to maintain our nuclear deterrent, also underpins the Nation's nuclear arms policy.

As President Clinton stated in August 1995, "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."

Thus, Mr. Chairman, within the U.S. national security framework, the specific task of stockpile stewardship is to maintain high confidence in the safety, reliability, and performance of the nuclear stockpile indefinitely without nuclear testing, and part of this task is to maintain the capability to return to testing and production of new weapons if so directed by the President and the Congress.

So what is the program, what are the risks involved, and how do we plan to mitigate those risks? The stockpile stewardship concept is simple. Each year, representative samples of each type of weapon are returned from the active forces to the plants and the labs, disassembled, examined, tested, and analyzed for defects, much as you would go for an annual physical or take your car to a local automobile mechanic. If any defects are found, their effect on performance, safety, and reliability is assessed and if that effect is deemed significant, the defective part is remanufactured. Like

[1] The brochure entitled "Stockpile Stewardship Program, Overview and Progress," Department of Energy, Office of Defense Programs, dated October 1997, submitted by Mr. Reis appears in the Appendix on page 88.

the battery or spark plugs in your car, some parts we know will require replacement and these are replaced at regular intervals. That is it. It sounds simple enough.

Unfortunately, while a modern nuclear weapon has about as many parts as a modern automobile, it is much more complicated. Many of the parts of a nuclear weapon are made from very special materials—plutonium, enriched uranium, tritium—which radioactively decay and change both their properties and the properties of other materials within the weapon.

Nuclear weapons are designed and manufactured to extraordinarily rigid standards, both to enable huge amounts of explosive energy to be packaged in relatively small containers and to maintain phenomenal safety standards. A nuclear weapon less than the size of a small desk will have the explosive power to completely destroy a modern city, and yet must be able to survive the worst kind of accident you can think of with less than a one in a million chance of exploding. This level of performance and safety must be maintained throughout a weapon's lifetime, even as it ages and changes.

While we can expect that aging will cause the defect rate to rise, just as it does in both humans and automobiles, we cannot go out and buy a new warhead model. There is no new warhead production and some of the old factories are out of business. Moreover, the weapons designers who have had experience with nuclear explosive testing are also aging. In about 10 years, most of them will have been retired. This means that about the same time all of the weapons reach the end of their design life, we will no longer have anyone on the job with direct test experience.

Despite these challenges, people from the weapons laboratories, the production plants, and the Federal establishment involved in stockpile stewardship have testified and will so testify that we can do the stockpile stewardship job. We believe we can maintain the safety and the reliability of the nuclear weapons in the stockpile indefinitely without underground testing and keep the risk to manageable levels.

How do we expect to do this? First of all, we start from a solid position. The current stockpile has been well tested, is in very good shape, and is well understood. We have an extensive database on each of these weapons and we have a cadre of experienced designers, engineers, scientists, and technicians that can, with confidence, certify the safety and reliability of the current stockpile.

Now, since we cannot do a complete test of a nuclear explosion, we conceptually divide the explosion into each of those parts and test and analyze each of these separately, much as you would test the ignition system, the cooling system, and the brakes of your car. Then we put the whole thing together into a computer calculation, a simulation, to see if the resulting performance is within its specification. Each part of the simulation must predict the results of each of these separate tests, and where they exist, be consistent with data from previous underground nuclear tests.

Let me give you some very simplified examples of how this works. Some of the processes are relatively straightforward to simulate. The first part of the nuclear explosion sequence is to send the right electrical signal to the right place at the right time. We can test this exactly by flight testing actual weapons with inert mockups of the nuclear components.

We can do a good job of testing the first part of a nuclear explosion, the implosion of the plutonium pit, but we do not use actual plutonium—it would go off if we did—and we measure a number of important features by taking x-ray pictures during critical parts of the experiment. We can then compare these pictures with calculations and with previous actual underground nuclear test results. But current radiographic systems will not be sufficient to measure the effects of the potential defects in an aged pit, so we are building a new x-ray machine, the DARHT, which will look at the shape and size of an imploding pit model from two different directions and with much better resolution.

Beyond obtaining x-ray pictures of imploding pit models, however, we will no longer experimentally simulate a nuclear explosion, but instead use experimental facilities to obtain conditions that occurred during such an explosion and then check the results of these experiments to check computer calculations.

For example, we are investigating the way old plutonium behaves when subjected to the high pressures of an implosion through sub-critical tests at the Nevada test site and we expect to be able to generate conditions in temperature and pressure of nuclear explosions with lasers at the National Ignition Facility. These and other experimental facilities that are on line, under construction, or in the planning stage will give us a set of tools sufficient to investigate and help understand anticipated problems in the stockpile.

As I mentioned previously, the experimental information is tied into the assessment process through computation, or more precisely, numerical simulation. But we know that the level of computation needed to effectively simulate effects of an aging or a remanufactured part is much, much greater than that currently available, so we have begun a computation development program, the Accelerated Strategic Computing Initiative, in parallel with the experimental program.

There is no point in doing elegant experiments if you cannot interpret the results in terms of nuclear weapons safety and reliability, and there is no point in doing simulations if the computer codes cannot be grounded in reality. You need both, as well as returning to the archives to match the new techniques with the data from underground tests.

It is this troika of computer simulation, experiments, and previous nuclear test data that provides the complete tool box for the assessment process. Building this assessment tool box in time to train the new cadre of scientists and engineers is critical to the Stockpile Stewardship Program.

This leaves remanufacturing. We know now we will have to remanufacture and replace some parts, and are already doing so. We know that, eventually, we will have to replace just about every part in every weapon. That is the idea of stockpile life extension. But to crate these new parts, we cannot rely on the Cold War production complex that produced some tens of thousands of nuclear weapons. We are establishing a production complex that is much smaller, more flexible, and much more environmentally sensitive than the production complex it replaces.

We must use every applicable modern manufacturing technique, the best that U.S. industry can offer. We must understand the details of the manufacturing processes with sufficient precision so as not to introduce new defects into a remanufactured system. The key here is model-based manufacturing, similar to that which created the Boeing 777 and is being applied today by much of U.S. industry. Thus, around half of the Stewardship Program is devoted to producing current replacement parts and to planning and modernizing our production complex to match the new job. We envision a complex of approximately one-fifth the size of the Cold War complex but one that can return to higher levels of production if the need ever arises.

While we do not expect to need additional supplies of enriched uranium and plutonium, there is one nuclear material which we know we will have to produce, tritium, a radioactive isotope of hydrogen that is required for every modern nuclear weapon.

Tritium decays fairly rapidly. Approximately 5 percent is transformed to helium every year. The last tritium that was produced in the U.S. was in 1988, but with the end of the Cold War and the reduction of the numbers of nuclear weapons, we have had large amounts of excess tritium. This excess has been used to make up for the decayed tritium in the current stockpile, but eventually this will run out. Based upon current estimates, we must produce tritium by 2005 to support a START I nuclear stockpile.

After a number of years of analysis and changing requirements, we are down to two approaches for making tritium, using an existing commercial light water reactor or using a newly developed accelerator. The DOE will select a primary source for tritium production as soon as possible in fiscal year 1998.

So, in a nutshell, that is stockpile stewardship—maintaining the stockpile without testing, surveillance, assessment, remanufacture, tritium, labs and plants—a program that must develop a new generation of technical experts before the current generation retires.

Why do we think we can meet this challenge and what are we doing to manage the risks? First, let me reiterate that we start from a solid base. The current stockpile is well tested and well understood. The designers and engineers who built them are available and are active. Indeed, they are the ones who are creating the current Stockpile Stewardship Program. They are working on the stockpile now and they are helping to train their successors.

Second, we have laid out a plan for the Stockpile Stewardship Program, weapon by weapon, part by part, that projects the tasks that are required to maintain the stockpile over the next 10 years and beyond. We have concurrence in this program from the Department of Defense and the Joint Chiefs and the administration has committed to fund this program and all its parts.

Third, as one of the conditions for ratification, Safeguard F, the President requires us to annually certify, to him directly, the safety, reliability, and performance of each weapon type. This is done by the Secretary of Defense and Secretary of Energy on the advice of the Nuclear Weapons Council, the directors of the nuclear weapons laboratories, and the Commander in Chief of the U.S. Strategic

Command. If a high confidence in the safety or reliability of a nuclear weapon type which the two secretaries consider critical to our nuclear deterrent could no longer be certified, the President, in consultation with Congress, would be prepared to withdraw from the CTBT under the standard "supreme national interest" clause in order to conduct whatever testing might be required.

Fourth, we have a backup, Safeguard C, which requires us to maintain the Nevada test site in a state of readiness, and the subcritical and other experiments conducted there keep the people sharp and ready.

Fifth, Safeguard B states that ratification is conditioned on maintaining the vitality of our nuclear weapons laboratories, Los Alamos, Lawrence Livermore, and Sandia National Laboratories. Mr. Chairman, those are among the best in the world, and in my opinion, they are the best laboratories in the world and they are better now than they were 4 years ago because of the enthusiasm and vigor with which they are attacking the stockpile stewardship effort. History tells us that great labs need great missions, and stewardship is just such a mission. Our DOE labs will get even better because they will attract the kind of people who are drawn to solve tough problems of national importance.

Sixth, we are doing stewardship now and doing it successfully. It has been 5 years since the last underground nuclear test. We are just completing our second annual certification. We have modified the B61 bomb and seen it enter the stockpile to replace the aged B53 bomb. We have initiated a number of new experimental tools and our computation program has developed the world's fastest supercomputer by a factor of three.

And we have solved some problems by using stewardship tools that, in the past, would have likely required nuclear testing. We have literally done hundreds of experiments that increase our understanding of nuclear weapons. We have safely dismantled over 9,000 nuclear weapons since the end of the Cold War. We have produced numerous parts on time while continuing to downsize the complex. This is a system that works, and not just at the labs but also at the plants, Oak Ridge Y–12, Pantex, Kansas City, Savannah River, and the Nevada test site.

So let me finish by getting to the essential question. Do I have confidence that the stockpile stewardship will work? Can we maintain the nuclear weapons stockpile without testing 10, 20, or 30 years from now?

My answer now is an almost—almost—unqualified yes. The source of my optimism lies not in the immortality of the current stockpile weapons, though in truth, they are truly technological marvels, but in my faith in the integrity, courage, and competence of the people in our weapons labs and production complex. They are the men and women that designed and produced the weapons that ended World War II and kept the Cold War cold. They have put together a program that is comprehensive, coherent, and robust. They believe and I believe that they can do the job by, first and foremost, maintaining and supporting the institutions that do the job.

I have confidence in them, their integrity, their competence, and their overriding dedication to their mission. If we give them the tools that they need and stick with it, we can manage the risk. In this end, it is not an issue of technology but an issue of courage and will and persistence, and if we have the courage and will and persistence, we will not fail. Thank you, Mr. Chairman, and I would be glad to answer any of your questions.

[The prepared statement of Mr. Reis follows:]

PREPARED STATEMENT OF MR. REIS

Thank you, Mr. Chairman for the opportunity to testify before you today on the Stockpile Stewardship Program. This program is fundamental to our national security under a Comprehensive Test Ban Treaty. Because this is my first time before this committee, I'd like to begin, with a brief history of stockpile stewardship, tell you what it is, give you its current status, and then answer your questions. In addition to my written testimony, I would like to provide the subcommittee, with a recently published overview on the program, and if you wish, submit it for the record.

The Stockpile Stewardship program began in July 1993 when President Clinton announced he would continue the moratorium on nuclear weapons testing and seek a comprehensive test ban treaty for nuclear weapons, a goal that has been sought since President Eisenhower. In August of 1995, President Clinton announced his intention to seek a "zero yield" CTBT. He included as part of his announcement, six safeguards that would accompany the treaty. The first of these was that we will conduct a "science based stockpile stewardship program." The Senate Start II ratification text in January 1996 also commits the U.S. to a "robust Stockpile Stewardship Program."

President Clinton signed the CTBT in September of 1996, and on September 22 of this year he submitted it to the Senate for approval. As part of the submission, the Administration committed to fund stockpile stewardship at about $4.5 billion in FY 1999 and to use FY 99 as a baseline for future funding. This does not include funding for construction of a new tritium production source. Thus, stockpile stewardship which is essential to maintain our nuclear deterrent—also underpins the nation's nuclear arms control policy.

As President Clinton stated in August of 1995:

"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."

Thus, Mr. Chairman, within the U.S. national security framework, the specific task of stockpile stewardship is to maintain high confidence in the safety, reliability, and performance of the nuclear stockpile, indefinitely, without nuclear testing. And part of this task is to maintain the capability to return to testing and production of new weapons, if so directed by the President and the Congress.

So, what is the program, what are the risks involved, and how do we plan to mitigate those risks?

The stockpile stewardship concept is simple. Each year representative samples of each type of weapon are returned from the active forces to the plants and labs, disassembled, examined, tested and analyzed for defects, much as you would go far an annual physical or take your car into your local automobile mechanic. If any defects are found, their effect on performance safety and reliability is assessed, and if that effect is deemed significant, the defective part is remanufactured and replaced. Like the battery or spark plugs in your car, some parts we know will require replacement, and these are replaced at regular intervals. That's it. It sounds simple enough.

Unfortunately, while a modern nuclear weapon has about as many parts as a modern automobile, it is much more complicated. Many of the parts of a nuclear weapon are made from very special materials—plutonium, enriched uranium, tritium—which radioactively decay, and change both their properties and the properties of other materials within the weapon.

Nuclear weapons are designed and manufactured to extraordinarily rigid standards, both to enable huge amounts of explosive energy to be packaged in relatively small containers, and to maintain phenomenal safety standards. A nuclear weapon, less than the size of a small desk, will have the explosive power to completely destroy a modern city, and yet it must be able to survive the worst kind of accident you can think of with less than a one in a million chance of exploding. This level of performance add safety must be maintained throughout the weapons lifetime, even as it ages and changes.

While we can expect that aging will cause the defect rate to rise—just like it does in both humans and cars—we can't go out and buy a new warhead model—there is no new warhead production, and some of the old factories are out of business. Moreover, the weapons designers who have had experience with nuclear explosive testing are also aging, in about ten years most of them will have retired. This means that about the same time all of the weapons reach the end of their design life, we will no longer have anyone on the job with direct test experience!

Despite these challenges, people from the weapons laboratories, the production plants, and the federal establishment involved in stockpile stewardship have testified, and will so testify, that we can do the stockpile stewardship job. We believe we can maintain the safety and reliability of the nuclear weapons in the stockpile indefinitely without underground testing and keep the risks to manageable levels.

How do we expect to do this?

First of all, we start from a solid position. The current stockpile has been well tested, is in very good shape and is well understood. We have an extensive data base on each of these weapons, and we have a cadre of experienced designers, engineers, scientists and technicians that can, with confidence, certify the safety and reliability of the current stockpile.

Now, since we cannot do a complete test of a nuclear explosion, we conceptually divide the explosion into each of its parts and test and analyze each of these separately, much as you would test the ignition system, the cooling system, and the brakes on your car. We then put the whole thing together into a computer calculation—a simulation—to see if the resulting performance is within its specification. Each part of the simulation must predict the results of each of the separate tests, and where they exist, be consistent with data from previous underground nuclear tests. Let me given you some very simplified examples of how this works.

Some of processes are relatively straight forward to simulate. The first part of the nuclear explosion sequence is to send the right electrical signal to the right place at the right time. We can test this exactly by flight testing actual weapons with inert mockups of the nuclear components.

We can do a good job of testing the first part of the nuclear explosion, the implosion of the plutonium pit, but we do not use actual plutonium—it would go off if we did—and we can measure a number of important features by taking x-ray pictures during critical parts of the experiment. We can then compare these pictures with calculations and with previous actual underground nuclear test results. But current radiographic systems will not be sufficient to measure the effects of potential defects in an aged pit, so we are building a new x-ray machine—the DARHT—which will look at the shape and size of an imploding pit model from two different directions and with much better resolution.

Beyond obtaining x-ray pictures of imploding pit models, however, we will no longer experimentally simulate a nuclear explosion, but instead use experimental facilities to obtain conditions that occur during such an explosion and then use the results of these experiments to check computer calculations. For example, we are investigating the way old plutonium behaves when subjected to the high pressures of an implosion, through subcritical tests at the Nevada Test Site, and we expect to be able to generate the conditions of temperature and pressure of nuclear explosions with lasers at the National Ignition Facility. These, and other experimental facilities that are on line, under construction, or in the planning stage, will give us a set of tools sufficient to investigate and help understand anticipated problems in the stockpile.

As I mentioned previously the experimental information is tied into the assessment process through computation, or more precisely, numerical simulation. But we know that the level of computation needed to effectively simulate effects of aging or a remanufactured part is much, much greater than that currently available, so we have begun a computation development program—the Accelerated Strategic Computing Initiative—in parallel with the experimental program. There is no point in doing elegant experiments if you can't interpret the results in terms of nuclear weapons safety and reliability, and there is no point in doing simulations if the computer codes cannot be grounded in reality. You need both, as well as returning to the archives to match the new techniques with the data from underground nuclear tests.

It is this troika of computer simulation, experiments, and previous nuclear test data that provides the complete tool box for the assessment process. Building this assessment "tool box" in time to train the new cadre of scientists and engineers is critical to the stockpile stewardship program.

This leaves remanufacture—we know now we will have to remanufacture and replace some parts, and are already doing so. We know that eventually we will have to replace just about every part in every weapon—that's the idea of stockpile life extension. But to create these new parts we cannot rely on the cold war production complex that produced some tens of thousands of nuclear weapons. We are establishing a production complex that is much smaller, much more flexible, and much more environmentally sensitive than the production complex it replaces.

We must use every applicable modern manufacturing technique; the best that U.S. industry can offer. We must understand the details of the manufacturing processes with sufficient precision, so as not to introduce new defects into a remanufactured system. The key here is model-based manufacturing—similar to that which created the Boeing 777 and is being applied today by much of U.S. industry. Thus, around half of the stewardship program is devoted to producing current replacement parts, and to planning and modernizing our production complex to match the new job. We envision a complex of approximately 1/5th the size of the cold war complex, but one that can return to higher levels of production if the need ever arises.

While we do not expect to need additional supplies of enriched uranium and plutonium, there is one nuclear material which we know we will have to produce: tritium—a radioactive isotope of hydrogen that is required for every modern nuclear weapon.

Tritium decays fairly rapidly; approximately 5 percent is transformed to helium every year. The last tritium that was produced in the U.S was in 1988, but with the end of the cold war and the reduction of numbers of nuclear weapons, we have had large amounts of excess tritium. This excess has been used to make up for the decayed tritium in the current stockpile, but eventually this will run out. Based upon current estimates we must produce tritium by 2005 to support a START I nuclear stockpile. After a number of years of analysis and changing requirements we are down to two approaches for making tritium—using an existing commercial light water reactor or using a newly developed accelerator. The DOE will select a primary source for tritium production as soon as possible in FY 1998.

So in a nut shell, that's stockpile stewardship—maintaining the stockpile without testing—surveillance, assessment, remanufacture—tritium, labs, and plants—a program that must develop a new generation of technical experts before the current generation retires.

Why do we think we can meet this challenge, and what are we doing to manage the risks?

First, let me reiterate that we start from a solid base. The current stockpile is well tested and well understood. The designers and engineers who built them are available and are active. Indeed they are the ones who are creating the stockpile stewardship program. They are the ones who are working on the stockpile now, and are helping to train their successors.

Second, we have laid out a plan for the stockpile stewardship program weapon by weapon, part by part, that projects the tasks that are required to maintain the stockpile over the next ten years, and beyond. We have concurrence on this program from the Department of Defense, and the Joint Chiefs, and the administration has committed to fund this program and all its parts.

Third, as one of the conditions for ratification, Safeguard F, the President requires us to annually certify, to him directly, the safety, reliability and performance of each weapon type. This is done by the Secretary of Defense and the Secretary of Energy, on the advice of the Nuclear Weapons Council, the Directors of the nuclear weapons laboratories and the Commander-in-Chief of the U.S. Strategic Command. (If a high level of confidence in the safety or reliability of a nuclear weapon type which the two Secretaries consider critical to our nuclear deterrent could no longer be certified the President, in consultation with Congress, would be prepared to withdraw from the CTBT under the standard "supreme national interest" clause in order to conduct whatever testing might be required.)

Fourth, we have a back up. Safeguard C, requires us to maintain the Nevada Test Site in a state of readiness, and the subcritical and other experiments conducted there help keep the people sharp and ready.

Fifth, Safeguard B states that ratification is conditioned on maintaining the vitality of the nuclear weapons laboratories—Los Alamos, Lawrence Livermore and Sandia National Laboratories. Mr. Chairman, those labs are among the best in the world—in my opinion they *are* the best in the world—and they are better now than they were four years ago because of the enthusiasm and vigor with which they are attacking the stockpile stewardship effort. History tells us that great labs need great missions, and stewardship is just such a mission. Our DOE labs will get even better because they will attract the kind of people who are drawn to solve tough problems of national importance.

Sixth, we are doing stewardship now, and doing it successfully. It has been five years since the last underground nuclear test. We are just completing our second annual certification. We have modified the B61 bomb and seen it enter the stockpile to replace the aged B53 bomb. We have initiated a number of new experimental tools, and our computation program has developed the world's fastest supercomputer—by a factor of three. And we have solved some problems by using stewardship tools that in the past would have likely required nuclear testing. We have literally done hundreds of experiments that increase our understanding of nuclear weapons. We have safely dismantled over nine thousand nuclear weapons since the end of the Cold War, have produced numerous parts, on time, while continuing to downsize the complex. This is a system that works, and not just at the labs but also at the plants: Oak Ridge Y–12, Pantex, Kansas City, Savannah River, and the Nevada Test Site.

So let me finish by getting to the essential question: Do I have confidence that stockpile stewardship will work, can we maintain the nuclear weapon stockpile, without testing, ten, twenty, thirty years from now?

My answer now is an (almost) unqualified yes.

The source of my optimism lies not in the immortality of the current stockpile of weapons—though in truth they are truly technological marvels—but in my faith in the integrity, courage and competence of the people in our weapons labs and production complex. They are the men and women that designed and produced the weapons that ended World War II and kept the Cold War cold. They have put together a program that is comprehensive, coherent and robust. They believe, and I believe, they can do the job by first and foremost maintaining and supporting the institutions to do the job. I have confidence in them—their integrity, their competence and their overriding dedication to their mission. If we give them the tools that they need, and stick with it, we can manage the risk. In the end this is not an issue of technology but an issue of courage and will and persistence, and if we have the courage and will and persistence, we will not fail.

Thank you, Mr. Chairman, and I would be glad to answer any of your questions.

Senator COCHRAN. Thank you very much, Secretary Reis. We appreciate your being here and cooperating with our Subcommittee.

Let me ask you a question that seems to just leap out at me from what I have been able to learn about the Stockpile Stewardship Program and that is, how long will it be until we have the necessary degree of certainty that the program will be sufficient to ensure the safety and reliability of our nuclear weapons? That is, when will we know if the Stockpile Stewardship Program will work?

Mr. REIS. That is a question, Senator, that, of course, I have asked myself, I have had to answer in numerous hearings over the past few years. Senator Kempthorne always asks me that question. Senator Domenici always asks me that question.

The answer is, you have to ask that question every year. That is why we have put in the annual certification. Every year, you have to go in and say, OK, where are we now? Where are we going? Are there basically any problems? We are doing it now. It is not a question of waiting 10 years and then asking the question. You have to ask it now. You have to ask it a year from now. You have to continually ask it now.

We start from a base, as Dr. Schlesinger said and I am sure—again, we have just gone through our second annual certification. We feel solid right now. We continually ask that question in the future.

One, as the problem gets more difficult over time, we are putting in more capability over time and it is that match, if you will, that you have to continue to ask for. The second part of that question is that if it turns out that you cannot—the answer to that comes back and says, gee, we do have to go back and test, that does not mean the Stockpile Stewardship Program has failed. It means the Stockpile Stewardship Program might have succeeded in the sense you have asked the right question.

Senator COCHRAN. Under the Comprehensive Test Ban Treaty, do we have enough flexibility so that we could go back and test if we made a determination that we needed to in order to verify safety and reliability?

Mr. REIS. If we make a determination, again, under the "supreme national interest" clause, we would—and again, we basically ask that question every year. The Secretary of Energy and Defense will go back to the President and say, look, we cannot certify on the safety and reliability and then the President has said that he will be prepared to withdraw from the treaty at that point and then go back and do the testing.

Senator COCHRAN. If given the choice, though, would it not be more prudent to see how well the Stewardship Program works before we abandon nuclear testing?

Mr. REIS. Well, it has been now 5 years since our last test, Senator, and the Stockpile Stewardship Program is working. It gets back, I think, to the comment that Dr. Schlesinger said about leadership. I think this is one where you have to lean forward, and while there are risks, we think those risks are manageable.

Senator COCHRAN. Most of the questions that have been asked today so far have related to the reliability of the weapons, whether they will work, whether they are going to deteriorate over time, and if so, how much and how serious is that. I am also interested, and I know other Senators are, too, in whether these weapons meet the safety requirements established for the weapons. Have these weapons that we have now been made as safe as they could be made or as safe as they could be made if testing were permitted?

Mr. REIS. Senator, we are always concerned about the safety of those weapons. That is the first thing that people look at. As you know, in the past, weapons have been withdrawn from the stockpile because they did not meet our criteria. The criteria is just as rigid under a non-testing regime as they are in a testing regime. Much of the work in terms of doing the experimental facilities and in terms of the computational understanding really goes right to the safety questions.

Senator COCHRAN. Do you think we have safety measures that are advanced to the point where they should be in our nuclear weapons at this time?

Mr. REIS. At this time, yes, I believe so, and let me also recommend or state that we do not stop there. I mean, we are continually looking for ways to improve the safety of the stockpile.

Senator COCHRAN. And do you think we can do that without testing?

Mr. REIS. Yes, I do. I think most of the concerns, based on if we keep the current stockpile—if you move to a different type of stockpile or a new stockpile, of course, all bets are off. But most of the concerns about safety really relate to the non-nuclear components, making sure that the signal does not get to the detonators at the wrong time and that is the sort of thing we can do a lot of detailed testing on and are doing detailed testing on.

Senator COCHRAN. Senator Levin.

Senator LEVIN. Thank you, Mr. Chairman.

Do you have less confidence now in the weapons' reliability than we did in 1992?

Mr. REIS. I can only speak to you about 1993, when I began to understand this.

Senator LEVIN. OK.

Mr. REIS. I, frankly, have as much or perhaps even more confidence in the weapons now than I would in 1993.

Senator LEVIN. So even though we have not done testing, you have more confidence now in reliability without testing than you did when we were testing, and what do you base that on?

Mr. REIS. I base that on my feelings and in terms of where the laboratories are and where the laboratories are going and that they have accepted this stockpile stewardship challenge with vigor. When I got there in 1993, people were concerned about the future of the nuclear weapons programs. Many very, very good scientists, engineers, and technicians were leaving. They were looking for other things to do. They were not sure whether there was a future here. I think that if you will visit the laboratories, you will find a very, very different attitude in terms of the way they have accepted this stockpile stewardship challenge.

Senator LEVIN. There is a new certification process. Can you describe what is new about the certification process the President put in place when he decided to seek the CTBT?

Mr. REIS. Yes, sir, and we have been working very hard on that and we are just at the end of the second annual certification. What is new about it is——

Senator LEVIN. Dr. Schlesinger said there always had been some kind of a certification process. It was our understanding there was a new process put in place when the President announced the——

Mr. REIS. That is correct.

Senator LEVIN. What is new about it?

Mr. REIS. In the past, once a weapon had been certified, it was considered OK unless there was a problem, and, of course, you did a continual surveillance process and unless a problem came up, you considered it certified.

What we are doing now is essentially recertifying every single weapon. Every single weapon is evaluated by not just the laboratory that designed that weapon but that is reviewed by other laboratories. It is reviewed by the Department of Defense, the Joint Chiefs. We have a detailed weapon-by-weapon certification process where we analyze the weapon, where the designers come in, where the engineers come in. We have conferences and really look at the figures, again, weapon by weapon, and we go through that now, again, on a yearly basis, every single weapon, every problem.

Indeed, the weapons laboratory directors and the Commander in Chief of Strategic Command are required now to write a letter back to the Secretary of Defense, the Secretary of Energy, describing what has happened and with that is a detailed backup of all the technical data. To my knowledge, that has never been done on an annual basis before.

Senator LEVIN. Is there anyone who is not involved in the certification process who should be, in your judgment?

Mr. REIS. I cannot think of any. We have a lot of people right now, the services, each of the services, the Nuclear Weapons Council, which is a group of people made up of the services and the Department of Energy, each of the three weapons laboratories. I think we have covered just about everybody, Senator.

Senator LEVIN. Near the end of your statement, you said that you have almost unqualified confidence that the Stockpile Stewardship Program will work without testing 10 or 20 or 30 years from now. Is the basis of your "almost" an uncertainty as to whether Congress will adequately fund the Stewardship Program or is there another piece to the "almost"?

Mr. REIS. I think that is primarily it. I think, one, I am not concerned about this Congress. The Congress has been, I think, very good in the sense of trying to understand what we are doing and occasionally making adjustments. Some of those adjustments are actually pretty good. But I think we are really talking about——

Senator LEVIN. That is sort of an almost unqualified statement.

Mr. REIS. Almost unqualified.

Senator Thompson is here. [Laughter.]

It is not so much this Congress or this administration because we are really talking about in 10 or 30 years. I think one of the things that Senator Thompson mentioned in his talk is, well, how do we get into place something that—not just think about 2 years, 5 years, 10 years. We are really talking about how does one really invest in the future.

I think the answer really does come back, if we put the process in properly, and I think we are in the process, again, the process of putting that process in, so we keep this on the front burner. It is a very important issue and will remain so. As long as people recognize how important nuclear weapons are, not just in terms of their technical ability but their safety and all those other problems, that future administrations and future Congresses will support it properly. But that is where the "almost" came from.

Senator LEVIN. So your "almost" comes from your uncertainty as to whether Congress 10, 20, or 30 years from now——

Mr. REIS. That is correct.

Senator LEVIN [continuing]. Will adequately maintain these programs.

Mr. REIS. That is correct, and again, because we are talking about, as Dr. Schlesinger said and everybody said, gee, the issue is not now. It is really the 10, 20, or 30 years from now. That is why it is important, I believe, Mr. Chairman and Senator Levin, to look hard at what we are doing now in terms of the stewardship. It is not something that will just show up 10 or 15 years from now and we have to decide then whether it is working or not. You really have to keep asking this question every year.

Senator LEVIN. Is the Stockpile Stewardship Program intended to be a complete substitute for testing?

Mr. REIS. It is not a complete substitute for testing.

Senator LEVIN. And can it be successful without being a complete substitute?

Mr. REIS. If we stick to what it is supposed to do, which is to maintain the current stockpile indefinitely without testing, I think it can be a substitute. In other words, if you ask it to do that job, it will do that job.

Senator LEVIN. Have we looked at the remanufacturing process that the Russians are engaged in? Why are we not doing it? Is it because of environmental reasons, cost, or it is just not a good idea, or what? Do you know?

Mr. REIS. Well, yes. It is—I guess the quick answer is he says, yes, we have, and the answer to that is yes, it is both very costly and I believe the amount of people they have working in their production complex—and I could get those numbers for you more accurately, Senator—it is probably 100,000, whereas we have about 30,000, so it was a productivity question.

There is also a question of style. We just, somehow or other, just continually manufacture things over and over again. It is not—I do not want to say it is just not the American way of throwing things away that are still good, but it really is a cost—it basically is a cost issue, and every time you remanufacture a whole thing, of course, there is the potential for introducing new defects.

Then, as Secretary Schlesinger said, we have gone a long way to improving the environmental issues in terms of how we do our plants. I think, and you are aware, a good deal of the money that comes to the Department of Energy to maintain the nuclear weapons are now in the cleanup effort. In fact, the cleanup budget is greater than the stockpile stewardship budget. That will not happen in the future. We are ensuring ourselves that the work at Y–12, Pantex, the plants, and the labs are environmentally sound.

Senator LEVIN. Is there an immediate requirement for pit production?

Mr. REIS. There will be a requirement for a low level of pit production in the near future and we are going to meet that requirement.

Senator LEVIN. Finally, if the Comprehensive Test Ban Treaty were ratified, all of the declared nuclear powers, not just us, would be prohibited from testing. Are we in a better position than other nations to maintain the reliability of our inventory based on this stewardship program?

Mr. REIS. I cannot really speak to all of the other nations, Senator, and we would have to probably go into closed session and you would have to ask other people in terms of what they are doing. But my sense certainly is that we would be in a better position.

Senator LEVIN. A better position than other nations?

Mr. REIS. Yes, sir.

Senator LEVIN. To maintain the reliability of our inventory without testing?

Mr. REIS. Yes, sir, if we maintain the commitment and the will to do this job.

Senator LEVIN. Thank you. Thank you, Mr. Chairman.

Senator COCHRAN. Thank you, Senator Levin.

Senator Thompson.

Chairman THOMPSON. Thank you, Mr. Chairman.

Your initial statement that you had an almost unqualified position as to the confidence you had in our Stewardship Program 20 or 30 years down the road, I thought was just a candid assessment of the obvious. To me, it has to do with more than just adequate funding, which, of course, is necessary. I mean, how anyone can say that technologically we can be sure of where we are going to be 20 or 30 years down the road is misplaced, to say the least.

It seems to me like with regard to the question of how can we be sure when will we be able to sure that our Stewardship Program is working, it is when we try it out, ultimately. Hopefully, we will never have to, but it seems to me it is like how well are you keeping your car up, and you replace all of the parts, get the best available people to work on it, and over a 20- or 30-year period, you do everything you know how to do, but you never try to start it. You really do not know whether or not you have done the right things until you start it, and I think that is just common sense.

It points up to me the importance of all of the different things that you are talking about here, our design capabilities and, of course, I am very much interested, as you know, in Y–12 and the production side of things. I think you very candidly point out the problems of getting in new design people who have no test experience, new components, maybe some of the component suppliers are out of business. Every time you remanufacture, you bring in the possibility of new defects. So it is very, very important that we have the best that we can have under the circumstances.

I am very concerned about the ramifications of the treaty, but assuming for a moment that that is ratified, it certainly points out the importance of all these things. If you had a table full of experts swearing on a stack of Bibles that they are 100 percent sure that this thing is going to work out in 20 or 30 years, that would not make any difference to me, as one individual. But your common sense approach to doing the best you can, I think, is about all we can do under the circumstances.

Can you give me any assurance that DOE intends to support and strengthen the production activities at the four production plants?

Mr. REIS. I certainly can, Senator Thompson. One of the things you may notice, that we are not calling it stockpile stewardship and management. We are calling it stockpile stewardship. It is one stewardship program. I think people have somehow separated the two and tend to pose plants versus labs and that just does not make any sense. We are going to remanufacture. The whole part of stockpile life extension is the necessity.

You cannot do manufacturing without building things. You cannot. So we intend to remanufacture. What we will not do is manufacture before we have to, but we know if you are going to keep things 30 years, the design life was 30 years beyond the life, eventually, just about all the parts are going to have to be manufactured. Those are not simple parts. Those represent some of the best—again, Y–12, at Pantex, at Kansas City, that is some of the best manufacturing in this country and we are just going to have to keep that manufacturing technology and keep those people—and it is the people, not just the machines that I think you have got to really be concentrating on.

Chairman THOMPSON. Have you made a determination as to what the budgetary requirements are going to be in the out years in order to keep that capability?

Mr. REIS. We have laid out a detailed plan which we call, euphemistically, the Green Book. We have laid it out over the next 10 years. Again, we worked from the parts to the pieces to the experiments to the computing. We have a commitment from the administration at $4.5 billion per year, not including the source of production, and we believe that will be sufficient to do the job.

Chairman THOMPSON. Not including what?

Mr. REIS. The production of tritium. A production source of tritium would be in addition to that.

Chairman THOMPSON. But of the $4.5 billion, how much are we talking about on the production side of things?

Mr. REIS. Approximately half of that money goes to the production side.

Chairman THOMPSON. Thank you very much, Mr. Chairman.

Senator COCHRAN. Mr. Secretary, there are a couple of questions I want to ask you about the budget request. We understand that the plan the administration has for funding is that over the next 5 years, there will be in the budget $4.5 billion each year and possibly at least that much for the next 5-year period following that. Until just recently, the administration was suggesting that the Stockpile Stewardship Program would require only $4 billion per year. Do you know why that was changed to $4.5 billion? What are we getting for the additional $500 million that we now think we need that we did not think we needed just a few months ago?

Mr. REIS. Senator, that is another question that I have been working on very hard over the past 6 months. I think we are learning more. What we have done, again, over the past 2 years, was really lay out with our colleagues—and, indeed, this is with our colleagues from the Department of Defense, with the people from Strategic Command, who would be the appropriate commander in chief to do that, more of a detailed understanding in terms of where we are going. We have a better understanding in terms of some of the production needs as well as the laboratory needs. We are in the process now, as you know, of downsizing. That downsizing requires an investment. You just do not move from A to B because you have to ensure yourself when you get to B you are working on the right dollars.

We have really scrubbed through in detail what the requirements are. As you know, we are going through discussions of START I, START II, those sorts of things. So we just have a better handle on the problem. There is not one thing that I would say, well, I am getting for that additional $500 million a year. It is the total program. You cannot say—again, what we are now beginning to understand much better is the relationship between the detailed requirements that come over from the Department of Defense and our ability to respond to those requirements.

Senator COCHRAN. I cannot remember what we did in our energy appropriations bill. I am on the Subcommittee that is chaired by Senator Domenici on appropriations that funds the DOE activities. I do not know whether we got into the detail so much that we allocated the $4.5 billion for this next fiscal year in the same way the administration requested that we do it. Is there any problem that you see developing in terms of political interests and pressures that could develop that would cause funds to be allocated within that so that they would jeopardize the program?

Mr. REIS. Let me go back. First, let me just correct, this year, in fiscal year 1998, the administration submitted a budget at the approximately $4 billion a year level. The Congress appropriated about $4.2 billion. With that addition, you always get suggestions about where to put those dollars, and having been at this game for a long time, Senator, I tell you that despite all the pain, it is pretty close. It is not perfect, but over time, working with——

Chairman THOMPSON. It is not perfect, but we could help you get it perfect. [Laughter.]

Mr. REIS. Godspeed, Senator. In particular, Senator Domenici's Committee, with Senator Reid as ranking member, I mean, we have been working very closely with them. They are very interested in what we are doing and they give us the right kind of——

Senator COCHRAN. The labs come in probably with requests that are higher than that, do they not, and the production facilities? If you added up everybody's request that comes through the process, you would have requests that exceeded $4.5 billion, is that not correct?

Mr. REIS. I think that is fair to say that is correct.

Senator COCHRAN. So it is an interesting challenge that we face in terms of a budget and the funding of these requests.

Mr. REIS. It is more than interesting, it is stimulating.

Senator COCHRAN. Senator Levin.

Senator LEVIN. I have just a couple of questions. You indicated that the Stewardship Program is working now.

Mr. REIS. Yes, sir.

Senator LEVIN. Parts of the Stewardship Program are going to be phased in, is that correct?

Mr. REIS. That is correct. As you look out over in time, let us take, for example, the first part of that, I think, indeed, Dr. Schlesinger mentioned the need to do hydrotesting. We have facilities now that do hydrotesting. We have one at each of the laboratories. We are looking at improvements on that. We have committed to look at improvement on that. That is the DARHT. That will basically allow us to look in two dimensions.

As you begin to think about looking further and further downstream, when we are trying to get better and better understanding, we are saying, all right, maybe it would be better to actually produce like a CAT scan, in fact, a motion picture CAT scan of how this implosion really works. But we are looking at research on techniques to allow us to go even basically further than that.

In particular, I think we are looking at the computation area. I think that is one area that I really do have to disagree slightly with Dr. Schlesinger, at my peril, I should add. But we recognized right from the start that we are going to have to move into three dimensions and do it at very, very high resolution, which means a lot of computing. So when we say we are going to need 100 teraflops, even though that is a factor of 10,000 greater than what one could get available to us just 2 or 3 years ago, we are building a program which is now, a teraflop which will be three teraflops in another 2 years and will be 100 teraflops in about 5 or 6 years.

So the program is not static. It really tries to think ahead in terms of what we understand what we will need. That is where we work it and then work backwards to solve the problems as we are moving forward.

Senator LEVIN. How are you able to certify that the stockpile is safe and reliable now, based on the Stewardship Program, when that Stewardship Program is not yet fully phased in?

Mr. REIS. Right now, Senator, we have very good test information on all of the nuclear weapons. We have all of the, or not all, but almost all of the people who worked on that program. They are answering questions right now that have come up on several situations. Where in the past we might have had to go back and do tests, we have actually gone through some of these areas and so when we do the annual certification on a year-to-year basis, what we have determined is that we are doing just fine.

In addition, we have produced the modification of the B61, the so-called B61 Mod 11. While it is sort of an arch-type of what we would do because the physics package stays the same. There were no modifications of that. But we modified the conditions, the environments. Secretary—I guess we can call him Secretary Schlesinger, he has been everything else—mentioned that these environments are very difficult and we have to understand them. We have been through that now and have been able to deliver that, working with Y–12, working with Pantex, working with Kansas City, a modification, and have been able to certify, or so far it has been accepted, that this will work. Now, as time goes on, we will get even better and better at that.

Senator LEVIN. Thank you. Thank you, Mr. Chairman.

Senator COCHRAN. Thank you. Senator Thompson, any further questions?

Chairman THOMPSON. No.

Senator COCHRAN. Thank you very much, Secretary Reis, for being here today and helping us with this hearing.

Our next witness is Robert Barker, Assistant to the Director of Lawrence Livermore National Laboratory. Dr. Barker has had 30 years of experience in every aspect of the nuclear weapon program of the United States and has contributed to U.S. efforts to control the proliferation of weapons of mass destruction.

In 1995, Dr. Barker established the laboratory's Department of Defense Programs Office and served as the Acting Director for the first year. Dr. Barker assumed the position of Assistant to the Director in 1992, upon his return to Lawrence Livermore National Laboratory, after having spent 9 years in government service in Washington.

Dr. Barker, welcome. Thank you very much for being here. We have, I think, a copy of your statement and we will put that in the record in its entirety. We encourage you to make such summary comments from it that you think will be helpful to the Subcommittee. Thank you. You may proceed.

## TESTIMONY OF ROBERT B. BARKER, ASSISTANT TO THE DIRECTOR, LAWRENCE LIVERMORE NATIONAL LABORATORY

Mr. BARKER. Thank you, Mr. Chairman. It is indeed a pleasure to be here. This probably is my fifth or sixth appearance before Senator Levin, because as the Assistant to the Secretary of Defense, I testified annually in support of the Department of Energy budget. As the Assistant to the Secretary of Defense, I was responsible for understanding and making sure the Department of Energy's budget was supportive of defense requirements. It is very hard to leave that kind of environment behind.

I probably should begin my comments this afternoon by making clear that I am here representing myself. As you have commented in your introduction of me, Mr. Chairman, I have had a professional career devoted to nuclear weapons related work, ranging from doing nuclear weapons design to serving three Secretaries of Defense as their expert on nuclear weapons matters. The details of that career are described in more detail in my statement. I will not go into it further now, but I do want to make clear that I do not represent the Department of Energy, the University of California, or the Lawrence Livermore National Laboratory in my appearance this afternoon.

I am not going to read my statement. I am going to paraphrase some of it. But I do want to introduce something that I only recently became aware of. If one of the staff could take these pieces of paper from me, I could provide a copy to you and Senator Levin.

The unclassified extract from the Bush report follows:

UNCLASSIFIED EXTRACT FROM:

Report to the Committees on Armed Services and Appropriations of the Senate and the House of Representatives on Nuclear Weapons Testing required by Section 507 of the FY 1993 Energy and Water Development Appropriations Act.

Transmitted by President George Bush, January 19, 1993

D. (U) Proposed Test Program

(U) In signing the Energy and Water Development Appropriations Act, 1993, President Bush described Section 507 of the Act as highly objectionable. Specifically, the President noted that Section 507:

> may prevent the United States from conducting underground nuclear tests that are necessary to maintain a safe and reliable nuclear deterrent. This provision unwisely restricts the number and purpose of U.S. nuclear tests and will make future U.S. nuclear testing dependent on action by another country, rather than on our own national security requirements. Despite the dramatic reduction in nuclear arsenals, the United States continues to rely on nuclear deterrence as an essential element of our national security. We must ensure that our forces are as safe and reliable as possible. To do so, we must continue to conduct a minimal number of underground nuclear tests, regardless of the actions of other countries. Therefore, I will work for new legislation to permit the conduct of a modest number of necessary underground nuclear tests.

(U) Despite our strong concerns with Public Law 102–377, the Departments of Defense and Energy have endeavored since its enactment to devise a fiscally, militarily and technically responsible testing program to comply with its constraints. We have concluded that it is not possible to do so, for several reasons.

(U) First, regarding weapons safety, the Administration considers the planned enduring nuclear weapons stockpile to be reliable and safe. Given the weapon's safety and the high cost of introducing new warheads incorporating additional safety improvements throughout the deployed force, we do not believe it would currently be cost-effective to incorporate them in the existing stockpile.

(U) However, one or more of the weapons systems in the enduring stockpile might develop a significant flaw and require repair or replacement. Of all U.S. nuclear weapons designs fielded since 1958, approximately one-third have required nuclear testing to resolve problems arising after deployment. Therefore, we should have available weapon designs with enhanced safety features, that are thoroughly designed and tested, should they be needed. This aspect of planning for the future becomes more compelling recognizing that the weapons in the enduring stockpile may be retained well into the mid-21st century.

(U) The administration advocates a series of nuclear tests to develop backup warheads which would provide enhanced reliability and safety, and serve as a hedge against the emergence of a significant flaw in one or more weapons types in the exiting stockpile. However, it is not possible to develop warheads with the requisite reliability and safety within the constraints of Public Law 102–377. They cannot and should not be developed in haste. Realistically, the effort will take more than 15 test over three years. In addition, post-production tests would be required to have confident in the warheads; such test could be well into the future, and thus would not be allowed under Public Law 102–377.

(U) Second, in accordance with earlier Congressional direction, the Administration has engaged in a major effort to increase predictive capability, and thus reduce our reliance on nuclear testing for force safety and reliability. It is questionable whether tests dedicated to that purpose would be allowed under Public Law 102–377. Even if they are, the limited amount and duration of underground nuclear testing allowed would permit us only marginally to increase our predictive capability, and would certainly not bring it to a point that we could maintain the safety and reliability of the U.S. nuclear deterrent without underground nuclear tests.

(U) Third, the legislation provides for one test of the reliability of a nuclear weapon per year. That in itself might be adequate, but the requirement for weapons reliability testing is a long-term one, that will not come to abrupt end on September 30, 1996. The U.S. nuclear deterrent is far too important to our security and that or allies to forswear in the near future these tests required to ensure that it remains safe and reliable.

(U) Fourth, the legislation does not allow underground nuclear testing to ensure that U.S. forces, other than our nuclear weapons, would be able to fulfill their functions despite exposure to nuclear effects. Such testing is extremely important for a wide range of systems, including conventional systems, sensor of all types, other defensive systems, and all command and control elements. Thus the constraints of Public Law 102–377 will have an adverse impact on a wide range of U.S. capabilities, in addition to our nuclear deterrent.

(U) In consequence, the Administration has concluded that it is not possible to develop a test program within the constraints of Public Law 102–377 that would be fiscally, militarily and technically responsible. The requirement to maintain and improve the safety of our nuclear stockpile and to evaluate and maintain the reliability of U.S. forces necessitates continued nuclear testing for those purposes, albeit at a modest level, for the foreseeable future. The administration strongly urges the Congress to modify this legislation urgently, in order to permit the minimum number and kind of underground nuclear test that the United States requires—regardless of the action of other states—to retain safe and reliable, although dramatically reduced deterrent forces.

Mr. BARKER. Mr. Chairman, when you invited me here today, you asked me to try to identify the risks attendant to the cessation of nuclear testing and the adequacy of the Department of Energy's Stockpile Stewardship Program as an alternative to testing. I have taken that responsibility very seriously, because I think it is important in the deliberations of the Senate as it considers the Comprehensive Test Ban Treaty that the Senate look hard at the shortfalls that have been introduced by the cessation of testing and look hard to see what they believe the limitations of the Stockpile Stewardship Program may be. My job is to emphasize the shortfalls, and that is what I am going to do.

The first thing I want to observe is that things have changed dramatically in the last less than 5 years. The piece of paper that I have distributed, which I only became recently aware of, or maybe I was reminded that it existed, dates from January 1993. In October 1992, George Bush, then President of the United States, signed what was referred to as the Hatfield-Exon-Mitchell Amendment, part of H.R. 5373, and that amendment, Section 507 of that bill limited the number and purpose of nuclear tests and set a specific date for the cessation of nuclear testing, namely September 1996.

When President Bush signed that legislation, he characterized this particular section as “highly objectionable,” so much so that in his signature statement, he said that he would work for legislation to permit continued testing.

On January 19, 1993, President Bush forwarded to the Congress a report to the Committees on Armed Services and Appropriations of the Senate and the House of Representatives on nuclear weapons testing as required by Section 507. I will read the last paragraph of that to you, it says, "In consequence, the administration has concluded that it is not possible to develop a test program within the constraints of Public Law 102–377," that is, the Energy and Water Development Appropriation Act of 1993, "that would be fiscally, militarily, and technically responsible. The requirement to maintain and improve the safety of our nuclear stockpile and to evaluate and maintain the reliability of U.S. forces necessitates continued nuclear testing for those purposes, albeit at a modest level, for the foreseeable future. The administration strongly urges the Congress to modify this legislation urgently in order to permit the minimum number and kind of underground nuclear tests that the United States requires, regardless of the action of other States, to retain safe, reliable, although dramatically reduced deterrent forces."

This report to the Congress was a classified report and what I have presented is a totally unclassified section of that report which addresses the proposed test program. When you have the time to look at it, you will see that as President Bush goes through the objections to the limitations on testing proposed by the legislation, it very closely parallels the areas that I have identified as risks in my prepared statement.

He addresses the issue of being able to address problems that arise in the stockpile that bear on reliability and safety. He raises the issue that the safety of the stockpile could be improved and will not be able to be improved with the cessation of testing. He identifies the fact that the inability to do nuclear tests will prevent us from evaluating the survivability of our own military systems to the nuclear effects that might be imposed by other powers.

Clearly, here is a very unequivocal statement about the continued need for nuclear testing made by a President of the United States in January 1993. Here we are, not yet 5 years later, a Comprehensive Test Ban Treaty has been signed and the Senate has before it the issue of giving its advice and consent to that treaty.

I think there are numerous areas for the Senate to explore in its consideration of advice and consent that bear very dramatically on the risks of the U.S., and I would like to go through them very briefly and then take your questions.

I think maybe one way to begin is to take a look at some of the issues that were raised with Secretary Reis, and using my own statement, give my answers to some of those issues.

Maybe I could begin by making reference to a comment made by Senator Thompson. He said, "You will know it works when you try it," and that, indeed, has been the philosophy that the U.S. has followed up until now. We have done a nuclear test of every weapon we have put into the inventory as it comes off the production line, usually within 1 year or so after it comes off that production line. We have also annually taken at random one weapon out of the inventory and tested it to see if it still works. Now, that was a requirement of the Defense Department. The Defense Department was the one that insisted that the Department of Energy take an old weapon out of the inventory and test it, because despite the assurances provided to the Department of Defense by the laboratories, by the best scientists in the world, the Defense Department's view was, we will really know it works when it works and so let us adopt this test program.

On the issue of confidence, I say very unequivocally in my statement that our confidence is less today than it was in the past. I think that is a totally defensible statement based on the following things. One, in the past, every year, we used to do a stockpile confidence test. We have not for 5 years. We have, as Dr. Reis said, found changes in the stockpile. He has said that we have solved them without testing. In the past, we would have tested. I would challenge that the test and demonstration of the result is a much more positive thing than judgments drawn even by the best scientists based on calculations and laboratory experiments.

Now, I am not saying that safety and reliability are today at an unacceptable level because of this current situation. What I am saying is there clearly has been a diminution in confidence and we should admit it. In fact, I think one of the great challenges for the Senate to understand is how will we as a Nation will measure this erosion in confidence. Maybe as SSP facilities come on line, maybe some confidence will increase again. In fact, there have been curves in existence that have been used by the Department of Energy in the past which show the decline of confidence as a function of time until stockpile stewardship facilities come on board and then that curve turning around and going back up.

I do not think there is any issue that confidence has declined and I think it will be of great interest to the Senate to determine how one is measuring confidence, what factors go into that deliberation, and for the Senate to make up its own mind about what is acceptable and what is unacceptable, what is adequate and what is not adequate.

If I may quote from another part of my statement, in the area of risk. I think one of the greatest concerns we have is that we might not even today know what the risks are.

In my statement I have rattled through a bunch of questions which I do not believe have yet been answered. How much confidence in the reliability and the safety of the stockpile is enough? How much confidence has been lost already because we have stopped testing? How much loss of confidence will trigger a need for a nuclear test? To resolve the issue, who will make that decision? How much safety is enough? What is the probability of success for the Stockpile Stewardship Program? What is the probability that a major stockpile problem will arise before stockpile stewardship works? What are the risks of trying to meet a new weapon requirement for the stockpile without nuclear testing?

I think the Senate has a great interest in the answer to all of those questions. Unfortunately, I cannot give you the answers today. I think there are experts from both the laboratories and review groups, that have been established as part of the certification process designed by the President, that can give you very interesting testimony on this issue. While all Senators may not have the time to burrow into all of these details, I think the Senate as a whole will want some of their members to probe these issues at great depth.

At this point, let me just say that I want to join the previous two speakers in heaping praise on the Stockpile Stewardship Program. I think Assistant Secretary Reis has done an absolutely incredible job in managing the development of this program. In fact, I am hard pressed to identify anyone else who could have pulled it off. He got the three labs to work together to design a program where something absolutely had to be done because the labs were told, you are not going to do nuclear tests.

In fact, if you did a poll of laboratory scientists these days, you would find they are absolutely convinced they will never test again. I think it is up to the Senate, when they look into this whole issue to make a decision as to whether they will give their advice and consent, to make a determination as to whether that is true, whether there will, indeed, be testing available to the weapon laboratory scientists or will there not.

Clearly, the patent assumption today on the part of most nuclear weapons designers and engineers that they will not test and they are putting their all, very, very energetically putting their all, into a Stockpile Stewardship Program that definitely deserves the Nation's full funding. There is no doubt about that. The issue in my mind, is whether there should be nuclear testing, as well, to make sure that the Stockpile Stewardship Program is working and to make sure that we have the ability to address problems that will arise in one of several different areas.

Anecdotally, I can tell you that while I was the Assistant to the Secretary of Defense for a period of some 5½ years to three different Secretaries of Defense, virtually once a year, on average, the Department of Energy would come to me and say, one of the weapons in the inventory is not safe or may not meet its reliability requirements. That is, it may not work. I do not mean one weapon, I mean an entire class of weapons. This caused us to have to redline a weapon. That is to say, this weapon, in effect, is not in the inventory, or requires a major change in its operational capability, because we have no confidence in its safety or no confidence in its reliability.

The day before I was informed of these problems, as the Assistant to the Secretary of Defense, I could have gotten infinite assurances the stockpile was safe and reliable, and I was being given those assurances in an era when nuclear testing was allowed. I was being given those assurances by the same scientists and engineers who are today at the Nation's nuclear weapons laboratories, except maybe we have lost some of the more experienced ones as a result of retirement in the last 5 to 8 years.

So if anything, the experience base has been eroding and the fact that we have not had a problem significant enough, apparently, to result in a test in the last 5 years is no guarantee that one will not happen tomorrow. An annual certification is good the day it is made, and based upon past experience, a problem could pop up anytime thereafter. That is my personal experience.

I do not think we can take a tremendous amount of comfort that problems will not arise because we have a certification program. We may find problems we would have otherwise missed because of the certification program, but it does not guarantee that surprises will not occur.

Now, I say that ceding to no one in my respect of the competency of the people at our nuclear weapons laboratories. I am one, and I think that the laboratories are, indeed, the best laboratories in the world. But these scientists and engineers are human beings, Mr. Chairman and Senator Levin. They are not perfect robots and history says that they have erred. When I was a nuclear weapons designer, I sure erred and had nuclear tests that did not do exactly what I wanted them to do. So the first area of concern where one wants to understand the risks is in the area of problems of reliability and safety popping up in the stockpile.

Another area which I think should be of grave concern is the safety of the stockpile. The current stockpile is safe. The current stockpile is safe because each weapon in it, by and large, incorporated the best safety features that existed at the time when the weapon was put into the inventory. As time went on, new safety inventions came in. The way we did business in the old days, older weapons systems would have been replaced and the replacement would have included the latest safety features.

But we are not doing that anymore. We are not modernizing our stockpile. It seems to me the very prudent thing to have done before the cessation of testing was to make sure that every weapon in the inventory had every safety feature consistent with the current state of the art, but that was not done.

So today, we are living with the fact that every weapon in the inventory does not have every feature in it that we know how to build. The substitute has been administrative controls, and we all know that sometimes administrative procedures can fail. I have the greatest respect for the civilians and the military that take care of these weapons, but we are putting a terrible burden on them by asking them to, by procedure, provide for safety that could have been provided by an inherent safety feature in a nuclear weapon design. I think the Senate should be asking whether this is an acceptable risk for the United States when it considers its advice and consent to a Comprehensive Test Ban Treaty.

The third area is the area of new requirements. As has been said, I think, by the previous two speakers, one of the requirements of this administration coming out of the Nuclear Posture Review is that the Department of Energy be prepared to meet new requirements. I think you will find the literature of the laboratories of the Department of Energy's history rife with citations about the dangers of putting something new into the stockpile without testing.

I am going to offer for the record a rather hefty report, but one that I think is probably the most authoritative document on the subject. It is titled, "Report to Congress on Stockpile Reliability, Weapon Remanufacture, and the Role of Nuclear Testing." It was done in October 1987. The author is George Miller, then the Associate Director for Defense Systems at the Lawrence Livermore Laboratory and now the Associate Director for National Security there, and by two of his staff.[1]

On page 11 of that document, it says, "Testing of newly produced stockpile systems has shown a continuing need for nuclear tests. Even an 'identical' rebuild should be checked in a nuclear test if we are to have confidence that all the inevitable small and subtle differences from one production run to the other have not affected the nuclear performance." He provides an example in this report of the same kind of a problem occurring with the Polaris missile when the Navy tried to rebuild it after a cessation of production and finding great difficulties in building an identical missile.

Another very interesting element of this document is that, if I can refer back again to the report that President Bush sent to the Congress in January 1993, President Bush says, "Of all U.S. nuclear weapon designs fielded since 1958, approximately one-third have required nuclear testing to resolve problems arising after deployment." This document details most of those examples, the ones that had occurred as of the date of the document. So one-third of the inventory produced by Los Alamos, and one-third of the inventory produced by Livermore were affected. The kind of problems that popped up after these weapons were in the inventory are listed here.

So whether it be stockpile problems, whether it be new requirements to meet the new challenges of the new world, nuclear testing has been essential always in the past to meet those kinds of challenges. I think the Senate needs to understand whether it is an acceptable risk to not be able to respond to those kinds of situations in the future.

Let me just say a few more words about the Stockpile Stewardship Program and then quit. I think, as a matter of fact, the threats or the risks associated with stockpile stewardship have already been fairly well covered in the hearing up to this point.

I think the Members of the Subcommittee have recognized the fiscal liabilities. With what confidence can one assume a commitment to a decade of funding at the $4.5 billion level in the presence of a balanced budget environment and growth in other budget areas?

There are already people who are assuming that this program is just like any other program and it can be incrementally whacked and still do its job. I think until a thorough review is done of the SSP by the Senate and the Senate itself is convinced that there is fat in there, any reduction should be viewed as a significant increase in the risk of depending upon a Stockpile Stewardship Program.

So there is the whole fiscal risk, and you, gentlemen of the Senate, I think, are much better able than I to assess the credibility of sustained funding at a $4.5 billion a year real dollar value. I am inclined to believe that the number should probably be higher than $4.5 billion, but that, again, is an issue for you to explore, for the Senate to explore.

[1] Report entitled "Report to Congress on Stockpile Reliability, Weapon Remanufacture, and the Role of Nuclear Testing," dated October 1987, submitted by Mr. Barker appears in the Appendix on page 112.

The other area of risk with SSP is the technical risk. I think Senator Thompson basically hinted at it, that you are talking about very long-term projections for very complex technical things. You will find that in this Nation, the American way is the high-tech way and you will find that many of those high-tech programs do not meet their milestones and some of them even fail.

I personally think the chances of the SSP elements ultimately succeeding are good, but I am less sanguine that they will meet this 10-year time line that has been laid out for them, trying to dovetail the retirement of the last nuclear weapon designer with design experience with the full operation of SSP. That is asking an awful lot. It is not only asking for technical success, it is asking for technical success on an immovable schedule. Again, I think the Senate has plenty of data in front of it by which to make an assessment about the risks associated with making that assumption.

I have probably gone on longer than I should have because I have forgotten to look at my watch, but let me just tick off those areas of risk again. Problems in the stockpile dealing with reliability and safety, whether the safety itself is good enough for American citizens, and third, whether we are prepared to abandon the possibility of modernizing our systems in the future in response to changing national security requirements.

The areas of risk are abundant and I certainly hope that the Senate will give them every consideration before it takes its decision on advice and consent to the Comprehensive Test Ban Treaty.

Only one last comment, please, and that is even if the CTBT were not ratified, in the absence of testing, SSP is absolutely critical. The issue of SSP is to do as good a job as can be done without testing. My own druthers would be very similar to what Secretary Schlesinger proposed, except I would include without ratification, namely, continued testing at some low level and even the ability to conduct high-yield tests as it proved necessary to maintain reliability in the stockpile. Thank you, sir.

[The prepared statement of Mr. Barker follows:]

PREPARED STATEMENT OF MR. BARKER

I have been asked to testify today on the risks attendant to the cessation of nuclear testing and the adequacy of the Department of Energy's Stockpile Stewardship Program (SSP) as an alternative to testing. I am pleased to do so because I have been concerned for some time about the lack of public awareness and discussion of the tradeoff between the risks and purported benefits of the existing cessation of testing and its potential permanent codification in the Comprehensive Test Ban Treaty (CTBT). Already it has been more than five years since the last U.S. test of a nuclear weapon. It is imperative that the Senate undertake an assessment of whether the risks inherent in the cessation of testing are acceptable and whether the purported benefits are real and significant enough to warrant the costs.

My comments are my own, based upon a professional career devoted to nuclear weapons related work, ranging from being a nuclear weapon designer to serving three Secretaries of Defense as their expert on nuclear weapon matters. The details of that career are described in more detail below. I do not represent the Department of Energy, the University of California, or the Lawrence Livermore National Laboratory in appearing here this afternoon.

Let me start by briefly summarizing my conclusions:

First, sustained nuclear testing, with no less than six tests per year, is the only demonstrated way of maintaining a safe and reliable nuclear deterrent. Our confidence in the safety and reliability of our nuclear weapons has already declined, to an as yet unquantified extent, since 1992, the year we deprived ourselves of the nuclear testing tool to evaluate stockpile safety.and reliability.

Second, stockpile problems affecting safety and reliability are inevitable; they can arise anytime, even as soon as tomorrow. New weapon requirements will arise as the current, Cold War stockpile is perceived to not meet evolving national security needs. Nuclear weapon safety can be improved. The ability to promptly conduct nuclear tests will be essential to confidently meeting these challenges. Especially in the case of a loss of confidence in the reliability or safety of a stockpiled weapon system, we cannot afford to wait years to fix the problem.

Third, the Stockpile Stewardship Plan, a very creative plan developed by the nation's nuclear weapon laboratories and production facilities, under the leadership of Dr. Reis, to respond to the lack of nuclear testing, is not now, and never will be—even ten years from now when its major components might be operational—a "substitute" for nuclear testing in the sense of giving us *equal* confidence in the safety and reliability of our nuclear weapons. Nor will SSP alone allow us to improve the inherent safety of nuclear weapons or provide new nuclear weapon designs in response to new requirements.

Fourth, if a sustained, robust, nuclear test program cannot be assured a minimum requirement is *a fully funded SSP and the ability to conduct limited nuclear testing.* Two options might be:

> Routine low yield (0.5–1.0 kt) testing, in conjunction with SSP, that can still allow us to address many of the critical issues we will face (At these yields, it should be noted, we could not confidently detect another nation's clandestine testing);
>
> Infrequent tests conducted to validate SSP capabilities and to address a specific stockpile problem or to meet a new requirement, upon concluding that SSP is inadequate to the task. (These are the same tests whose execution would require the "Supreme National Interest" clause to be exercised if the U.S. were party to the CTBT.)

In each case nuclear testing readiness should be maintained so as to enable the conduct of a test within less than a year of identifying the need for the test.

Fifth, the cessation of testing, with its clear risks to the maintenance of a credible deterrent, has been justified on the basis that national security is enhanced through non-proliferation benefits. I can find no evidence that this assertion of benefit has been subjected to any reasonable standard of proof. It seems all too likely that we are accepting "risk" with no "benefit."

In the remainder of my comments I will review with you first those aspects of my career in nuclear weapons related work that have been most relevant to my reaching these conclusions. I will make clear my premises, and amplify on the basis for my assessments.

*A Career in Nuclear Weapons Work*

I began my career in nuclear weapons work when I joined Lawrence Livermore Laboratory in 1966 fresh from receiving my Ph.D. in Physics. I became a nuclear weapon designer, learning to simulate nuclear weapon explosions on the computers of the time, bringing designs from calculated concepts to real hardware which were then tested in underground nuclear detonations.

Over the next seven years I moved from novice designer to leader of the strategic nuclear weapon design group. For the five years following I managed the Laboratory's nuclear weapon systems analysis organization, working with the military services and the Office of the Secretary of Defense, to assure that the nuclear weapon design efforts of the laboratory would meet the future needs of the Department of Defense. I then became manager of LLNL's Special Projects organization, among whose responsibilities were the analysis of the nuclear weapon capabilities of other nations, including those of proliferant countries. In 1982 and 1983 I served as the Deputy Associate Director for Arms Control, providing the Laboratory's technical assistance to the Departments of Energy, Defense, State, and the Arms Control and Disarmament Agency.

From October 1983 to October 1986 I served in the Arms Control and Disarmament Agency as the Deputy Assistant Director for Verification and Intelligence. In this capacity I was responsible for evaluating the effectiveness and ineffectiveness of verification technology and performing assessments of other nations' noncompliance with existing treaties to which the U.S. was party.

In October 1986 I became Assistant to the Secretary of Defense (Atomic Energy) (ATSD(AE)), the position I held until May 1992. In this capacity I was the principal advisor to the Secretary of Defense on all nuclear weapon matters, including nuclear weapon safety, security, and reliability and was DOD's day-to-day interface with the Department of Energy for nuclear weapon matters.

I returned to LLNL in 1992 where I serve as an Assistant to the Laboratory Director.

*Lessons Learned*

What have been the primary lessons of the various periods of this career? As a nuclear weapon designer I learned the limitations of simulations and the humility that comes with the failure of a nuclear test. Computer calculations, regardless of how good or fast the computer is, are only as good as the data and models you give them *and* the knowledge and experience of the individual doing the calculations. Even today no computers are big enough or fast enough to simulate all that goes on when a nuclear weapon explodes. The true knowledge of and experience with the limitations of calculations came from understanding the differences between calculations and experiments, including nuclear tests.

As a system analyst I learned that nuclear weapon systems inevitably lose effectiveness in the face of emerging threats, changing technologies, and evolving requirements. Targets once threatened will burrow deeper, out of the range of effectiveness of existing weapons. Advances in detection and precision strike capabilities will threaten the survival of U.S. delivery systems, thus calling for longer range, or faster delivery, or stealthier characteristics, any one of which might necessitate changes to the nuclear weapon to be delivered. Weapons designed for the Cold War are unlikely to support the precision, limited damage strikes that may be required to deter proliferant nations' use weapons of mass destruction.

As an evaluator of other nations' nuclear weapon programs, I learned that mirror imaging is dangerous, and we should not assume that others will have the same need for testing that we have. Every nuclear nation's nuclear weapons will not decay at the same rate; every nation will not lose confidence in their nuclear weaponry at the same time. We cannot predict whether our weapons will have a longer shelf-life and effectiveness than our potential opponents'. Where we have striven for minimum weight, others may have chosen to maximize tolerance for production defects. Where we have chosen to build unique designs for every application, never expecting to rebuild an old design, they may have chosen to plan to routinely reproduce older designs. The risks of no testing will not be the same for all nuclear weapon states. We cannot assume the least risk for ourselves.

In the arms control arena I discovered that while Treaty proponents may argue that "adequacy" of verification is all that's needed to "deter" violations after entry into force, too often those same advocates of "adequacy" will demand absolute proof of violations, a standard of evidence that was demonstrably not achievable before treaty ratification. It is to hoped that CTBT hearings will explore whether the capability will exist to absolutely prove any violation of the "zero" limit.

In the Pentagon, I became the customer of the DOE nuclear weapon infrastructure. In my five and one-half years as ATSD (AE) I found myself going to the Secretary of Defense too many times to tell him that DOE had just informed me that a weapon type in the inventory was not safe or would not work. These were not minor problems; these were catastrophic failures. In each case, all was well the day before, with no indication of safety or reliability problems. The next day all weapons of a given type were red-lined as unfit for duty. Nuclear testing was critical in some cases to the finding of these problems and, in some cases, to achieving confidence that the fixes for the problems were acceptable.

In each area of my career I have had the opportunity to see a different aspect of the U.S. nuclear weapon system. My judgments about the risks of the cessation of testing while trying to maintain a safe and secure stockpile come from someone who was "there", someone who has had to live with the real and potential consequences of failure.

*Key Assumptions*

Any discussion of the risks to the credibility of our nuclear deterrent posed by the abandonment of nuclear testing should be based on a clear understanding of the underlying premises. My three key assumptions are:

*Nuclear weapons are now and for the foreseeable future will remain an important element of the nation's national security posture.* The views of this Administration on this issue have been made clear in testimony before this committee by Under Secretary of Defense Walter Slocombe. President Clinton has said ". . . I consider the maintenance of a safe and reliable nuclear stockpile to be a supreme national interest of the United States." While nuclear threats have diminished with the end of the Cold War, they have not disappeared. The need to deter the potential use of weapons of mass destruction, nuclear, chemical, biological, against the interests of the U.S. and its allies has increased. We must maintain our deterrent nuclear force for as long as threats remain, or have the potential to emerge, and until such time as technologies are developed which could verify without doubt that no nuclear threats are posed against us.

*The credibility of our nuclear deterrent can only be sustained if we, ourselves, are confident it will work.* That is, we must believe that nuclear destruction of whatever we target will be sure and swift once the decision is made to use a nuclear weapon. We, especially in our open society, cannot sustain the credibility of deterrence for long if we lose confidence in the actual performance of the weapons.

*We must make sure that our nuclear weapons are safe. To do less would be immoral.* The history of U.S. nuclear weapon development is that with the design of each new weapon, efforts were made to incorporate the latest safety features in a steadily evolving safety technology. When weapons remained in the stockpile so long that their safety features were too deficient with respect to then current standards these systems were retired solely because of this deficiency. This approach must continue to be our standard.

*The Risks for "Reliability" and Safety*

The prudent approach to ending nuclear testing, as with any endeavor, would have been to demonstrate the success of an alternative approach before abandoning what has been demonstrated to be successful. The Congress, in the FY89 Defense Authorization Bill, required the Department of Energy to define a Test Ban Readiness Program. The resultant program was designed to develop and determine the effectiveness of non-nuclear test alternatives by direct comparison with the results of an ongoing nuclear test program. This program would have required ten years to implement and required approximately ten nuclear tests per year to validate the alternatives to nuclear testing. The program was terminated in 1992 by the premature cessation of testing.

The U.S. abandoned the prudent approach when it ceased nuclear testing in 1992 without demonstrating a reliable substitute for nuclear tests. Instead we have abandoned the known and embarked on a path whose risks are unknown but could be very great.

There are a number of questions about risk that should be critical in discussions of a CTBT and SSP. The questions sound as if there were quantitative answers. How much confidence in the reliability and safety of the stockpile is enough? How much confidence has been lost already because we have stopped testing? How much loss of confidence will trigger a need for a nuclear test to resolve the issue? How much safety is enough? What is the probability of success for SSP? What's the probability that a major stockpile problem will arise before SSP "works"? What are the risks of trying to meet a new weapon requirement for the stockpile without nuclear testing?

In my view there has been a major failure in coming to grips with these questions. It is not even clear that it has been decided who should bear the responsibility for "officially" answering the questions. For example who decided that today's nuclear weapons are safe enough and that further testing should not be conducted to make weapons as safe as currently possible before stopping testing?

The nuclear weapon community has difficulty giving quantitative answers to these questions. The national security policy community has failed to specify quantitative requirements. Without answers to these questions, how can anyone feel comfortable with the risks on continuing down the current path? The biggest risk may be that we don't even know what the risks are

I will address four areas of risk that bear on the credibility of the U.S. deterrent: stockpile defects; accepting less than the best in nuclear weapon safety; the inability to respond effectively to new threats and requirements; and betting on SSP before it has shown what it can do.

*Stockpile Defects*

As I stated earlier, inevitably, based on the history of the stockpile to date, a problem will be discovered in a weapon type in the inventory. Past problems have been due to the aging of weapon components and the discovery of design defects years after a weapon has entered the inventory. The problems can bring into question the safety or reliability of all the weapons of a particular type. The risks of trying to solve such problems without nuclear tests have not been quantified.

I have used the word "reliability" because that is the custom in the nuclear weapon business, but it is the wrong word. Reliability conjures up in most people's minds a vision of some fractional or percentage failure rate in something. Today there are many people who will say "You have so many weapons, the Cold War is over, it doesn't matter if the reliability is only 65 percent (or some other low number) instead of the 99.9 percent you've been used to demanding." While this attitude is itself debatable, when I and my colleagues, talk about loss of "reliability," we are talking about the concern that all weapons of a given type will fail to perform their mission.

John Nuckolls, a former Director of the Lawrence Livermore National Laboratory, has likened these different uses of "reliability" to the difference between owning an automobile "lemon" and finding that your automobile is in a "recall" because the manufacturer has discovered a fatal flaw in every car built of that model. The "lemon" is an example of a statistical problem, where only some limited percentage is bad. We can stand some "lemons" in the stockpile; we are unlikely to be able handle a "recall" affecting reliability or safety without nuclear testing to help us fix the problem.

At this point, in the limited debate that has occurred to date, somebody (not anybody who has actually been responsible for producing hardware) says "You don't need to do to nuclear tests; just rebuild the weapons to their original specifications and the rebuilt weapons will last as long as the first production." Wrong! Rebuilding weapons in trouble as closely as possible to the way they were built originally may be the lowest risk approach to solving stockpile problems, but it is not trivial and far from risk free. In the future we will find establishing confidence in a rebuilt weapon to be as challenging as a new weapon requirement.

Difficulty in recreating a piece of hardware with the same performance as the original is not unique to the nuclear weapon complex. When production was interrupted on the rocket motor of the Navy's Polaris sea-launched ballistic missile and then restarted, even with the same design specifications, it could not be reproduced. The fix required redesign and recalling retired people to provide data on how the original motors were made. Missile motor testing was available to the Navy to help them understand their problem and to be confident that they had found a solution. Nuclear testing needs to play the same vital role when nuclear weapons must be rebuilt.

*Safety*

There are weapons in the stockpile today which are less safe than they could be because they do not include the full suite of modern safety features. Without nuclear testing, improvements in the inherent safety of nuclear weapons are impossible. Future research could discover approaches that could add additional inherent safety, but these too would be precluded by the inability to conduct nuclear tests.

The history of U.S. nuclear weapon development is that with the design of each new weapon, efforts were made to incorporate the latest safety features in a steadily evolving technology of safety. When weapons remained in the stockpile so long that their safety features were too deficient with respect to then current standards, these systems were retired solely because of this deficiency.

Currently available safety technology consists of features that can be incorporated into the design of a nuclear weapon, thereby providing inherent safety. These features can not only preclude a nuclear detonation, except when intended, but can also dramatically reduce the possibility of the detonation of the nuclear weapon's high explosive in violent accidents and reduce the probability of the dispersal of plutonium in fires. Some weapons in the current stockpile were produced before all these features were available. The missing safety features in some weapons cannot be added without nuclear testing.

Today these safety shortfalls are partially compensated for by handling procedures whose objective it is to shield the weapons from the violent events that could result in plutonium dispersal. Such procedures will always be dependent upon the human beings who must execute them. I have the highest regard for the military and the DOE civilians whose job it is handle and transport these weapons, but I cannot help thinking that the nation would have been kinder to them and the rest of us if all available inherent safety features were part of today's stockpile. I was amazed when the decision was made to stop testing without conducting the few tests it would have taken to make the entire stockpile as safe as it could be made.

The absence of nuclear testing also removes any incentive for designers to invent further enhancements to inherent nuclear weapon safety. Even if such features are invented they will sit unused as long as we deny ourselves the ability to conduct nuclear tests.

Will we continue to settle for less than the safest nuclear weapons we know how to build? Hopefully the Senate will revisit this decision to abandon our long held standard of making our nuclear weapons as safe as technology allows.

*New Requirements*

Nuclear testing has been critical to the development of new nuclear weapons, even when that consists of packaging existing design concepts into new or modified delivery systems. There seems to be agreement that the production of new designs without nuclear testing constitutes unacceptable risk. Where differences of opinion exist is whether it is necessary or advisable for the U.S. deny itself new nuclear weapon capabilities. Are we prepared to accept the risks of not deploying new nuclear weapon systems as necessary?

Today's nuclear stockpile contains weapons designed to meet the requirements of the Cold War. It is an open question how long these same weapons will meet the needs of the post-Cold War world. It is certainly true that during the Cold War nuclear weapon systems, particularly strategic weapon systems, were periodically modernized. Modernization was driven by advances in technology that were not unique to nuclear weaponry. Targets became harder to threaten; they became less vulnerable to deployed yields and delivery accuracy. Our delivery platforms—submarines, aircraft, land-based systems—became vulnerable to attack as the acquisition and targeting systems of potential adversaries improved. As a result, the U.S. response was to preserve deterrence by increasing the lethality of our nuclear weapon systems and diminishing their vulnerability. Usually the weapon system changes caused us to require new nuclear weapon designs.

Several studies done for the Defense Department during the last Administration concluded that deterrence of attacks with weapons of mass destruction, nuclear, chemical, and biological weapons, against the interests of the U.S. and its allies would be enhanced by the addition of new nuclear capabilities to the U.S. nuclear arsenal. The testimony before this Committee by Under Secretary Slocombe describes a broad basis for the continued retention of an effective nuclear deterrent. It is difficult for me to believe that we will be able to maintain a credible deterrent against this array of potential threats if we are not prepared to deploy new nuclear weapon systems as our current ones become progressively less effective as a result of strong efforts to make them so. This Administration's 1994 Nuclear Posture Review, whose conclusions have been endorsed in the recent Quadrennial Defense Review, requires the DOE to maintain the ability to "Maintain capability to design, fabricate, and certify new warheads."

The record seems clear: it is a requirement to be able to meet new requirements. Nuclear testing is needed to meet new requirements. The absence of nuclear testing risks our ability to preserve deterrence in a technologically changing world.

*SSP*

The risks posed by depending solely upon a Stockpile Stewardship Plan for safe and reliable nuclear weapons come from two directions—one technical and the other, financial. There is the risk that even a fully funded SSP, which achieves all its technical objectives, will fall short of achieving the levels of confidence we need for the safety and reliability of nuclear weapons. From the other direction there is the risk that even if a fully funded SSP would ultimately demonstrate acceptable levels of confidence, inadequate funding over the decade needed to determine the degree to which SSP will work will doom SSP to failure. In either case, there is the risk that full SSP capability will be delayed, for technical or fiscal reasons, to the point that the experienced nuclear weapon designers with nuclear weapon testing experience will have retired before the new staff, with new capabilities, are ready to take their place.

The Laboratories in which the country has entrusted the maintenance of our nuclear deterrent for the entire nuclear era were told by this Administration that they would not test again and must do their best without testing. When asked to build a substitute for nuclear testing, under the outstanding leadership of Assistant Secretary Reis, the Laboratories generated a plan to greatly increase computational capability and to create new facilities that could more closely approach the physical conditions of nuclear explosions. It is a brilliant plan. This capability, if brought to reality, would not only allow better approximations of nuclear performance, it would also greatly enhance the ability to attract and retain the scientists whose judgments-must be depended upon when those with nuclear testing experience retired. A *sine qua non* of this plan was that the new capabilities become operational before the experienced cadre of nuclear weapon scientists retired.

The plan is very challenging technically, and very exciting for the scientists involved. It calls for an increase of a factor of 100,000 in scientific computing capability. This requires computers that run faster, vast machine memories, and new ways of storing and analyzing calculations. The machines for imaging the implosions of nuclear weapons, without nuclear yield, will press the frontiers of technology. The objective is to create an x-ray movie of an imploding nuclear weapon (without producing nuclear yield) to capture the instant when a nuclear explosion would begin. Other machines will create the conditions of temperature and pressure heretofore found only in nuclear weapons and stellar objects to enable a better understanding of how nuclear weapons operate and to explore the effect of certain defects on nuclear performance. As good as this plan is, think I can say that no one with operational knowledge of nuclear weapon development and production believes that it can achieve the same levels of confidence that were achieved with nuclear testing. Will they be good enough?

Any one of the objectives set out constitutes a significant scientific achievement. For all of them to succeed on schedule may be an even bigger accomplishment. I have great faith in my colleagues and am inclined to believe that ultimately, given funding, the objectives of calculational speed and facilities performance will be achieved. But the timelines are demanding and one or more of the projects may not be completed before the last scientist who had nuclear testing experience retires. The most prudent plan therefore would be for the United States to continue to conduct nuclear tests as necessary to calibrate the new capabilities and give the new generation of designers a new nuclear test experience base from which to assess their new tools.

The real challenge that should be on the lips of every individual who thinks it's a good idea for the U.S. to have a safe and reliable nuclear deterrent is "Prove to me that this SSP is good enough to entrust U.S. national security to it." The consequences of failure are too great for anyone to simply assume SSP will do the job.

What are the odds that SSP will be successful? Dr. Sig Hecker, the recently retired Director of the Los Alamos National Laboratory, has said he can not guarantee success. Dr. Vic Reis, the Assistant Secretary of Energy for Defense Programs has asked the question of numerous prestigious groups of scientists, and according to him the vast majority believe that, if fully funded, the odds of success are better than 50/50. Senior nuclear weapon Laboratory scientists and managers have said the odds are "good." I was among a group of ex-DOD officials who served on a panel at the request of Dr. Reis, to evaluate the ability of SSP to meet DOD's requirements. We concluded that ". . . confidence in maintaining a safe and reliable stockpile without nuclear tests will be good, but it will never be as good as was achieved with nuclear tests." The Senate will have to decide whether it thinks these odds are good enough for U.S. national security.

Turning to the financial perspective, the DOE's SSP contains the budgeted portion of what the Laboratories have said they needed. The SSP also needs to provide for the production of tritium to meet weapon needs and the retention of a production complex that can rebuild those weapons which must be replaced and any new nuclear weapon production. This not an inexpensive program. Recently it has been announced that more of what was needed will be funded.

The Senate should explore in depth whether there are still funding shortfalls in the funded SSP. Can it meet all the needs that have been identified from tritium production to maintaining a production capability to assuring a safe and reliable stockpile?

I suggest one significant shortfall is the ability to promptly conduct a nuclear test when one is shown to be unavoidable if a safe and reliable deterrent is to be maintained. I emphasize promptness here because I am uncomfortable with the vision of us discovering a fatal flaw in the safety and reliability of a stockpiled weapon type and then taking years to do the test to determine that we can confidently fix the problem. (I am even more troubled by the specter of the public debate that would ensue prior to a decision to test if the supreme national interest clause procedures outlined by President Clinton were carried out under a CTBT while the whole world knew that it was triggered by a major U.S. stockpile problem.)

Both internal and external to the Administration, the debate about the adequacy of funding seems to have become dominated by those who want to impose some arbitrary financial limitations, independent of what the recognized experts say they need. (Ironically, according to my reading of the newspaper, those outside government who claim the job can be done more cheaply are the same people who have devoted their lives to eliminating our nuclear deterrent. One might suspect their motivation in gutting the SSP is more to ensure its failure.)

The Senate will have to make its own assessment of the prospects of sustaining the necessary level of funding over the next decade to bring all the elements of the SSP to fruition on time. Then the Senate can decide if the risks associated with success being dependent upon full funding are acceptable.

*Concluding Comments*

In my comments today I have focused on the risks associated with the cessation of testing and not solely on the CTBT. The damage to our confidence in our deterrent is just as damaging with or without a CTBT if we continue to deny ourselves the ability to conduct nuclear tests as necessary.

Full funding of the SSP is our hedge, especially if it contains funding to ensure we can promptly conduct nuclear tests when it is clear we have no other choice. The

Senate can ensure the option to test to preserve our deterrent exists *by not giving its advice and consent to the CTBT.* The Senate can advance our chances of promptly conducting nuclear tests when needed *by eliminating the current legislative restraints on a President's ability to test when he sees fit.* The removal of these legislative constraints will also send a clear message that the Senate supports a reliable and safe nuclear deterrent. The Senate can send the strong message that it is not standing in the way of the nuclear testing needed to ensure a reliable deterrent.

I have not dwelt on the other deficiencies of the CTBT today. Lest it be thought that I support contentions that this treaty would inhibit proliferation in any way let me set the record straight. A proliferator does not need to conduct nuclear tests to establish a nuclear capability. South Africa demonstrated that. Also, one of our earliest designs was untested before it was used in war. While untested designs will be of lower yield, heavier, and larger than optimized, tested weapons, such weapons are all that's needed for some countries to devastate their neighbors. However, a proliferator can conduct tests with little or no risk of detection, or, if conducted on the high seas, without fear of attribution. Such tests may add additional confidence or increase sophistication for the proliferator.

I am also concerned that the CTBT will add to proliferation. Without testing, as have discussed at length, the effectiveness of our nuclear deterrent is guaranteed to erode. Those nations who have felt confident of our nuclear umbrella will rightfully lose that confidence and, in an increasingly uncertain world, some may conclude they must develop their own nuclear deterrent.

In conclusion, I see no benefits to U.S. ratification of the CTBT, and terrible costs. But even with no CTBT we pay the costs unless we are ready, able, and willing to conduct the nuclear tests that will maintain the nuclear deterrent component of our national security posture.

Senator COCHRAN. Thank you very much, Dr. Barker. We appreciate your testimony.

In connection with the yield issue on testing, Dr. Schlesinger mentioned that one of the most troubling aspects of this entire arrangement is the commitment to a no-yield program, that some testing with modest yields, and he mentioned 1 to 2 kiloton yields as what he had in mind, would be important to undertake or to have the ability to do in order to maintain some confidence in the reliability and safety of our arsenal. Do you agree with him on that? What military utility is there in conducting a test of 10 kilotons or less?

Mr. BARKER. I think you will find that in the two laboratory directors' responses to Senator Kyl's questions. I think, Director Tarter of the Lawrence Livermore Laboratory talked about half-a-kiloton testing. I think Dr. Hecker talked about a kiloton testing. If you go back to the Carter era, which is, I think, what Secretary Schlesinger was referring to, 1 to 2 kilotons was what was talked about, those numbers were largely keyed to trying to say we should not impose upon ourselves any limitation that we cannot verify and that there is, indeed, utility to evaluating the reliability and safety of the stockpile down to yields as low as someplace between a half a kiloton and a kiloton.

Clearly, higher yields will deliver higher reliability. Ten kilotons would be a significant advantage for many weapons in the inventory, but not all, and clearly, under current treaty, we have the ability to conduct tests up to 150 kilotons. We found great value in doing tests up to that level at certain times in our past.

Senator COCHRAN. In your opinion, as one who has experience designing and testing nuclear weapons, would nations like Russia and China be able to conduct testing that could evade our detection up to 10 kilotons or less?

Mr. BARKER. I think that is a distinct possibility, Senator. The one scenario that I think everyone agrees is the most challenging is a nuclear test that took place in the broad ocean area. If a nuclear test took place in the middle of the South Atlantic with nobody around, to whom would it be attributed? Any Nation that could pull off that kind of an event, even though detected and measured by our detection systems, the ones conducting the test may receive the full benefit from it.

Whether one can conduct tests underground and avoid detection in certain areas of both Russia or China, it is possible, certainly up into the few kiloton range. Look at the ambiguity, the continuing ambiguity associated with the test[s] in the neighborhood of Novaya Zemlya as an indication of the kind of turmoil that will exist in any attempt to verify a zero-yield treaty.

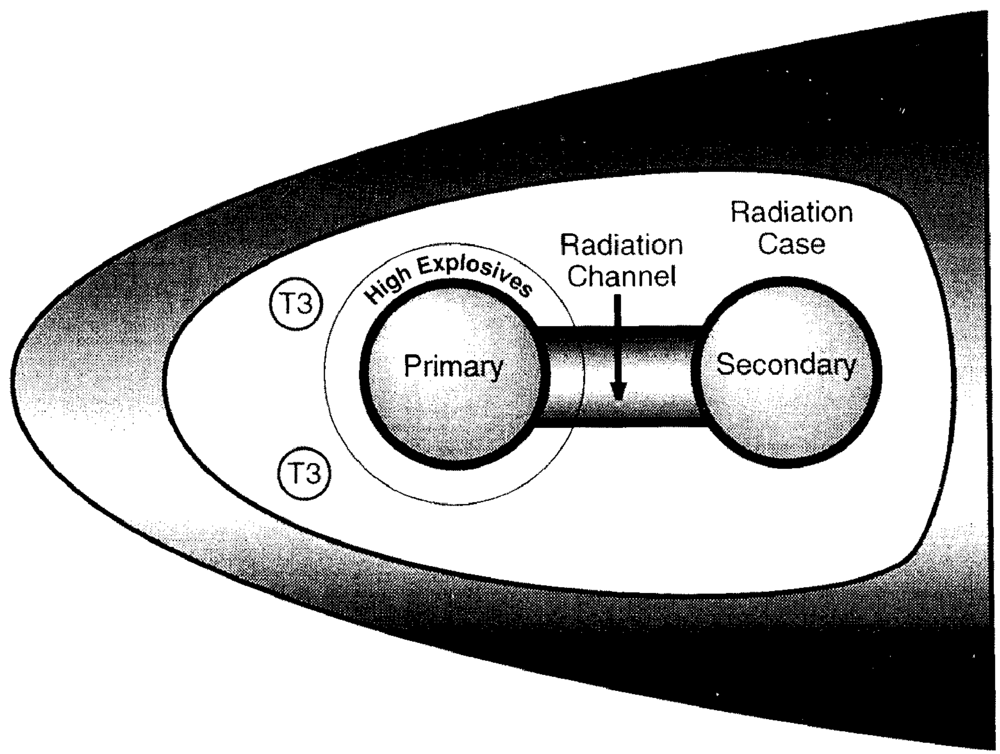
Senator COCHRAN. Do nations that aspire to acquire nuclear weapons have to test in order to develop nuclear weapons?

Mr. BARKER. Definitely not. In fact, one of the first two weapons we used in Japan was not previously tested. The South Africans announced in 1993 that they had a nuclear weapons program in which they had stockpiled a few weapons of a design that had never been tested. We have known for a long time that certain kinds of weapons can be developed and deployed with reasonable confidence without testing, and the unfortunate, tremendous spread of information that was once classified. As Secretary Schlesinger, when he first saw this picture here, (pointing to diagram of nuclear weapon) said, "When I was Secretary of Energy, all that was classified." That kind of a thing cannot help but raise the prospects that nations can, indeed, develop nuclear weapons without testing and have some reasonable confidence that they will work.

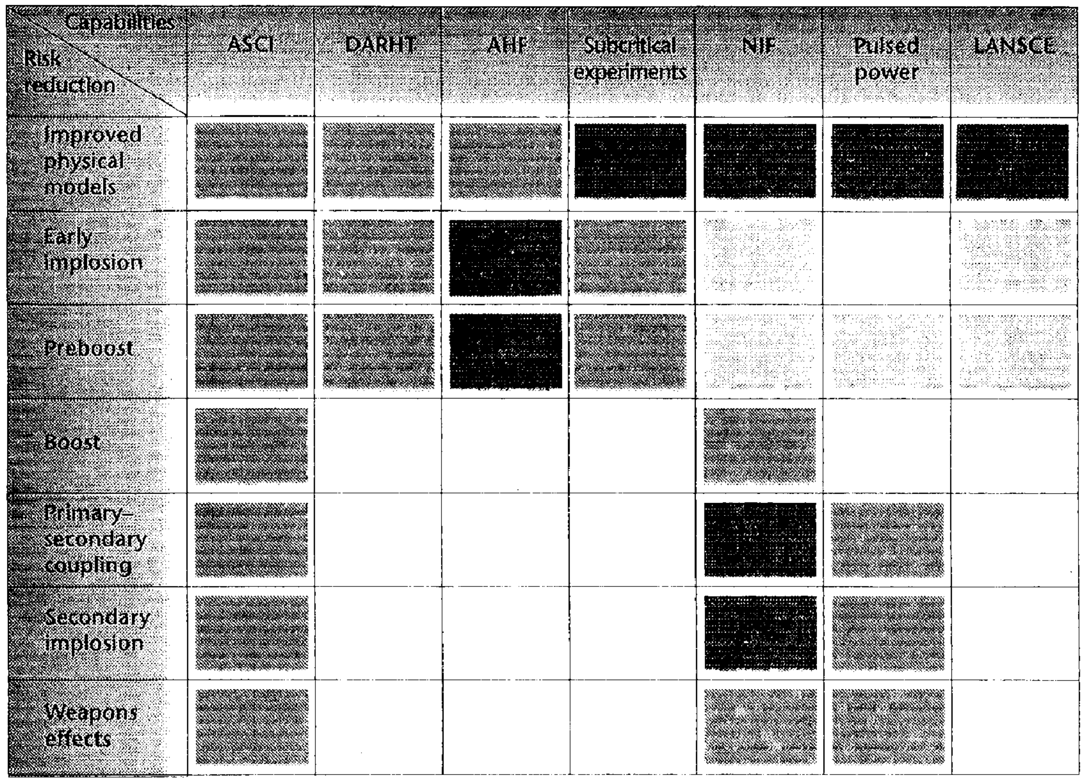
Senator COCHRAN. You referred to the charts that we have here, and I think I should make a point of including both of these charts, copies of them, in our hearing record.

[The charts referred to follow:]

# Notional Nuclear Warhead



## SSMP Capabilities



Senator COCHRAN. Would you explain to us what we should understand from the first chart, the nuclear warhead chart?

Mr. BARKER. The figure on the left, provided by the Department of Energy, is entitled a "Notional Nuclear Warhead." There are several key features identified that are intended to focus attention on certain parts of the Stockpile Stewardship Program. We have a primary, which contains high explosive and fissile materials on the left. We have a thing called a radiation channel, which couples a primary to the secondary. The secondary is actually the source of most of the yield of a nuclear weapon. The thing called a case surrounds everything.

The two little circles that have "T3" written in them are representative of the tritium bottles. As Dr. Reis said in his testimony, tritium is the lifeblood of a nuclear weapon. Without tritium, you will not get the primary to provide a sensible yield that would allow it to make a secondary work. Tritium decays at a rate of about 5½ percent per year. So tritium must continuously be replenished into warheads in order to make them work. Tritium production is very, very important.

High explosives are a good example of one of the organic materials that are inside a nuclear weapon. Plutonium, as everyone knows, is a radioactive material so that having plutonium inside this case is like having an electric light bulb on, continuously providing heat which will degrade organic materials eventually. One of the jobs of the Stockpile Stewardship Program will be, as the need has been from time immemorial, to detect changes that will make a weapon no longer operational including the degradation of organic materials.

The secondary is of great interest to Senator Thompson because that is the thing that is fabricated in his State, and as was mentioned by Secretary Schlesinger and Secretary Reis. Currently, our ability to make some of those materials is dramatically reduced at Y–12 at this time, so these are all challenges.

Now, the other chart, provided by the Department of Energy, probably almost nobody but me can read. Across the top, it has the various capabilities associated with the Stockpile Stewardship Program: the Accelerated Strategic Computing Initiative; the Dual Access Radiographic and Hydrodynamic Test Facility at Los Alamos; the Advanced Hydro Facility, which is a gleam in our eye as a successor to DARHT so we can get actually three-dimensional moving x-ray pictures of an imploding device; sub-critical experiments; the National Ignition Facility; pulsed power; and LANSCE.

On the vertical axis are listed the various steps in the operation of a nuclear weapon, going all the way from basic physics through early implosion all the way down to a secondary explosion and weapon effects. The color of the boxes is meant to indicate the correlation between those facilities and those phenomena. Where there is a colored box, that particular SSP facility will give information that is important to understanding the particular fundamental phenomena.

We have "secondary implosion" here, the second box from the bottom. There are only three boxes colored. One is the calculational box under ASCI. One is NIF, which the color is darkest because NIF is the most relevant to that phenomena, and then pulsed power facilities are also colored. This is a Department of Energy-generated chart and designed to help people understand how these facilities are different from one another and how critical they are to different aspects of the operation.

At the same time, I guess the flip side of that, if I am going to emphasize risk, is that it points out the vulnerability in our understanding if one of those capabilities should not come through on time or perform as expected.

Senator COCHRAN. In connection with that, it is my understanding that before we are able to achieve success or even know if success is possible, significant increases in computing resources will have to be developed and will be required to enable science-based simulations and model development that exceed now our present understanding of aging effects, like you talked about in this nuclear warhead model, and to anticipate needed replacements of degrading materials and components.

In your view, is the new computational capability that the Department of Energy anticipates accomplishing necessary to the Stewardship Program? Is it something that this ASCI is likely to achieve or certain to achieve? What is your opinion about that?

Mr. BARKER. I am with Senator Thompson. Nothing is certain. But I think that ASCI is a program that has the greatest chances of success because it links the best capabilities this country has. It links universities, it links laboratories together. But the kind of advances that are required to do the three-dimensional calculations that Secretary Schlesinger first mentioned and Dr. Reis also talked about, at the level of detail to take into account the kind of flaws that can pop up in a nuclear weapon is a very daunting task.

One talks about improvements in capability of computers by factors of 100,000, and Dr. Reis said 10,000, based upon achievements that have occurred in the last year or so. That is a big number and it has three major elements associated with it. One is to get machines that go that fast. Two is to be able to have those machines deal with the volume of data that is associated with the performance of a nuclear explosion. And third is the software challenge of making that data comprehensible to a human being.

Those are all huge challenges. I think everyone who is involved in it is enthusiastic, from universities to laboratories, but I would not be so rash as to guarantee success and I do not think the laboratories would guarantee success.

Senator COCHRAN. But it is a key element in this entire program.

Mr. BARKER. Absolutely critical, yes.

Senator COCHRAN. There is something the Department of Energy has known as the Green Book, I understand. It is a document dated February 29, 1996, which suggests that significant increases in these computing resources will have to be developed in order to determine things like whether materials are degrading or components are deteriorating to the point where the aging effect on the nuclear weapons would exceed what you could tolerate.

Do computing needs necessary for the Stockpile Stewardship Program exceed the current capabilities at the DOE laboratories?

Mr. BARKER. That is absolutely true.

Senator COCHRAN. There is no question about that. When will we know if ASCI, then, will achieve the necessary new computational capability?

Mr. BARKER. Well, that is one of the areas where there is a time line in existance for increases in capability, and so one can, indeed, track in real time whether or not those capabilities have been achieved.

Senator COCHRAN. What is that time line, do you know?

Mr. BARKER. I believe that curve is in the Green Book, Senator.

Senator COCHRAN. It is in the Green Book? I see.

There is another point in all of this, too, it seems, and that is that several of the facilities will take some number of years, maybe as many as 10 years, to build. Is that correct, and if that is correct, can an adequate level of confidence in the safety and reliability of the stockpile be maintained in the interim?

Mr. BARKER. That schedule is, indeed, correct. In fact, the Advanced Hydrodynamic Facility, as far as schedule is concerned, is the longest term of the things up there. I guess that is a good 10 years out. The National Ignition Facility is, I guess, 7 years out before it becomes operational.

These are all, as I said, significant technical challenges, and in the meantime, until they become operational, one will have to depend upon earlier SSMP capabilities and the experience base of the personnel who have stayed on board. That is a very complicated piece of arithmetic, weighing the iltimate capabilities of the SSP and the retained experiential base of nuclear weapons designers and engineers from the past.

That is clearly an area of risk, again, one that it is very important that the Senate assess in its deliberations. If the capability to test existed, I will point out, one has a better opportunity of training the new scientists that come on board. One has the opportunity to validate SSP capabilities as they come on board and so there is a tremendous additional advantage to our confidence if we have testing in addition to SSP.

Senator COCHRAN. When you were mentioning the National Ignition Facility, I think my information is that Department officials have said we will not know until at least 2003 if the National Ignition Facility will achieve ignition. Is that your understanding, too?

Mr. BARKER. Yes. That is correct. Like Senator Thompson said, you will not know until you do it. There will be a lot of experiments going on before one gets to that point and a lot of calculations, but the proof will be in the pudding.

Senator COCHRAN. As a practical matter, if we get to that point and ignition is not achieved, is that grounds for the Department of Energy to suggest to the President that as a matter of national security interest, we have to abandon the treaty or we have to proceed with a testing program? What will happen?

Mr. BARKER. Well, let me see. You mean my honest personal answer?

Senator COCHRAN. Based on your experience and your——

Mr. BARKER. We are talking about 10 years into the future.

Senator COCHRAN. Two-thousand-and-three, so that is 6 years.

Mr. BARKER. Seven years. Thank you, Senator.

Senator COCHRAN. Six years.

Mr. BARKER. There will be experiments other than ignition that can be done with that facility that will have some utility. I think the issue that bothers me most is the validation of the correlation between the data from NIF and nuclear tests. By 2003, it will be 11 years since the last nuclear weapons test. How will we achieve confidence that what we are simulating in a NIF is the same as what we would have seen in a nuclear test? If we did have nuclear testing available to us, we could design experiments that would allow side-by-side comparison and we will not have that if we cannot test.

Senator COCHRAN. Then back to my question, where the Department of Energy suggested to the President that he needs to, as a matter of national security interest, proceed to use testing to verify safety——

Mr. BARKER. Logic might say yes, Senator, but I cannot predict what a Department of Energy will say 7 years from now.

Senator COCHRAN. Or what the President would do in response to the recommendation or the observation.

Mr. BARKER. Correct. No. Even the langauge of the safeguard, which the laboratory directors have cited quite frequently. Clearly, it provides them with a significant comfort factor in association with feeling comfortable about a lack of testing. That language is, I think, "will consider". It does not say, "we will test". It says, "we will consider", and it requires the joint judgment of the Congress and the President and the directors, et cetera. It is a very complex process that, again, I would encourage the Senate to evaluate whether it believes that that is a process that would ever lead to a decision to do a test.

Senator COCHRAN. Thank you very much. Senator Levin.

Senator LEVIN. Thank you, Mr. Chairman.

Mr. Chairman, you positively responded to my suggestion late last week that we invite Bruce Tarter, who is the Director of Lawrence Livermore, to testify. Regrettably, the invitation which you authorized did not get to him until after he had left on Friday, so he did not even know about it until this morning, when it was too late to come. He did submit some testimony which he prepared today, and which I would like to submit for the record.[1]

Senator COCHRAN. Without objection, it will be made a part of the record.

Senator LEVIN. Also, I would ask that the record be kept open so that we could ask Dr. Tarter or other witnesses questions.[2]

Senator COCHRAN. I think that is an excellent idea. It will be done.

Senator LEVIN. Dr. Barker, first, let me ask you a question about a review document that you participated in back in, I believe, August 1997. This, I gather, was a review which was made by some persons who were previously involved in the nuclear weapons programs, it looks like about 8 or 10 people, is that correct?

Mr. BARKER. Yes.

Senator LEVIN. This was supposed to be a review of DOD's requirements for DOE's defense programs in 2010, and I notice that

[1] The prepared statement of Mr. Tartar appears in the Appendix on page 71.

[2] Questions and responses from Mr. Reis, Mr. Barker, Dr. Tarter, and Mr. Hecker appear in the Appendix on pages 69, 70, 71, and 72 respectively.

the requirement to test is not one of the requirements that that group identified, is that correct, or were you just taking the DOD requirements and deciding how to comply with them? In other words, were you folks suggesting what was necessary or were you given the fact that there would be no testing?

Mr. BARKER. We were asked by Assistant Secretary Reis to, using our understanding of defense requirements, formulate a defense requirement for the DOE to meet its requirements under a comprehensive test ban.

Senator LEVIN. In other words, you were not given the option of recommending that there be testing?

Mr. BARKER. Correct. You will find in here that we thought it was very important to be ready to do a test if one were necessary, but one of the ground rules was the assumption that there would not be routine testing.

Senator LEVIN. I understand. And that was a ground rule. You accept it as a ground rule, even though you do not agree with it?

Mr. BARKER. Yes.

Senator LEVIN. Now, do you advocate immediately resuming regular nuclear tests?

Mr. BARKER. I think that would be the most reliable thing for the stockpile, Senator, yes.

Senator LEVIN. So you recommend that we repeal that bill, the Exon-Mitchell-Hatfield bill and resume testing immediately?

Mr. BARKER. I believe that this country should be in a position to do a test as promptly as it determines one is necessary. The elimination of that legislation, I do not call for it by name in my statement but I do ask the Senate to consider eliminating such limitations so that a President, any President, could conduct a test as promptly as possible with as little hullabaloo as possible if he discovers a major stockpile problem.

Senator LEVIN. Well, that is a little different from my question, though, because my question was whether or not you recommend that we immediately resume regular nuclear weapons testing, because we used to do that? We used to take one——

Mr. BARKER. You and I, we were both in the business at the time, yes.

Senator LEVIN. It used to be done regularly. You, in your testimony, said that—was it one a year or whatever the number was, or one from——

Mr. BARKER. One stockpile confidence test?

Senator LEVIN. Yes. Do you recommend that we resume those confidence tests?

Mr. BARKER. I think we would have higher confidence if we had them.

Senator LEVIN. That is not really the question, because I do not think anybody necessarily disagrees with you. The question is whether we have adequate level of confidence without them, and that is where it seems to me the testimony is, that the folks who are supervising the stockpile and have the stewardship responsibility over the stockpile say that we have a very high level of confidence and we are satisfied that the stockpile is safe and reliable. We get that certificate. We just got another one.

My question to you is, do you recommend that we resume the confidence testing, and your answer is that it would give us a higher level of confidence, but I do not think that is the issue.

Mr. BARKER. I will say, yes, I would recommend the resumption of those tests.

Senator LEVIN. OK.

Mr. BARKER. I do not expect it to happen, but I would recommend it.

Senator LEVIN. No, I understand that. But nonetheless, you do recommend, then, the repeal of that law and that we resume regular confidence testing?

Mr. BARKER. I would wholeheartedly support what President Bush asked of the Congress in January 1993. I think that would allow testing for safety, reliability reasons, allow us to improve safety.

Senator LEVIN. Now, that was 2 years before the Stewardship Program was put together, is that not correct, that 1993 statement of President Bush?

Mr. BARKER. Yes. We are running into a nomenclature problem. If you look at Sig Hecker's letter to Senator Kyl, he points out that the day that legislation was signed, he returned to Los Alamos and said the Los Alamos designers and engineers had to begin immediately to think of a program that would substitute for testing. So the three nuclear weapons laboratories began in October 1992 to think about how could they possibly do their job of continuing to certify the reliability and safety of the stockpile without testing. It was not until the President made his statement that he would not use the 15 tests available to him under Exon-Hatfield-Mitchell that the Department of Energy, I think, began to work with the laboratories to put together a serious program.

So dating it back to 1994, which I guess is what you just did, is probably the era of a collective, coordinated effort, but the concept of stockpile stewardship was something that came up immediately, as soon as testing was ended.

Senator LEVIN. But the actual program was not put together until a couple of years later.

Mr. BARKER. Correct.

Senator LEVIN. And then the Commander of the Strategic Command at one point said he was not satisfied, is that not correct, but later on said that, in fact, he was satisfied that the Stewardship Program would give a high level of confidence in the reliability and safety of the stockpile? Is he not signed off on this program now, whereas he did not a couple of years before?

Mr. BARKER. Let me see. I probably cannot authoritatively answer that question.

Senator LEVIN. But things have changed. There is now, is there not, a Stewardship Program which is in place, and now people can judge that program——

Mr. BARKER. Exactly.

Senator LEVIN [continuing]. Including the Commander of Strategic Command, and that was not in place when President Bush wrote those words, is that correct?

Mr. BARKER. Correct.

Senator LEVIN. So now there is an assessment that needs to be made of a specific Stewardship Program that has a $4 billion-plus budget which had no budget or almost no budget at that time, is that correct?

Mr. BARKER. The Senate should make that assessment, I agree.

Senator LEVIN. All right. Now, I think you indicated that the 15 tests that were allowed under the Mitchell amendment have not been used, is that correct?

Mr. BARKER. Correct.

Senator LEVIN. The Navy indicated, for instance, when given an opportunity to get a safety improvement inside an SLBM warhead, that they declined to even get that safety improvement because they were confident of the safety of the existing warhead, is that correct?

Mr. BARKER. I would refer you to President Bush's transmittal that I provided to you a moment ago, because what it says is that a decision was made that under those circumstances, a crash program to develop a safer warhead would be unwise. But President Bush goes on to say, better would be a continuing testing program that would allow a backup warhead to be made that would have all those safety features so that when it came time to retire the existing one, one would have the best of all safety features in a submarine-based system.

Senator LEVIN. But the Navy was given an opportunity to conduct a test, is that not correct, and declined that opportunity, or is that not accurate?

Mr. BARKER. That is a level of detail that I cannot address—I had left the government in May 1992 and so I guess what we are talking about is something that occurred subsequent to that.

Senator LEVIN. I think we will ask the Navy for the record, then, whether or not they were, in fact, pursuant to the Mitchell amendment, given an opportunity to conduct a test and declined to do so, and if so, why, if we could ask that question, perhaps, of the Navy, Mr. Chairman.

Senator COCHRAN. What do you want to do, write a letter?

Senator LEVIN. Yes. Could we ask the Navy whether or not they had the——

Mr. BARKER. Senator Levin, you have raised a very important issue, and that is who is it who should decide what constitutes adequate safety in the nuclear weapons stockpile. Do you want the Navy and the Air Force to independently decide what is safe enough for them? Do you want the Secretary of Defense to do that? Do you want the President of the United States to do that? Does the Senate of the United States want to vote on what constitutes adequate safety of nuclear weapons that, after all, are stored in the United States of America?

Senator LEVIN. Is there anybody that does not participate in the annual certification that you think should?

Mr. BARKER. That should? I think there is quite a spectrum of people involved in that process.

Senator LEVIN. No. My question is, we get an annual certification relative to safety and reliability. I take it you do not disagree with that recent certification, or do you?

Mr. BARKER. Yes.

Senator LEVIN. Do you disagree with the recent certification of safety and reliability of our stockpile?

Mr. BARKER. Since I was not part of that process, Senator, I am not in a position to answer that question.

Senator LEVIN. OK.

Mr. BARKER. My suggestion is that the Senate of the United States wants to make itself aware of all of the factors that led to those conclusions. I have not seen the package that was sent to the Congress earlier this year, I guess, in conjunction with the first certification process. The second certification process has not yet reached the Congress, it is my understanding, and I guess it was Assistant Secretary Reis who described it. You and he had a dialogue about what that process was, which very accurately described it.

There are very, very detailed meetings, very detailed discussions. It would be a mistake to characterize the process as saying that there are no concerns developed during it and then a subjective judgment is made that things are OK. My question is, is that process being run the way it should? Does the Senate of the United States want a bigger voice in understanding what constitutes acceptable risk?

Senator LEVIN. My question of you is, is there anybody who is not involved in that process of annual certification that, in your judgment, should be in terms of position or title?

Mr. BARKER. No. My view is that there are enough people involved in that process. There are many experts who are not involved in the process, but any more to the current process would just complicate things beyond belief.

Senator LEVIN. All right. Do you agree generally with the goals of the Nonproliferation Treaty?

Mr. BARKER. Absolutely.

Senator LEVIN. Do you believe that an indefinite extension of that treaty would have been possible without the Test Ban Treaty?

Mr. BARKER. Yes.

Senator LEVIN. I disagree with you on that as a matter of history, but that is OK. That is a direct answer and I welcome it.

What do you think the world's response would be if we decided to resume testing, as you recommend? Do you think it would have any effect on other participation in the Test Ban Treaty?

Mr. BARKER. My background, as you know, is in physics, so I am probably not really very qualified to answer that question. But again, I invite the Senate to explore that in its consideration of the advice and consent to the Comprehensive Test Ban Treaty. I have a great deal of difficulty identifying which nation it is that will proliferate if we do not ratify the CTBT. I also have difficulty identifying what nation will give up its nuclear weapons if we do ratify the CTBT.

Senator LEVIN. I wonder if we could ask Vic Reis about the signoff of CINCSTRAT on the Stewardship Program and on the CTBT while he is available. Could we do that?

Senator COCHRAN. You mean call him back to the witness stand?

Senator LEVIN. If he is familiar with it. He is sitting here.

Senator COCHRAN. If you do not mind, Mr. Secretary, could you come back and respond to this question from Senator Levin?

Senator LEVIN. I wonder if you could tell us whether or not the CINC of the Strategic Command has signed off on our Stewardship Program.

Mr. REIS. Senator, perhaps I could back up just a bit and answer some of the questions you asked Dr. Barker, because I can help you a little bit on that because I do remember the history.

One, we have had a change in Commander in Chiefs of the Strategic Command. When we first began to put together the Stockpile Stewardship Program, Admiral Chiles, who was then CINCSTRAT, was asked by, I suspect it was your Committee or the Senate Armed Services Committee asked him what he thought of it. He said, "I do not know. I have not seen it yet. We just do not have a plan." I know who my customer is, and so we immediately started putting together a plan and worked not just with the Department of Energy but with the Defense Department, with Strategic Command directly, with also other parts of the government, as well, OMB, and put together first one document and then we just completed a second, a detailed plan.

As part of that, and working with the Commander in Chief of the Strategic Command, we have worked together very closely over the past 2 years to put this down. The Commander in Chief, General Habiger, first Admiral Chiles, now General Habiger participates, I would say, with extreme vigor in the annual certification process. As part of development of the Safeguard F, he is named specifically. He would have already advised the Nuclear Weapons Council, but the Chiefs, the Chairman felt it was important to get his voice in very, very specifically and that he would write his own letter to the Secretary of Defense as part of this process.

As part of that, General Habiger started a blue ribbon panel as part of his strategic advisory group. In fact, he has a weapons group that does that and added people. These were former weapons designers, former members of the military, really some of the genuinely best people in the world who then go through this with an extremely detailed, independently of what the laboratories are doing, just go through weapon by weapon, part by part, and, of course, they are the old, if you will pardon the expression, the old bulls who, if anything, tend to be more conservative. Those are the weapons that they, in some respects, they designed, so they are pushing it very hard.

They have now done this twice. Their report is available. When it comes, it will also be available for Congress to—when we send it up, that is available for Congress to look at.

Senator LEVIN. Does that mean that they join in the certification that——

Mr. REIS. Absolutely. They are part of that certification process and we do everything we can to ensure they get all the information. He produces that report, however, independently. He sends that report to the—in fact, he gives it first to Dr. Smith. He gives it first to the Chiefs. Then he will, as a matter of courtesy—obviously, it basically comes together when he writes it.

But I think you will find General Habiger has visited every single one of our laboratories on several occasions. He has visited every one of the plants and so he has done a more than yeoman job, I think, in ensuring himself that he fulfills his responsibility.

So when he signs off, as he has in the past 2 years, it is not done lightly. They press us very hard on a lot of things and, of course, we welcome that. That is really your sort of independent—you remember, this is, in a sense, like going to a doctor and that is sort of like going up to the Mayo Clinic. I mean, they really bring in the best of the people to look at this.

Senator LEVIN. Thank you. Thank you so much. Thank you, Dr. Barker, as well.

Mr. BARKER. I want to support everything that Dick just said, Senator. I misunderstood your question. I thought you had asked whether the CINCSTRAT bought into the SSP program and that was where I was not clear.

Senator LEVIN. Thank you.

Senator COCHRAN. Thank you.

Dr. Barker, let me ask you a couple of other questions. We have used up about all of the time that we have available to us. We have a vote coming up here at 5 o'clock, I think, and other obligations.

The aging process for plutonium is something that is not very well known in that it has been in existence for just over 50 years. Do the labs, in your view, have a good understanding of how the aging process affects plutonium, and is there an understanding of how aging would affect our nuclear weapons in general?

Mr. BARKER. The answer to that question, Senator, is no, and that is one of the major reasons for some of those activities that are detailed on the chart up there, the components of the Stockpile Stewardship Program. It is one more reason why it is very important that this program be successful, because we do need to understand the performance of plutonium in the long term in our weapons. As Secretary Schlesinger said, at the moment, we have no ability whatsoever to produce plutonium components in quantity.

Senator COCHRAN. My other question had to do with safety features and modernizing safety features. Is it possible without a testing regime to modernize safety features? I mean, if you come up with some new technology that you think would improve the safety of nuclear weapons, how can you introduce that in the system without testing?

Mr. BARKER. I think in the course of the hearing this afternoon, there has been a little bit of confusion regarding safety. There are two kinds of safety enhancements that we can add. Some have to do with the electrical safety, to make sure that the currents that would fire a weapon do not get to the detonators at the wrong time. Those kinds of features can be tested in the laboratory. There are other features that are designed to make sure that unauthorized persons cannot make a weapon work. Those kinds of things can, by and large, be tested in the laboratory.

There are also things called inherent safety features. What I was making reference to in my statement is the fact that we have developed an insensitive high explosive that the most violent of impacts, the biggest jolts of energy will not detonate. That is not in every weapon in the inventory. We have developed a feature that allows us to protect plutonium in a fire, such that if a weapon were to burn, the plutonium will not melt, get vaporized and go into the atmosphere. That feature is not in every weapon in the inventory.

If we had continued to modernize the stockpile, those kinds of features would have been included as the replacements for today's inventory came in. If these weapons are going to last forever, a very serious question to ask is whether we should not have included all those safety features before we stopped testing forever, and that is one of the issues that was raised in the report that President Bush sent to the Congress in January 1993.

Senator COCHRAN. Or the Senate, as one other option, could insist that as a condition to this ratification process, that we be permitted to improve the safety features, introducing modern technology and testing for that purpose only.

Mr. BARKER. Correct, and that would probably take several years of nuclear tests to do that, Senator.

Senator COCHRAN. Could we do that with relatively low-yield testing of the kind that was described by Secretary Schlesinger?

Mr. BARKER. I think you would find the laboratories would agree it could be done at acceptable risk at those kinds of yields. Obviously, much higher confidence would be achieved if one could test at yields closer to 10 kilotons.

Senator COCHRAN. My final question has to do with the proliferation issue. Our Subcommittee has responsibilities for monitoring compliance with the NPT, and from time to time, this Subcommittee has undertaken to have hearings on that subject and get briefings from administration officials on that issue and work closely with the International Atomic Energy Agency in helping to ensure that safeguards are maintained at nuclear plants and the like.

What is the effect of our failure to ratify the CTBT, the Comprehensive Test Ban Treaty, on proliferation? You had a question similar to that from Senator Levin and it struck me that there would be no negative consequences in terms of proliferation. Is that your testimony?

Mr. BARKER. That is my conclusion, Senator. I am sure you will find people who will disagree with that, but it certainly is my conclusion.

Senator COCHRAN. I appreciate very much your taking time to be with us today and the work you have done to prepare for the hearing. All of the witnesses, I think, have added to our understanding of the issues involved in the Comprehensive Test Ban Treaty and the proliferation issues that are involved, as well.

That concludes the hearing. I am going to be sure that we include the documents that were referred to both by you, Dr. Barker, and other witnesses in our hearing record so that we have a complete picture of what was said today.

With that, our hearing is adjourned.

[Whereupon, at 5 p.m., the Subcommittee was adjourned.]

# A P P E N D I X

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## QUESTIONS AND RESPONSES FROM MR. REIS SUBMITTED FOR THE RECORD

*Question 1:* During the hearing you were asked if confidence in the stockpile had declined since the cessation of testing in 1992. A reading of your response in the record would indicate you only addressed your confidence in being able to deal with future problems. Has confidence in the stockpile declined since 1992?

*Answer:* At the hearing, I stated that "I frankly have as much or perhaps even more confidence in the weapons now than I would [have had] in 1993." My confidence in the stockpile is based on DOE's Quality Assurance and Reliability Testing program which monitors both nuclear and nonnuclear test data and the reliability history of all stockpiled nuclear weapons. My confidence is further reinforced by my knowledge of the thoroughness and intensity demonstrated by the people at the DOE weapons labs during the resolution of stockpile issues that have arisen since the cessation of testing in 1992. I would also note that the nuclear weapon laboratory directors and the Commander-in-Chief United States Strategic Command have completed the second annual certification which reaffirms their confidence in the safety and reliability of the nuclear stockpile without the need for nuclear testing.

*Question 2:* Dr. Hecker, in a letter to Senator John Kyl, dated September 24, 1997 states the nuclear weapons laboratories ". . . could not guarantee the safety and reliability indefinitely of the nuclear stockpile without testing." To your knowledge have the laboratory directors ever "assured" the President that our nuclear deterrent under a CTBT can be maintained through a Science Based Stockpile Stewardship program without nuclear testing? Was the President provided with any caveats if such assurance were given?

*Answer:* The weapons laboratory directors or their representatives met with the President's National Security Council (NSC) staff prior to the President announcing his decision to proceed with a zero-yield CTBT in August 1995. The laboratory directors, through the NSC staffs, assured the President that the Stockpile Stewardship Program offered the best chance to maintain the nuclear stockpile under a CTBT assuming sustained support from both the Congress and the Administration. The President further emphasized the need for this sustained support in his 1993 CTBT announcement.

*Question 3.* During the hearing Senator Levin asked whether the Commander of the Strategic Command ". . . was satisfied that the Stewardship program would give a high-level of confidence in the reliability and safety." You joined Dr. Barker in responding to the question but described the history of the certification process and General Habiger's participation in it. Are you aware of General Habiger saying that he is satisfied that the stockpile stewardship Program will provide a high level of confidence in the reliability and safety of the stockpile for the foreseeable future without nuclear testing? Has he endorsed full funding of SSP at the $4.5 billion level for the next decade?

*Answer:* On an annual basis, General Habiger provides an independent certification input to the Secretary of Defense on his confidence in the stockpile without the need for nuclear testing. A part of the certification process is to note potential issues with individual warheads that may require corrective actions in the foreseeable future. Because General Habiger's input to the certification report addresses emerging and potential issues, he is stating his confidence in the stockpile, not only for the reporting year, but also for the foreseeable future.

With regard to the question of the $4.5B budget, General Habiger gave testimony to Senator Robert Smith's Strategic Forces Subcommittee (March 1997) which clearly indicates support for a budget level that is required to do the job to maintain the nuclear deterrent under a CTBT. General Habiger stated that STRATCOM's confidence in the success of the stockpile stewardship program will depend, among other factors, on how well the program is funded. No specific dollar amount was mentioned at the March 1997 hearing and I am not aware of other comments by General Habiger relative to a $4.5 billion budget for the next decade.

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QUESTIONS AND RESPONSES OF MR. BARKER SUBMITTED FOR THE RECORD

*Question:* Dr. Barker, in your discussion of the Report sent to the Congress by President Bush in January of 1993, you have made no mention of the President's concerns about the impact of the Hatfield, Exon, Mitchell provisions (Section 507, of Public Law 102–377) on the effort to develop predictive capability. Is this still an important issue?

*Response:* My failure to address President Bush's concerns in the area of the development of predictive capability was a significant oversight on my part. There is a tremendous irony in the Hatfield, Exon, Mitchell amendment's elimination of testing in support of the development of predictive capability. President Bush stated that the limited number of tests permitted by Section 507 ". . . would certainly not bring it (our predictive capability) to a point that we could maintain the safety and reliability of the U.S. nuclear deterrent without underground nuclear tests." President Clinton chose to not perform even the few tests Section 507 allowed.

The FY 88 Defense Authorization Bill required the Department of Energy to develop a program that would reduce the dependence of stockpile safety and reliability on nuclear testing. The program that was developed by DOE and the laboratories, sometimes known as the Test Ban Readiness Program, called for the development of increased predictive capability, both computational and experimental capabilities, whose validity would be established by direct comparison with the results of an ongoing nuclear test program. In other words, this program's objective was to scientifically verify the credibility of predictive capabilities *before* any decision to stop nuclear testing. The nuclear testing moratorium initiated by Section 507 and perpetuated by President Clinton, if codified by ratification of the CTBT will prevent ever knowing if the predictive capabilities, now known as SSP capabilities, will provide the same answers as would a nuclear test. If the CTBT is not ratified, we will retain the ability of some future President to conduct nuclear tests for the purpose of determining if SSP is giving the right answers.

*Question 2:* Senator Levin asked Dr. Reis, "Are we in a better position than other nations to maintain the reliability of our inventory based on this stewardship program?" Do you see SSP as a superior, higher confidence method of preserving confidence in aging nuclear weapons than the continuous rebuilding process that is attributed to the Russians?

*Response:* It is not at all clear that U.S. dependence on SSP, without nuclear testing, will give rise to higher confidence in stockpile safety and reliability than the Russians would achieve by periodic remanufacture of their weapons. The Russians may be better off.

If our understanding is correct, the Russians produced their weapons with a limited time warrantee. Therefore they knew that they would need to periodically remanufacture their weapons, when the warrantee ran out, and could have, should have, put in place procedures that would assure that the remanufactured weapons were identical to the initial production. They would have had to preserve initial production machinery, and to have specified materials and manufacturing processes in sufficient detail to guarantee that remanufactured weapons would perform identically to weapons from the original production run. Over the last 40 years they have had the opportunity, through nuclear testing, to establish that their remanufactured weapons do replicate the performance of earlier production runs. Thus they have had the opportunity to *validate* the credibility of their process.

In contrast, the United States, if nuclear testing does not resume, will be hard pressed to validate SSP. And SSP will be what the U.S. will have to depend upon for confidence that its remanufactured weapons will perform in the same way as did the initial weapons produced. The U.S. has not anticipated that it would rebuild weapons in production quantities after initial weapon production. The pace of weapon system modernization was such that we, in general, retired weapons well before their projected end-of-life and new weapon systems demanded optimized new nuclear weapons. Because we did not anticipate remanufacture in quantity, there are real concerns among the experts that our "specs" for the weapons in the stockpile may not accurately specify all the parameters that must be controlled to replicate the performance of the original weapon. In the 1987 Report to Congress on Stockpile Reliability, Weapon Remanufacture, and the Role of Nuclear Testing, that I referenced in my testimony, the authors state, "Even an 'identical' rebuild should be checked in a nuclear test if we are to have confidence that all the inevitable, small and subtle differences from one production run to she other have not affected the nuclear performance."

## PREPARED STATEMENT OF MR. BRUCE TARTER

Mr. Chairman, Senator Levin, and Members of the Committee, I am the Director of Lawrence Livermore National Laboratory (LLNL), one of the three Department of Energy (DOE) laboratories responsible for the safety and reliability of the nuclear weapons that comprise our deterrent forces. We are an integral part of efforts being implemented by DOE Defense Programs to maintain confidence in the safety and reliability of the U.S. nuclear weapons stockpile without nuclear testing or new weapon development.

Livermore's commitment to maintaining a safe and reliable nuclear weapons stockpile is an enormous responsibility—an undertaking described by President Clinton as being "a supreme national interest of the United States." As steps are taken to reduce global nuclear arsenals and prevent proliferation, the nation must retain sufficient nuclear forces to deter any adversary. My responsibility is to assure the President that nuclear weapons in the enduring U.S. arsenal remain safe and reliable. To date I have been able to provide such assurances with confidence even though we last conducted a nuclear test in 1992. The challenge will become greater as the weapons continue to age beyond their designed lifetimes and as experienced nuclear weapons designers retire.

Our Laboratory is strongly committed to making the Department of Energy's Stockpile Stewardship and Management Program (SSMP) work. This program is designed to maintain the safety and reliability of the U.S. nuclear weapons arsenal that underpins national security within the constraints of a CTBT. I enthusiastically support the SSMP and am quite optimistic that we will achieve the very challenging program goal of preserving confidence in the stockpile.

*Changing National Needs and Technical Programs*

The SSMP builds on the fact that mission of the nuclear weapons programs at Livermore has changed in a fundamental way. We have moved from the weapon development paradigm of the Cold War (design, test and build) to a weapon-assurance paradigm (stockpile surveillance, assessment, and refurbishment). Now there are no requirements for new nuclear weapon designs and our responsibility is maintenance of the reliability and safety of a stockpile consisting of nuclear weapons that are well-tested—they have a good pedigree. However, the weapons are aging beyond their intended lifetimes and there will inevitably be changes in the weapons, some of which will require a "fix" that in the past would have been validated by a nuclear test.

To meet the challenge, we are able to build on the substantial increase in our understanding of the fundamentals of weapon science that we achieved in the decade leading up to the cessation of nuclear testing in 1992. In addition, we expect that we can continue to increase our knowledge base of nuclear weapons physics through nonnuclear testing and advanced computer simulations, which will significantly compensate for the cessation in testing. The SSMP is making use of—and in some cases driving—tremendous advances in technology. The SSMP will implement advanced surveillance technologies to anticipate the detailed effects of aging together with advanced, flexible manufacturing technologies to greatly reduce the cost of required refurbishment without introducing new defects. We are rapidly advancing the state of the art in supercomputing and we are pursuing the design and construction of major experimental facilities that will enable weapon scientists and engineers to resolve important stockpile issues and validate their physics simulation models. These new capabilities will be developed and tested by experienced weapons scientists and engineers, who will then train the next generation of stockpile stewards to use the new tools correctly.

The ultimate measure of SSMP success will be our continuing ability to assure the President on a yearly basis the safety and reliability of the stockpile without nuclear testing. The program includes formal processes, conducted with the Department of Defense (DOD), for validating assessments of stockpile performance and modification actions. The processes, which we will seek to improve as we gain experience in them, fundamentally depend on the use of expertise and capabilities at each of the laboratories and independent evaluations—widely referred to as "peer review."

Should the SSMP fail to achieve its objectives, vitally important safeguards specified by the President on August 11, 1995, allow the U.S. to resume nuclear testing if the deterrent is judged to be at risk.

*A Highly Qualified and Experienced Technical Staff*

Confidence in the stockpile since the beginning of the nuclear age has relied on much more than the limited number of development and stockpile confidence tests we conducted at the nation's nuclear test sites. During weapon development we did not test designs at all extremes of conditions anticipated during stockpile lifetime and potential use. Nevertheless, national leadership has had full confidence in the system that maintains U.S. nuclear weapons and in the judgments of the technical staff. In the future, the nation will be even more reliant on the these judgments, their supporting scientific capabilities and tools, and the peer review processes established to ensure rigorous critique of the work performed. Accordingly, the SSMP will develop the skills and capabilities of the next generation of stockpile stewards. This requires moving ahead with the SSMP as rapidly and completely as possible so that our current cadre of experienced scientists will be available to both train and evaluate the skills of their successors. They will provide an extremely important assessment of both the people and their capabilities in implementing the SSMP, and thereby will contribute in a major way to a determination that the SSMP is indeed successful.

*Sustained Program Support*

My greatest concern regarding the success of the SSMP is the possibility of a lack of timely and sustained support. Maintenance of the safety and reliability of the nation's nuclear weapons stockpile is an extremely important matter and difficult challenge. Program support must be timely because we must get on with the task before existing experienced people retire or leave to pursue other endeavors. In addition, the support must be sustained at an adequately funded level because every element of the SSMP is needed for the success of the program as a whole. The technical risks in SSMP will be significantly greater if we are forced to stretch out activities in time or reduce the scope of planned research activities to meet more constrained budgets.

*Summary Remarks*

The DOE's Stockpile Stewardship and Management program has been formulated and is being pursued to assure the safety and reliability of the U.S. nuclear weapons stockpile in the absence of nuclear testing. We must retain confidence in the nuclear weapons themselves, in the system that maintains them, and in the judgments of the technical staff, who will rely on experimental and computation tools to obtain needed data. So far, the quality of the stockpile and the implementation of the SSMP have enabled me to certify to the President the safety and reliability of our weapons without the need for a nuclear test.

Livermore is strongly committed to making SSMP work. Provided that the SSMP continues to receive strong bipartisan support and we proceed expeditiously, I am quite optimistic that the program will enable us for the foreseeable future to maintain confidence in the stockpile.

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## LETTER TO SENATOR KYL WITH QUESTIONS AND RESPONSES FROM MR. TARTER

LAWRENCE LIVERMORE NATIONAL LABORATORY
*September 29, 1997*

THE HONORABLE JON KYL
*United States Senate*
*702 Senate Hart Building*
*Washington, DC 20510*

DEAR SENATOR KYL: Thank you for the request for technical input regarding the Comprehensive Test Ban Treaty. I hope the information provided in my attached answers to your 21 questions is responsive to your needs.

In addition I want to express how strongly both my Laboratory and I are committed to assuring the safety and reliability of the nation's nuclear weapons. We have had this responsibility for over 45 years, and believe our ability to do the job has strongly depended on bipartisan support. Whatever course the debate in the Senate on the CTBT takes, I hope this common commitment can be preserved in those deliberations.

I would be pleased to provide you with any additional information. I appreciate the opportunity to respond to your questions, and thanks for your continued support.

Sincerely,

C. BRUCE TARTER
*Director*

RESPONSE TO QUESTIONS REGARDING COMPREHENSIVE TEST BAN TREATY (CTBT) FOR SENATOR JON KYL FROM C. BRUCE TARTER, DIRECTOR, UNIVERSITY OF CALIFORNIA, LAWRENCE LIVERMORE NATIONAL LABORATORY

*Question 1.* Will confidence in the safety and reliability of U.S. nuclear weapons decline without nuclear testing?

Although we have not tested since 1992, I continue to have confidence in the safety and reliability of the nuclear weapons in the stockpile. Specifically, I have so stated for the past two years through the Annual Certification Process established by the President.

My ability to provide that certification has resulted from several factors: (1) The weapons in the stockpile are well-tested—they have a good pedigree; (2) we have a cadre of experienced personnel who can evaluate stockpile issues and recommend responsive actions needed to retain that confidence; and (3) we have developed and are pursuing the Stockpile Stewardship and Management Program (SSMP), which puts in place capabilities and methodologies to identify, assess, and respond to problems that occur in the stockpile. This program relies heavily on the independent judgments and unique capabilities of DOE's two nuclear weapon design laboratories to provide peer review of one another.

However, as the stockpile ages there will inevitably be changes in the weapons, some of which will require a "fix" that in the past would have been validated by a nuclear test. I believe the SSMP, if carried out in accord with current plans, will provide me with the confidence necessary to certify the safety and reliability of weapons with those changes. Specifically, the computer simulation, experimental capabilities, and expert judgment resulting from the SSMP will allow me to provide the formal statement of stockpile confidence made through the Annual Certification Process.

Without a successful SSMP or extensive nuclear testing, however, I believe the confidence in the nuclear stockpile would decline to an unacceptable level. Because it is unlikely that we will ever return to the high levels of nuclear testing of the past, it is absolutely essential that we move forward expeditiously with the SSMP.

Should I conclude at any time in the future that I can not certify the safety and reliability of a weapon type, I will make this clear in accordance with the President's Safeguard F.[1] Should I believe that a nuclear test is needed to resolve the uncertainty, I would so state.

*Question 2.* Do you expect the Stockpile Stewardship and Management Program (SSMP) to give you the same confidence in the stockpile as was achieved by nuclear testing? If not, by how much will confidence be reduced, assuming the SSMP is successful?

As discussed in Question #1 above, the measure of confidence is the ability to provide the annual certification statement to the President. Testing would make that an easier task, but I believe the SSMP can do the job.

Although the SSMP has already provided capabilities I needed to provide assurances to the President that the stockpile continues to be safe and reliable for the last two years, the major challenge lies ahead. More powerful computers, advanced experimental facilities, modern manufacturing facilities and enhanced surveillance capabilities are required to deal with inevitable aging problems in the stockpile and to demonstrate unambiguously our level of expertise to make judgments about the stockpile.

I should also point out that we have been able to retain great confidence in high yield weapons in the stockpile even though we could not test them above 150Kt

[1] Safeguard F, set forth by the President on 11 August 1995 as a condition for his acceptance of the CTBT, states: ". . . if the President of the United States is informed by the Secretary of Defense and the Secretary of Energy—advised by the Nuclear Weapons Council, the Directors of DOE's nuclear weapons laboratories and the Commander of the U.S. Strategic Command—that a high level of confidence in the safety or reliability of a nuclear weapon type which the Secretaries consider to be critical to our nuclear deterrent could no longer be certified, the President, in consultation with Congress, would be prepared to withdraw from the CTBT under the standard 'supreme national interest clause' in order to conduct whatever testing might be required."

since the Threshold Test Ban Treaty (TTBT) in 1974. Our confidence in those yields is based on our extensive testing at high yields prior to the TTBT, a thorough understanding of the science of "high yield," and the judgment of experts who designed and tested such weapons prior to the TTBT. The SSMP will exploit analogous factors to do its job: past test data, experienced personnel, and a program of experiments and computation designed to improve the scientific understanding so that confidence can be maintained well into the future.

*Question 3.* What proportion of the research and testing envisioned for the first 10 years of operation of the National Ignition Facility (NIF) is directly related to nuclear weapons? What proportion is indirectly related to nuclear weapons?

Almost all research to be conducted during the first ten years on NIF is either directly or indirectly related to nuclear weapons. A preliminary experimental plan for NIF has been developed that describes the number and type of experiments that will occur in the first several years. Approximately 85% of NIF experiments will be related to weapon physics. Half of that 85% will directly address identified weapon issues. These experiments will provide data on specific weapon issues that will have been identified in the weapon surveillance program or they will test weapon physics models contained in new computer codes being developed in the Accelerated Strategic Computer Initiative (ASCI).

The other half of the 85% will be experiments directed at achieving fusion ignition, both in the direct drive mode and indirect drive mode. They will provide an integral test of our weapon scientists' abilities to use computer models to predict the detailed outcome of complex experiments with physical conditions (i.e., temperatures and densities) similar to those in weapons. These technically challenging experiments will not only test and validate simulation codes, but they will strongly contribute to development of weapon scientists' skills and expert judgment. The success of these fusion ignition efforts should broadly affect the confidence others place in the capabilities of scientists and engineers engaged in SSMP and their technical judgments, which form the basis of the Annual Certification Review. Once fusion ignition is achieved, experiments with burning capsules will probe some of the underlying thermonuclear physics in weapons.

The remaining 15% of NIF experiments will be devoted to several user communities, including nuclear weapon effects testing, basic sciences, and fusion energy development, each of which will explore physics questions important to weapons science. The exact allocation among these users has not yet been determined. The effects experiments will, of course, be directly related to nuclear weapons. They will examine either nuclear weapon vulnerability issues or the effects of nuclear weapon output on other military systems such as detectors and electronic systems.

*Question 4.* A purpose of SSMP is to maintain a cadre of scientists and technicians who will be capable of designing and working on nuclear weapons. Will scientists and technicians working on SSMP have weapons classification clearances and will they have a clear commitment to working on nuclear weapons should the need arise?

Yes. A central objective of the SSMP is the development and maintenance of a cadre of personnel who can effectively utilize the new SSMP experimental and modeling capabilities to address warhead issues as they arise. Scientists and technicians working on SSMP at my Laboratory have the necessary weapon classification clearances, and are committed to the nuclear weapons program. The SSMP is the weapons program, not separate from the job of keeping the stockpile safe and reliable. Since most of these personnel will be continually working on weapons topics, we can expect their continued commitment to address future issues that might arise.

*Question 5.* Much of the capability of SSMP is a decade or more away from being fully functional. Furthermore, many of the technologies involved are unproven. From a technical standpoint, would it be advisable to conduct nuclear tests to calibrate the existing and planned technologies? If so, what is the lowest yield at which meaningful tests can be conducted? What is the minimum number of tests that would be required in the interim before SSMP becomes fully functional?

From a purely technical standpoint, some level of nuclear testing would be a useful addition to the SSMP to address the effects of aging-related changes on weapon safety and reliability and to validate the capabilities of the next generation of weapon scientists and their experimental and computational facilities, particularly in addressing hydrodynamic phenomena related to boosted primaries. However, occasional nuclear tests can not supplant the need for a comprehensive SSMP.

Today, we are depending heavily on the experience base of veteran nuclear weapon designers and their familiarity with a wealth of past nuclear test data. These designers are working with—and, in the process, training—their younger colleagues to develop and validate the much more sophisticated tools that will be needed for stewardship in the longer run. The most important issue is to make the transition from reliance on the nuclear test experience to validated experimental and computational tools in a carefully thought-out manner, as quickly and reasonably as possible. That goal is built into the design of the SSMP.

If additional tests were to be allowed, then 500 tons would be the minimum nuclear test yield that would be of value for validating experimental and computational tools used to assess weapon performance. For purposes of helping to validate models for assessing weapon safety, nuclear test yields of a few pounds would be of value. The rationale behind these levels is provided in a classified addendum to these answers. I must reemphasize that the incremental benefits of such tests would not be realizable in the absence of an effective SSMP to interpret and extrapolate the results.

*Question 6.* What are the specific measures by which you will know whether SSMP has succeeded or failed?

A critical yearly measure of the success of the SSMP will be our ability to provide formal statements of stockpile confidence through the Annual Certification process. Should we not be able to certify the safety or reliability of a weapon system in the enduring stockpile, the SSMP will not have been totally successful. Three supportive interrelated, detailed factors should be considered in assessing program success.

First, we can examine how the SSMP is progressing compared to the specific milestones set forth in the DOE Stockpile Stewardship and Management Plan. This comprehensive plan includes the detail needed to judge progress in providing the necessary experimental, computational and manufacturing capability and in demonstrating scientific and technical performance (e.g., demonstration of fusion ignition on NIF or experimental confirmation of 3-dimensional predictions of hydrodynamic implosion).

Second, we can examine specifically how well the tools being developed as part of the SSMP are working. In particular, the success of the SSMP, and the resulting confidence in the certification process, can be gauged by our future ability to "predict" past nuclear test data (failures as well as successes), to computationally match past and future non-nuclear (e.g., hydrodynamic) test data, to perform the experiments that provide the fundamental information needed for successful predictions, and to successfully achieve major relevant integrated demonstrations of our capability (one example, cited above, is fusion ignition on the NIF). Our computational simulations must consistently match a broad range of past nuclear test data and experimental data from the new facilities with a significantly reduced need for empirical factors and phenomenological models.

Third, there are ways we can assess the judgment of the scientists and engineers engaged in SSMP. It is absolutely crucial that we maintain expert judgment about nuclear weapon issues by developing the skills and capabilities of the next generation of stockpile stewards. We have to move ahead with the SSMP as rapidly and completely as possible so that our current cadre of experienced scientists will be available to both train and evaluate the skills of their successors. They will provide an extremely important assessment of both the people and their capabilities in implementing the SSMP, and thereby will contribute in a major way to a determination that the SSMP is indeed successful. Our ability to retain and attract new top-notch scientists and engineers to the program will be another key index of the program's success.

The judgment of the stockpile stewards will be exercised through the Annual Certification and Dual Revalidation processes, which entail formal peer review activities involving the two weapon design laboratories (LANL and LLNL). Each of the laboratories, with its own unique capabilities, will be put to the test before the other laboratory and experts from Sandia, DOE Defense Programs, and our customer, the DOD. Peer-review activities must include independent evaluations, dual revalidation and "red-teaming", and iterative critiques of each other's technical work. In the past, the two-laboratory system has proved crucial in addressing stockpile problems. In a future without nuclear testing, such peer review will play an increasing important—and very visible—role in establishing confidence in the stockpile.

*Question 7.* Since the last US nuclear test, have there been age-related or other changes in the stockpile that previously would have been addressed by conducting at least one nuclear test? If so, how certain are you of the fixes? If your level of confidence in the fixes is not extremely high, how has this affected your view of stockpile reliability?

The LLNL-designed warheads in the present stockpile are the W62 warhead for Minuteman III, the B83 bomb, the W84 warhead (previously for the Ground-Launched Cruise Missile), and the W87 Peacekeeper warhead (to be used on Minuteman III). The only change in these weapons that is now under way is the W87 Life Extension Program (LEP), which is an effort to prepare that warhead for an extended life in the stockpile with structural enhancements. We have previously stated that if we were still testing, we would conduct a nuclear test to demonstrate the performance of the W87 with the LEP change. I anticipate that at the end of the W87 LEP development we will be able to confidently certify the design after structural enhancement, based on past nuclear test results, new non-nuclear tests, and computer modeling assessments.

Completion of the W87 LEP and certification of the warhead's performance without nuclear testing will be a significant achievement, but not the first since we started the SSMP. We have already used our nonnuclear experimental facilities and the new computing capabilities developed in our ASCI Program to address a number of other stockpile issues. Resolution of some of these issues could in the past have involved some nuclear testing. Issues have arisen where the independent efforts of each design laboratory were needed to develop an effective solution that both laboratories could find acceptable. Because more complicated warhead performance issues may lie ahead and the base of nuclear test experience is steadily diminishing, we must continue to aggressively improve our SSMP capabilities. Some of these issues are discussed in a classified addendum to these answers.

*Question 8.* How safe is the stockpile today? Have there been any changes since the 1990 Drell safety study that would have changed the conclusions of that study today?

Today's stockpile is safe. If it were not, I would raise my specific concerns as part of the annual certification process. LLNL designed warheads in the present stockpile—the W62, B83, W84, and W87—are all safe in their stockpile deployments. Furthermore, the overall safety of the stockpile continues to improve as older warheads with less modern inherent safety features are being preferentially retired as a result of the end of the Cold War.

We have achieved an outstanding safety record with the U.S. nuclear stockpile through a combination of inherent safety features designed into the warheads and procedural requirements for their handling and deployment.

Newer weapon designs generally have included more and improved inherent safety features. The B83, W84, and W87 are unique in that they have the full set of advanced safety features of insensitive high explosive (IHE), fire resistant pits, and enhanced nuclear detonation safety (ENDS). The W84 and W87 have an extra positive safety margin in multiple combined abnormal environments because of their detonator designs. Although it does not include these most modern features, the W62 meets the safety criteria to which it was designed and is considered safe in its current deployment. Many of the recommendations of the Drell Panel were adopted and the changes that have been made since 1990 in response to the panel would have altered some of the panel's conclusions. These changes include:

(1) Formation of "Red Teams" to evaluate specific warhead safety issues (an activity now formally instituted in the Dual Revalidation process).
(2) Establishment of a Joint Advisory Committee (JAC) that actively reports to the Secretary of Defense on warhead safety issues.
(3) Institution of a joint training program for individuals who have responsibilities for weapon safety and security.
(4) Important safety improvements restricting transportation of weapons lacking IHE to ground transport unless otherwise approved at high level.
(5) A national policy review of the acceptability of retaining missile systems without IHE and fire resistant pits, which concluded that existing systems are acceptable.
(6) The conduct of detailed Weapon System Safety Analyses using risk assessment methods for all systems in the stockpile.
(7) In response to the Panel's concerns about the W88 Trident II warhead, changes to the loading procedure for the warhead on the missile, which later were changed back to the original process after a thorough experimental and computational review.

Finally, the retirement of older systems that were designed before the advent of modern safety features would probably change the tone and recommendations of parts of the Drell report if it were written today.

*Question 9.* What known safety vulnerabilities are we accepting? Should we be accepting them?

As I have responded in answer to the previous question, I judge the current stockpile to be safe. I also noted that safety is achieved through a combination of "inherent" design safety features and procedures for warhead handling and deployment. Over the years, modernization has shifted this reliance balance in the direction of improved inherent features, with the result that safety has become more resistant to human error during operations.

Some systems in the enduring stockpile have the full set of advanced safety features—insensitive high explosive (IHE), fire safety, and enhanced nuclear detonation safety (ENDS)—but others do not. Nuclear testing would have been needed to incorporate these features into the warheads that lack them. A national policy review conducted in response to the Drell Panel concluded that missile systems without IHE and fire resistant pits are acceptably safe considering how they are deployed and handled.

*Question 10.* Are there any tests you would advocate doing today, if allowed, to address safety or reliability concerns?

We see no immediate safety concerns that would warrant nuclear testing. Several activities are underway in the SSMP that could potentially affect weapon reliability—the W87 life extension program, the development of the B61-11, and the manufacture of new pits at the LANL TA-55 facility. In the past a number of these changes would have been evaluated with full or partial yield nuclear tests. As I stated in my response to Question #7, I am confident that the weapon laboratories will be able, through the evolving SSMP capabilities, to certify these changes without resorting to nuclear tests. This will be an important achievement.

*Question 11.* If U.S. leadership requires a new nuclear design, would you be willing to certify and deploy it without testing?

My answer depends on the design, and how much the design or its required operational environment departs from the existing nuclear test base. I believe it unlikely that an entirely new warhead, developed without the benefit of nuclear testing, would be certifiable by today's standards. However, some modifications of designs that had been previously tested successfully may be possible. My ability to certify such modifications would strongly depend on the conservatism of the design, the ability of weapon scientists to make use of existing data and information we will be able to obtain from future SSMP facilities, and the fidelity of computational capabilities to be developed in the ASCI program in predicting past and future experimental data.

*Question 12.* What yield of testing would be the lowest possible to accomplish new designs as well as safety and reliability.

If SSMP leads to a solid, fundamental understanding of nuclear weapons physics, we should not need any nuclear testing to maintain the safety and reliability of existing weapons. If we were to resume testing the lowest useful test for safety issues would be a few pounds, and for a reliability test around 500 tons.

As for a new design, the test yield required depends on many factors. If an existing design were repackaged or slightly modified, that would not really be a "new" design and the need for nuclear testing would be unlikely if SSMP goals are achieved. If the design were further from, but still similar in concept to, existing designs, I might be able to certify the design with only low yield (approximately 500 tons) testing. If the design were a major departure from existing designs we would need a number of tests at significant yields to design and certify the system.

*Question 13.* How difficult is it, technically, to maintain the capability to test without testing at some level?

It will be difficult to maintain the capability to quickly return to conducting full-scale nuclear tests. However, we plan to use the NTS to provide essential non-nuclear experimental capability to the SSMP. This use of NTS resources returns essential data for the stewardship mission, keeps laboratory and contractor technical teams together, and provides opportunity for conducting test-like operations on occasion. It also limits the decline in the capability to quickly execute nuclear tests. The current state of readiness to resume testing at NTS is two to three years.

The DOD Nuclear Weapons Council's Joint Advisory Committee on Nuclear Weapons Surety (JAC), agrees with this assessment: "maintaining test readiness as a mission is likely to succeed only if the activities associated with that mission produce a useful contribution to stockpile stewardship. Furthermore, a pure 'readiness' mission would not long attract the quality of people needed to resume testing. In a few years, test capability would have to be rebuilt almost from a standing start. Hence, to be viable over time, test readiness must be a by-product of ongoing activities including stockpile stewardship work at the NTS."

*Question 14.* If CTBT enters into force for the US, the budgetary and political pressures to close the NTS will increase significantly. How important is the retention and maintenance of the NTS?

The NTS is a critical element of and contributor to the SSMP. It provides an essential extension of the experimental capabilities of the laboratories. Subcritical experiments are one example of the essential work conducted at NTS. These dynamic and shock physics experiments using plutonium are key elements of SSMP activities to ensure continuing safety and confidence in the stockpile. Such experiments are most economically conducted underground at NTS, and some experiments using plutonium can be performed only at NTS. The Big Explosives Experimental Facility (BEEF) at NTS allows us to conduct experiments with amounts of explosives that exceed the environmental limits at the laboratories. The NTS is also being considered as a possible future site for facilities such as an Advanced Hydrodynamic Facility (AHF) and the X-1 pulsed power facility.

Furthermore, if the nation were to resume nuclear testing, NTS is the only suitable U.S. location to do so rapidly, safely, and economically. Owing to its remoteness and small local and regional population, NTS has been the major U.S. location for nuclear testing since 1951. The geology of the site is uniquely suited for cost-effective containment of radioactive debris.

*Question 15.* Why did your laboratory change its long-held view that nuclear testing is essential?

Our view on the need for nuclear testing has not changed in a fundamental way. As I have answered to Question #11, I believe it unlikely that an entirely new warhead, developed without the benefit of nuclear testing, would be certifiable by today's standards.

What has changed in a fundamental way is our mission. We have moved from the weapon-development paradigm of the Cold War (design, test, and build) to a weapon-assurance paradigm (stockpile surveillance, assessment, and remanufacture). To accomplish our present mission, we are building on tremendous advances in technology that enable ASCI and experimental facilities such as NIF. We are also building on the substantial increase in our understanding of the fundamentals of weapon science that we achieved in the decade leading up to the cessation of nuclear testing in 1992, together with the expectation that we can continue to increase our knowledge base through nonnuclear testing. An appropriately scoped and funded SSMP will enable further developments in experimental and computational capabilities that we believe will enable us to continue to certify the safety and reliability of the stockpile without nuclear testing.

While I am optimistic regarding the ultimate success of the SSMP, there are technical risks. Presidential Safeguard F provides for the performance of a nuclear test, should the SSMP fall short of meeting a specific challenge.

*Question 16.* What is your understanding of the limitations imposed by "zero"? Are these limitations acceptable in your view?

The Clinton Administration has adopted the policy that any experiments that will be performed under a CTBT will release "zero" nuclear yield. Our interpretation of zero yield means that experiments involving the use of fissile material must remain subcritical, i.e., a nuclear chain reaction is not sustained. (The need for this interpretation results from the fact that plutonium has an isotope that undergoes spontaneous fission and thus releases energy continuously.) We further understand that zero energy release does not preclude our performing inertial confinement fusion (pure fusion) experiments driven by lasers, or other analogous experiments.

The limitations posed by zero energy release are the same as those posed by the CTBT. The issue is whether certain kinds of activities would not be prohibited by a zero yield CTBT. The Administration will be submitting to the Senate as part of the CTBT ratification package a description of such activities. We have reviewed the activities and find them compatible with the SSMP strategy.

*Question 17.* What are your major concerns about your ability to fulfill your responsibilities under a zero CTBT?

My greatest concern is that the success of the SSMP would be hampered by a lack of timely and sustained support. Program support must be timely because we must get on with the task before existing experienced people retire or leave to pursue other endeavors. In addition, the support must be sustained at an adequately funded level because every element of the SSMP is needed for the success of the program as a whole. The technical risks in SSMP will be significantly greater if we are forced to stretch out activities in time or reduce the scope of planned research activities to meet more constrained budgets.

I am also concerned that the nation could be unprepared in the event that SSMP does not prove adequate to the task. Unless we maintain backup warheads [2] for each of the weapons in the enduring stockpile, there must be a willingness and capability to implement Safeguard F if we are unable to certify a particular stockpiled warhead type.

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[2] By backup warheads, I mean that there should be two warheads for each delivery system in the stockpile. For example, the W87 and W78 warheads for the Minuteman III missile are backups for each other should either one need to be removed from the stockpile. Likewise, the B83 and B61 Mod7/11 bombs serve as backups for each other, and the W76 and W88 serve as warheads for the Trident D-5 missile.

*Question 18.* What importance do you attach to being able to exercise the "supreme national interest" test?

I regard of utmost importance the ability to exercise the "supreme national interest" clause of the CTBT to address concerns that I have outlined here in my answers. This option mitigates the risks in pursuing a no-nuclear-testing strategy. We must be prepared for the possibility that a significant problem could arise in the stockpile that we will be unable to resolve. The fact that the President's Safeguard F specifically cites this provision reinforces its importance.

*Question 19.* What is the monitoring capability of the international system? Of U.S. national technical means?

If the proposed seismic, hydroacoustic, low-frequency sound, and radionuclide network of the International Monitoring System (IMS) are installed and operated as planned, the system is expected to detect, locate and identify with high confidence[3] non-evasive[4] explosions with yields of about one-kiloton or above conducted underground, underwater, or in the atmosphere. Detection, location, and identification would still be possible at yields less than one kiloton, but with reduced confidence. At lower yields, the number of non-nuclear events of similar size increases (e.g., mining explosions and earthquakes on land, explosions for geophysical exploration, volcanoes at sea, meteorite impacts in the atmosphere). These non-nuclear events increase the total number to be processed, and a small percentage of them generate signals similar to those expected from nuclear explosions. This increases the difficulty of identification. At sea, an additional challenge arises because it may not be possible to attribute a nuclear explosion to a specific evader, even if the nuclear explosion is identified. Experience with the actual networks coupled with supporting research should provide definitive estimates of capability and enable monitoring improvements. The Treaty's consultation and clarification, confidence building, and on-site inspection provisions should also help deter evasion attempts and improve confidence in the verifiability of the Treaty.

At an unclassified level, it is not possible to discuss the specific capabilities of the U.S. National Technical Means (NTM). They are addressed in a classified addendum to these answers.

*Question 20.* What is the U.S. capability, by whatever means, to detect very low level tests or experiments?

At an unclassified level it is not possible to discuss specific U.S. capabilities to detect very low yield tests or experiments. These capabilities are addressed in a classified addendum to these answers. However, in general, as the yield level of a test decreases, confidence in the ability to detect, locate, and/or identify the test also decreases. Intelligence assets, the CTBT's consultation and clarification, confidence building, and on-site inspection provisions, and ad hoc confidence building measures may allow the U.S. to address specific concerns (e.g., subcritical experiments at known test sites). However, such measures require the cooperation of the nation of concern, and activities conducted at undeclared locations could remain undetected.

*Question 21.* At what yield would a clandestine foreign nuclear test be a technically and militarily significant violation of the CTBT?

I am qualified to address the technical significance of violations at various yield levels. The military significance of such violations would best be answered by military experts in the DOD.

The technical significance depends strongly on the technological capability of the country performing the test, the type of device, the information they are seeking (e.g., a reliability test), and the uncertainty they are willing to accept. In a classified addendum to these answers, I have included a table on the Role of Testing Thresholds in Nuclear Weapons Development that describes what countries of three different levels of capability-those with a modest technology base, with a highly developed base, and the acknowledged nuclear weapon states-would gain technically from tests at various yields.

It is generally acknowledged that a first generation fission weapon can be developed and stockpiled without nuclear testing. This would include devices such as those used in 1945. Designs that are more advanced in their deliverability, use special nuclear materials more efficiently, and/or have greater military effectiveness are more likely to require some level of nuclear testing.

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[3] "High confidence" is not precisely defined, but here I have in mind the often-used measure of 90%.

[4] An "evasive" test is one that is designed to produce smaller or altered signals, or take advantage of masking by non-nuclear events.

LETTER TO HON. JON KYL FROM MR. HECKER, WITH ENCLOSURES

LOS ALAMOS NATIONAL LABORATORY OF THE UNIVERSITY OF CALIFORNIA

*September 24, 1997*

THE HONORABLE JON KYL
*United States Senate*
*702 Senate Hart Building*
*Washington, DC 20510*

DEAR SENATOR KYL: Thank you for your request for input on the Senate's deliberation on the ratification of the Comprehensive Test Ban Treaty (CTBT). As you indicate in your letter, the United States must have high confidence that the U.S. nuclear weapons stockpile remains safe and reliable. You are correct in stating that "the CTBT would profoundly alter the way in which we would maintain and improve the stockpile." In fact, this "profound" change has already occurred. It was ushered in almost exactly five years ago when President Bush declared a moratorium on nuclear testing; one that President Clinton extended before signing the treaty last year. Enclosed are my answers to the specific questions you posed in the spirit of providing you with the best technical information possible. Please allow me to add some overarching comments on the challenge ahead.

At Los Alamos, we have the responsibility to provide the nuclear weapons technology for the United States to carry out its national security objectives in concert with national policy. We support the nation's policy decisions; we don't make them. We provide sound technical judgment to the policy makers. We feel a great sense of responsibility for the nuclear weapons we designed—from cradle to grave.

During the Cold War our job was to design and help the military field the nuclear weapons to keep the U.S. deterrent viable. We did our job well—our weapons helped to prevent global war. We never allowed the United States to be surprised. Nuclear testing was imperative during an era of new weapons development. Our theoretical knowledge of nuclear weapons and ability to simulate nuclear explosions in laboratory experiments were inadequate to allow us to design and field new modern weapons without nuclear testing.

As we look back now, we can say that nuclear weapons "bought us time" while the Soviet Union collapsed under 75 years of communism, and eventually was dissolved on Christmas Day, 1991. When President Bush decided to declare a moratorium on nuclear testing in conjunction with halting the deployment of new nuclear weapons in September, 1992, our world changed dramatically. I recall returning from a trip to Washington, DC, right after President Bush's announcement to tell our people that we, the laboratories, must immediately change our approach to one of stewardship, away from nuclear testing and toward gaining a better fundamental understanding. I thought it was crucial that we would not be caught unprepared if the policy decision to stop testing held.

For the next nine months the idea of conducting 15 more nuclear tests, as discussed in the Hatfield, Exon, Mitchell amendment, before entering into a CTBT in 1996, was debated in Washington. We favored conducting such tests with the objective of preparing us better for a CTBT. However, all tests were ruled out by the Clinton Administration for policy reasons. On August 11, 1995, President Clinton declared his intent to seek a "zero-yield" CTBT.

By that time, the laboratories, in conjunction with Dr. Victor Reis, the Department of Energy's Assistant Secretary for Defense Programs, had developed what we believed was the best approach to nuclear weapons stewardship in a no-test environment—science-based stockpile stewardship (SBSS). With limited resources, we focused our efforts on implementing a science-based approach, rather than counting on an unlikely return to nuclear testing. We believed that SBSS, together with a stockpile management program that would provide for the ability to remanufacture all components of nuclear weapons systems, we had the best chance of discharging our responsibilities.

However, we also knew that there was risk associated with this approach and that we could not guarantee the safety and reliability of the nuclear stockpile indefinitely without testing. President Clinton acknowledged that risk and instituted a series of safeguards. Specifically, he stated, "While I am optimistic that the stockpile stewardship program will be successful, as President I cannot dismiss the possibility, however unlikely, that the program will fall short of its objectives. Therefore, in addition to the new annual certification procedure for our nuclear weapons stockpile, I am also establishing concrete, specific safeguards that define the conditions under which the United States can enter into a CTBT." He added, "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."

In my opinion, the science-based stockpile stewardship program, backed by strong bipartisan support, can, in the long term, serve the nation better than a program that lacks a strong scientific commitment and substitutes an occasional nuclear test for such commitment. Let me contrast the situation as I see it now, two years into the SBSS program, to what we faced in August, 1995. At that time, we had not conducted a nuclear test for three years. Our people at the Laboratory were discouraged, sensing a lack of national commitment to a comprehensive program of stewardship. Some of our best were preparing to leave or had left the nuclear weapons program. The production complex was in disarray; we had no firm plans on how to produce plutonium pits, make tritium, or manufacture other key replacement components for our aging nuclear weapons.

Now, two years later, the spirit and the excitement in the nuclear weapons program are back. Our people sense not only an immense challenge, but also that our government cares and supports their effort. Our best are coming into the nuclear weapons program. SBSS is rejuvenating the scientific and engineering spirit of our Laboratory. I am optimistic that we will be able to attract the best and the brightest to be stewards of our nuclear arsenal for the foreseeable future.

Moreover, I was able to certify the safety and reliability of the nuclear weapons eve designed in my annual certification letter to the Secretaries of Energy and Defense (a requirement instituted by President Clinton's 1995 CTBT decision). A copy of my letter is enclosed. Although we have not tested for five years now, I still have high confidence in the safety and reliability of our nuclear weapons in the stockpile. However, we have seen several age-related changes in the stockpiled weapons, which underscore the difficulty of the challenge ahead. Fortunately, we still have on board experienced designers and engineers to help us cope with this challenge. We are also beginning to apply the new tools of stockpile stewardship as they are developed. We feel a great sense of urgency to develop these tools and use them before these experienced people retire.

Senator Kyl, you stated in your letter that the ultimate decision on how much confidence is required in our nuclear arsenal is a political determination; one in which the Senate will play a key part through its advice and consent role on the CTBT. Our responsibility is to be prepared to do the best job for the nation whatever that decision may be. At this point, we must be prepared to ensure the safety and reliability of the stockpile without nuclear testing. I believe that not doing so and, instead, hoping for a return to nuclear testing is not responsible.

I hope you find these comments and my answers to your specific questions helpful as you prepare for your important role. Thanks for asking, and thanks for your continued support.

Sincerely,

S.S. Hecker
*Director*

Enclosure 1: Answers to Senator Kyl's questions
Enclosure 2: Letter dated September 9, 1997, to Secretary Pena and Secretary Cohen
Cy: The Honorable P. V. Domenici, U.S. Senate, Washington, DC
The Honorable J. Bingaman, U.S. Senate, Washington, DC
The Honorable F.F. Pena, U.S. DOE, Washington, DC
Dr. V.H. Reis, U.S. DOE, Washington, DC

*Enclosure 1. S.S. Hecker (Los Alamos National Laboratory) to Senator Kyl*

*Question 1.* Will confidence in the safety and reliability of U.S. nuclear weapons decline without nuclear testing?

The stockpile stewardship and management program, designed jointly by the Department of Energy's Defense Programs and the weapons laboratories, has allowed us to continue to certify the safety and reliability of the stockpile although it has been five years since we last conducted a nuclear test. As anticipated, our confidence in the nuclear stockpile has decreased somewhat during that time frame. This decline in confidence is an inevitable consequence of lack of testing. To date, we have found the decline in confidence manageable because we have not introduced any new weapons into the stockpile and we still have on hand a cadre of experienced nuclear weapons designers and engineers. Moreover, we have an adequate nuclear test history for the weapons in the stockpile. I have just sent my second annual letter to the Secretaries of Energy and Defense certifying the nuclear weapons we designed to be safe and reliable without nuclear testing. For the longer term, science-based stockpile stewardship is designed to develop new tools to better understand the fundamental science and technology of nuclear weapons that will help us shift to basing our confidence in the nuclear stockpile on SBSS, and away from our historic reliance on nuclear testing.

*Question 2.* Do you expect the Stockpile Stewardship and Management Program (SSMP) to give you the same confidence in the stockpile as was achieved by nuclear testing? If not, by how much will confidence be reduced, assuming that SSMP is successful?

I believe that the SSMP as currently configured and fully funded provides the best approach to keeping the confidence level in our nuclear stockpile as high as possible for the foreseeable future. We recognize there is no substitute for full-systems testing in any complex technological enterprise. This is certainly true for nuclear weapons. A robust nuclear testing program would undoubtedly increase our confidence. However, our long-term confidence in the stockpile would suffer if we substituted a program consisting of an occasional nuclear test for a robust stewardship program because it would lock us into an empirical approach tied to limited testing data without the benefit of the flexibility and resiliency provided by better scientific understanding.

The premise of SBSS is that we can offset the loss of confidence in the safety and reliability of existing weapons without nuclear testing by demonstrating improved understanding of the underlying science and technology. In effect, we limit the range of possible errors by replacing the empiricism of testing by thorough scientific and technological investigations. The various aspects of science-based stockpile stewardship (such as better computing, enhanced hydrotesting, enhanced surveillance, better materials studies, and high-energy-density physics experiments, etc.) are all designed to enhance our confidence without the benefits of nuclear testing. These activities have all been extensively reviewed by senior advisory panels. We must also retain the ability to remanufacture and replace all nuclear weapons components and develop the ability to certify those components without nuclear testing. Since the materials for some weapons component are no longer available and some manufacturing processes can no longer be duplicated, we will not be able to make components "the same." Hence, we must understand the consequences of different materials and different processes m order to evaluate and predict performance. This will also require a science-based approach.

We cannot assess at this time exactly how much our confidence will decrease over time and how well the SSMP will offset that loss, but we are currently developing a formal methodology by which the success of the SSMP will be evaluated. We will continue to depend critically on the annual certification process to assess if our current level of confidence is sufficient to certify the stockpile.

*Question 3.* What proportion of the research and testing envisioned for the first 10 years of operation of the National Ignition Facility is directly related to nuclear weapons? What proportion is indirectly related to nuclear weapons?

From the Los Alamos perspective approximately 2/3 of the Los Alamos experiments on NIF will be directly related to weapons physics and 1/3 will be indirectly related. Our Laboratory intends to utilize the special capabilities of NIF to the fullest extent possible to help us discharge our SBSS responsibilities.

*Question 4.* A purpose of SSMP is to maintain a cadre of scientists and technicians who will be capable of designing and working on nuclear weapons. Will scientists and technicians working on SSMP have weapons classification clearances and will they have a clear commitment to working on nuclear weapons should the need arise?

The principal responsibility of scientists and engineers engaged in SSMP will be doing everything that needs to be done to keep the weapons in the stockpile safe and reliable, today and in the future. They will divide their time between theoretical and experimental studies intended to improve our understanding of the physics of nuclear weapons and how this understanding can be applied to keeping the stockpile safe and reliable. The improved understanding will be applied to analyses of past nuclear test data, ongoing weapons surveillance data, and issues associated with remanufacturing various components. We will engage scientists from across the Laboratory to make certain that the best talent is brought to this challenging endeavor. Our people feel a special sense of obligation for all weapons designed and fielded by the Laboratory. We fully expect these scientists and engineers to have weapons classification clearances. However, I must report that today, because of some disagreements between DOE and the Congress, there are insufficient funds at DOE to provide timely security clearances for the people we need to do the job. Any help would be appreciated in this area.

*Question 5.* Much of the capability of SSMP is a decade or more away from being fully functional. Furthermore, many of the technologies involved are unproven. From a technical standpoint, would it be advisable to conduct nuclear tests to calibrate the existing and planned technologies? If so, what is the lowest yield at which meaningful tests can be conducted? What is the minimum number of tests that would be required in the interim before SSMP becomes fully functional?

I am pleased to report that some of the capabilities of SSMP that you have supported over the past couple of years are already paying great benefits. In this year's certification process, we demonstrated that the enhanced computational capabilities resulting from the Accelerated Strategic Computing Initiative (ASCI) were instrumental in helping us assess the stockpile.

ASCI also enabled the application of new computer codes to some particularly difficult X-ray radiographic analysis. Similarly, the newly-developed technique of dynamic proton radiography was used successfully to validate the new computational approaches. The benefits of ASCI will continue to accrue essentially immediately as we acquire increasingly more sophisticated and powerful computational capabilities. All of these will work toward ensuring that computation will provide us with the final integration of all previous test experience, all laboratory and subcritical experiments, and all theoretical understanding of nuclear weapons to allow us to predict the safety and reliability of existing weapons. Some of the experimental tools that require extensive development and facility construction will take longer to bring on board. These include facilities such as advanced hydrotest facilities, the National Ignition Facility, and pulsed-power machines. In all of the above, we feel a great sense of urgency to apply these new tools to existing stockpile issues while we still have on board designers and engineers with previous nuclear testing experience.

Of course, if nuclear testing were allowed, we would gain greater confidence in the new tools. We could validate these tools more readily, as well as validate some of the new remanufacturing techniques. One to two tests per year would serve such a function quite well. Yields of 10 kt would be sufficient in most cases. Yields of 1kt would be of substantial help. We have previously conducted a study of what can be accomplished at various yield levels. This study is classified and available through appropriate channels upon request.

Again, I would like to add the caution that conducting an occasional nuclear test in lieu of a fully-funded SSMP will jeopardize our long-term confidence in the stockpile. The SSMP is designed to predict and correct problems in the stockpile, whereas an occasional nuclear test would focus primarily on existing problems. It is critical at this time that we focus the attention of our people on being able to do the best possible job without nuclear testing.

*Question 6.* What are the specific measures by which you will know whether the SSMP has succeeded or failed?

This is a very difficult question to answer quantitatively. We are attempting to develop a formal methodology by which we can adequately quantify uncertainties in our assessment, thus allowing us to evaluate the success of SSMP. We envision a detailed process by which we will estimate uncertainties in fundamental data, theoretical descriptions and computational assessments of weapons, and the behavior of weapons materials over time. These estimates will be validated whenever possible by comparing them to laboratory experiments and to past nuclear test data. We will rely heavily on peer review by the Lawrence Livermore National Laboratory. We will also seek out other organizations in government and industry that have experience in assessing highly complex systems in which full-scale testing has been reduced or eliminated.

In the mean time, we will rely on the annual certification process to guide us on how successful we are with SSMP. In the longer term, our ability to continue to keep and attract the best scientists and engineers working on nuclear weapons will be a good test of the success of SSMP. Over the next few years, our ability to achieve the milestones of SSMP will provide some measure of its success. These milestones include specific enhancements of our computational capability, developing new tools for stockpile surveillance, and demonstrating the ability to remanufacture and certify critical weapons components.

*Question 7.* Since the last U.S. nuclear test, have there been age-related or other changes in the stockpile that previously would have been addressed by conducting at least one nuclear test? If so, how certain are you of the fixes? If your level of confidence in the fixes is not extremely high, how has this affected your view of stockpile reliability.

Yes, there have been several instances since the cessation of nuclear testing in September 1992, where we have found problems, either age-related or otherwise, for which in the past we would have turned to a nuclear test in the kiloton range to resolve. In the absence of testing, we have used the methodology of SSMP to evaluate the problem and suggest fixes if required. This has included more extensive calculations, non-nuclear laboratory experiments, comparison to previous nuclear test data, and the extensive experience of our designers and engineers. Moreover, our assessment has been checked against the rigors of peer review by the Lawrence

Livermore National Laboratory. We examined several problems of this nature during this year's certification cycle. At this time, we have sufficient confidence in our solutions to certify the stockpile without a resumption of nuclear testing. If our confidence in the fixes were not sufficiently high, we would not certify the stockpile. Our experience to date in resolving suspected problems has increased our confidence in SSMP and in the process of annual certification.

*Question 8.* How safe is the stockpile today? Have there been any changes since the 1990 Drell safety study that would change the conclusions of that study today?

I have full confidence in the safety of the stockpile today. I have certified the safety of the stockpile in this year's annual certification. We continue to assess all safety features of our weapons and continue to learn as much as we can. We have not seen any fundamental changes in safety concerns since the 1990 Drell safety study. The principal change since 1990 is that with a CTBT it will not be possible to make some of the potential safety improvements for greater intrinsic warhead safety that we considered during the 1990 time frame. Nevertheless, we certify the stockpile as being safe today, and we will continue to assess safety annually.

*Question 9.* What known safety vulnerabilities are we accepting? Should we be accepting them?

Not all weapons in the stockpile today contain all modern safety features such as insensitive high explosives, fire-resistant pits, and enhanced nuclear detonation safety. However, with the cooperation of the services we have placed restrictions on the handling and operations of these weapons that allow us to certify the safety of such warheads. Should we find an unacceptable safety vulnerability, then I will not certify the weapon. I would like to add that the nation made a major safety improvement to the stockpile by replacing the B53 bomb with the B61 Mod. 11 during this past year.

*Question 10.* Are there any tests you would advocate doing today, if allowed, to address safety or reliability concerns?

I have certified the weapons in the stockpile designed by the Los Alamos National Laboratory to be safe and reliable, without the need to resume nuclear testing at this time. I stand by that certification. There are no outstanding problems in the stockpile that currently require testing. Let me again caution that an occasional nuclear test in lieu of a robust stockpile stewardship program carries the risk of not retaining high confidence in the stockpile over the long term.

We were last asked in October 1992, what types of nuclear tests we would conduct if we were allowed 15 more tests before entering a CTBT. We laid out a series of tests at that time that addressed safety and reliability issues. Today, we would be concerned mostly about how to validate some of the new tools of SSMP and how to certify aged or remanufactured components.

*Question 11.* If U.S. leadership requires a new nuclear design, would you be willing to certify and deploy it without testing?

Personally, I would not certify a new design of a modern, high yield/weight ratio warhead (such as those we have in the stockpile today) without nuclear testing. If the new design were very robust with large margins in weight and volume, then it may be possible to certify such a "new" weapon.

*Question 12.* What yield of testing would be the lowest possible to accomplish new designs as well as safety and reliability?

The nuclear yield required would depend upon warhead requirements. I believe most designs could be adequately tested at yields between one and 10 kilotons. In 1995, the Department of Energy conducted a study for STRATCOM that provides some specific details related to your question. That study is classified and available upon request.

*Question 13.* How difficult is it, technically, to maintain the capability to test without testing at some level?

It is important to exercise the key skills required for nuclear testing. Otherwise, the time to reconstitute will increase substantially. Right now, we find that most of the key skills are being exercised with the subcritical tests at NTS. We are also working diligently to keep some skills alive by utilizing some of the techniques and people, previously at the test site, here at our laboratory. Merely preserving facilities and support infrastructure at NTS will not provide readiness. In spite of our best efforts, some special skills such as test containment reside in only a few individuals today, and some of the special equipment is no longer maintained or available from private industry.

*Question 14.* If CTBT enters into force for the United States, the budgetary and political pressures to close the Nevada Test Site (NTS) will increase significantly. How important is the retention and maintenance of the NTS?

The Nevada Test Site is very important to us. It allows us to conduct experiments with special materials such as plutonium and large quantities of high explosives.

Closing NTS would preclude subcritical experiments which are essential to understanding the properties of plutonium. For example, it is imperative to understand whether aging effects in plutonium could result in safety or performance problems in the stockpile. We presently do not have this data. In addition, we believe it is critical to keep NTS for potential future nuclear tests. It is an important element of the President's safeguard for the CTBT. We should not, under any circumstances, give it up.

*Question 15.* Why did your laboratory change its long-held view that nuclear testing is essential?

We did not change our view that from a purely technical standpoint nuclear testing in the appropriate yield range continues to be the most effective way to ensure the safety and reliability of the nuclear stockpile. However, once the President made his decision to end testing, it was our duty to do the best job we possibly could to keep the stockpile safe and reliable without nuclear testing. We agreed with the Department of Energy that without nuclear testing, the SSMP provides the most logical approach for certifying the stockpile today and decades from now. We said that we could not guarantee that SSMP would work, although we had reasonable confidence that it would, especially with the safeguards added by the President. These safeguards include a strong commitment to science-based stockpile stewardship and to strong laboratories, as well as the supreme national interest clause to withdraw from the CTBT should we lose our confidence in the safety and reliability of one of our key warheads. In addition, the President instituted a new certification process for the stockpile, which, for the first time, requires us to certify all of the weapons in the stockpile annually.

I should also add that in August 1995, when the President made his decision, we had already not conducted a nuclear test for almost three years. Our budgets had decreased precipitously over the previous six years. Our people were looking to get out of the nuclear weapons program. The production complex appeared hopelessly broken. The prospects of doing an occasional nuclear test was proving to be a barrier to adopt a new approach to nuclear stewardship. This situation has turned around dramatically in the past two years with the emphasis on science-based stockpile stewardship. Our people have a renewed commitment to stockpile stewardship and an enthusiasm for the development of a new methodology, based on rigorous science and engineering, to ensuring the safety and reliability of the stockpile.

*Question 16.* What is your understanding of the limitations imposed by "zero"? Are these limitations acceptable in your view?

During the discussions in the summer of 1995, we emphasized the importance of conducting laboratory experiments (including inertial confinement fusion with lasers or pulsed-power machines) and subcritical experiments at the Nevada Test Site as an integral part of the SSMP. We pointed out that "zero yield" has no technical basis. Plutonium (or any radioactive material, including radioisotopes used in medicine) could be considered to have a non-zero yield just sitting there because of radioactive decay. I believe the "zero yield" criterion was devised to preclude so-called hydronuclear experiments in which the nuclear energy released in those experiment is less than 4-lb equivalent of high-explosives. The SSMP is consistent with a ban on hydronuclear experiments. Today, we are keeping the NTS open and exercised with subcritical experiments, and we are proceeding with a vigorous program of laboratory experiments, including the construction of the National Ignition Facility at Livermore. If "zero yield" is interpreted more strictly than outlined here, then our SSMP approach falls apart. We could not live with that.

*Question 17.* What are your major concerns about your ability to fulfill your responsibilities under a zero CTBT?

My major concern is that the U.S. government remain committed to a vigorous stockpile stewardship and management program. No technical enterprise has much experience in maintaining complex systems without full-systems testing. While significant progress has been made in the construction of a comprehensive SSMP, it remains to be proven that the plan is sufficient to maintain confidence in the stockpile over the long term. President Clinton realized this when he announced his decision to pursue a CTBT on Aug. 11, 1995. He laid out a path that promised a vigorous program to keep the stockpile safe and reliable using all other means short of nuclear testing. He announced a set of safeguards that he was willing to take should we fall short of our goal. I should point out that we have lived with some restrictions on "full-systems" testing in the nuclear weapons program because of the limitations of 150 kilotons prescribed by the Threshold Test Ban Treaty observed since 1974. The CTBT represents a significant step beyond this limitation. The SSMP is designed to allow us to do so successfully. I hope Congress will join the President in reiterating the strong commitment to a vigorous, fully-funded stockpile stewardship and management program.

*Question 18.* What importance do you attach to being able to exercise the "supreme national interest" test?

I view the "supreme national interest" clause as being extremely important. The President's National Security Strategy holds that nuclear weapons are the ultimate deterrent against strategic attack of the United States. Hence, it is imperative that our nuclear weapons stockpile be maintained in a safe and reliable status. On August II, 1995, the President stated "While I am optimistic that the stockpile stewardship program will be successful, as President I cannot dismiss the possibility, however unlikely, that the program will fall short of its objectives. Therefore, in addition to the new annual certification procedure for our nuclear weapons stockpile, I am also establishing concrete, specific safeguards that define the conditions under which the United States can enter into a CTBT. In the event that I were informed by the Secretary of Defense and Secretary of Energy—advised by the Nuclear Weapons Council, the Directors of the DOE's nuclear weapons laboratories and the Commander of U.S. Strategic Command—that a high level of confidence in the safety or reliability of a nuclear weapons type which the two Secretaries consider to be critical to our nuclear deterrent could no longer be certified, I would be prepared, in consultation with Congress, to exercise our 'supreme national interests' rights under the CTBT in order to conduct whatever testing might be required."

*Question 19.* What is the monitoring capability of international system? Of U.S. national technical means?

The Comprehensive Test Ban Treaty establishes an International Monitoring System (IMS) that includes four synergistic monitoring technologies distributed worldwide:

- Seismological monitoring
  - monitor for earth tremors produced by nuclear explosions,
  - 50 primary stations, 120 auxiliary stations.
- Radionuclide monitoring
  - sample the air for debris from a nuclear explosion,
  - 80 stations monitoring particulates/aerosols,
  - 40 noble gas monitoring stations initially, 40 more later.
- Hydroacoustic monitoring
  - listen for sound waves that could be caused by a nuclear explosion in the oceans,
  - 11 stations.
- Infrasound monitoring
  - listen for very low-frequency sound waves in the atmosphere that could be caused by a nuclear explosion,
  - 60 stations.

These elements of the IMS will be very important in providing an effective verification regime. The CTBT does not specify the technical requirements for the performance of the IMS. The IMS is designed, however, to provide global coverage for potential nuclear explosions underground, under water and in the atmosphere. It provides no coverage in the upper atmosphere or in space. There is considerable disagreement in the scientific community over the low-yield detection capability of the IMS. We stress the importance of developing cooperative measures, on-site inspection, and transparency measures to make the IMS an effective verification tool.

The U.S. national technical means (NTM) has evolved over the years, and have been upgraded substantially since the 1970s. Seismic capabilities have improved over the years. However, low-yield explosions underground, especially if they are seismically decoupled from the geologic environment, continue to be a major challenge. Upper atmosphere and space monitoring via satellite-deployed sensors exists today, but will need to be replaced after the year 2000. New electromagnetic pulse detection instrumentation is needed on the GPS satellite to adequately cover atmospheric explosions.

The monitoring capability of the U.S. NTM is classified for reasons of not providing potential proliferators with sufficient knowledge to evade such means. We will provide you with classified responses through appropriate channels.

*Question 20.* What is the U.S. capability, by whatever means, to detect very low level tests or experiments?

We can categorically state that "zero yield" is beyond the verification capabilities of our NTM. For the detection and verification of very low yield levels the NTM will have to be supplemented by cooperative agreements, including on-site inspection protocols and transparency measures. Such agreements must be at least multilaterial and, preferably, part of an International Monitoring System.

*Question 21.* At what yield would a clandestine foreign nuclear test be a technically and militarily significant violation of the CTBT?

This is a very difficult question to answer because it depends greatly on whether the testing entity is an established nuclear power (even here, our response would be different for Russia and China), a rogue state, or a terrorist. We can state that crude nuclear weapons can, with the knowledge that is in the open literature today, be fielded without any nuclear testing. It is instructive to note that the bomb dropped on Hiroshima was not tested. A detailed answer to this question is also classified. Again, we will provide a classified response.

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LETTER TO HON. FEDERICO F. PENA AND HON. WILLIAM S. COHEN FROM S.S. HECKER

LOS ALAMOS NATIONAL LABORATORY OF THE UNIVERSITY OF CALIFORNIA

*September 9, 1997*

THE HONORABLE FEDERICO F. PENA
Secretary of Energy
United States Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

THE HONORABLE WILLIAM S. COHEN
Secretary of Defense
United States Department of Defense
1000 Defense Pentagon
Washington, DC 20301

DEAR SECRETARY PENA AND SECRETARY COHEN: Annual certification of the safety and reliability of the nuclear weapons stockpile was initiated by President Clinton in his August 11, 1995, announcement to seek a zero-yield comprehensive test ban treaty (CTBT). The Los Alamos National Laboratory has just completed the second annual cycle of this process, and *I am able to certify that the B61 (Mods 3, 4, 7, 10 and 11), W76, W78, W80 and W88 warheads are safe and reliable without the resumption of underground nuclear testing at this time.* The details of our assessment have been provided to Dr. Reis in classified reports. The concerns we expressed last year about the B53 bomb have been addressed by the Air Force replacing the B53 with the B61-11.

Our detailed review, conducted jointly with the Sandia National Laboratories and the military services, pointed out to me again the difficulty of the job ahead. We continue to see some age-induced degradation of materials and components as well as find some defects introduced in the initial manufacturing. Fortunately, we still have on hand people with experience and proper judgment to evaluate and correct these problems. None of these were judged to require nuclear testing. We are continuing to evaluate measures that will enhance the performance margins of primaries and to develop more sophisticated surveillance techniques.

With the replacement of the B53 bomb by an earth-penetrating version of the B61 bomb, we were faced for the first time in the no-test regime with having to certify a modification to an existing weapon. The B61-11 changes did not modify the physics package, but the Mod-11 must work under very different conditions from previous versions of the B61. We took advantage of several of the improved tools developed by the stockpile stewardship program and all previous, relevant nuclear testing data to provide an interim certification in December, 1996. We expect that our final certification in June, 1998, will still reflect a greater uncertainty than what we achieved in the past for modifications that were verified with nuclear tests.

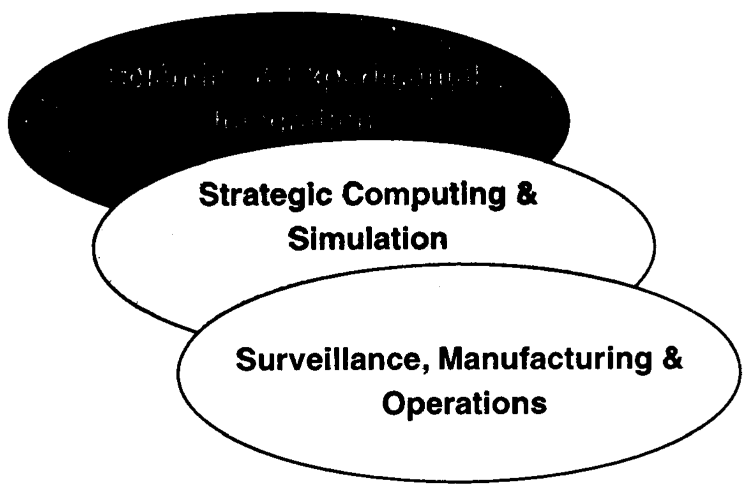
Although this year's certification process demonstrates that some of the improved stockpile stewardship tools such as the Accelerated Strategic Computing Initiative and proton radiography are already useful, we were also reminded that these tools are yet immature, and that we rely heavily upon our experienced weapons scientists and engineers for the actual certification. We will face future challenges as we maintain or repair weapons in the stockpile through life extension programs or other modifications. We must not only aggressively pursue improved hydrotesting, subcritical experiments at the Nevada Test Site, and enhanced surveillance and integrate those into our certification with a more powerful computing and simulation capability, but we must also continue to remain sufficiently skeptical of these tools to avoid falling into the trap of rising confidence but diminishing competence. Training the next-generation of scientists and engineers to use the new tools while we still have the experienced personnel around will be key to our success, and it continues to provide a sense of urgency for the stockpile stewardship and management program.

Sincerely,

S.S. Hecker
*Director*

# Stockpile Stewardship Program

## Overview and Progress




**Department of Energy**
**Office of Defense Programs**

**October 1997**

# Preface

In the early 1990s, as part of its continuing world leadership role in the arms control arena, the U.S. halted production of new nuclear warheads and conducted its last nuclear explosive test. Thus ended an era in which the U.S. modernized its nuclear weapons stockpile by continually replacing aging systems with new systems and in which nuclear testing served as the ultimate arbiter of the safety, reliability, and performance of the natioh's nuclear weapons stockpile.

With the decision to cease production of new nuclear warheads and end nuclear testing, the nation 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 a Stockpile Stewardship Program. The strategy and key components of this new approach are described in the May 1995 DOE report *The Stockpile Stewardship and Management Program: Maintaining Confidence in the Safety and Reliability of the Enduring U.S. Nuclear Weapon Stockpile.* This overview and progress report updates the 1995 report and describes the program accomplishments to date.

Since the genesis of the Stockpile Stewardship Program in 1992, significant progress has been made. 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 (the Green Book) has been developed and is already in its second annual revision. The Presidentially mandated first Annual Certification of the stockpile was completed in February 1997, and many new capabilities and facilities for the Stockpile Stewardship Program are well under way. The Dual-Axis Radiographic Hydrodynamic Test Facility is under construction, and the groundbreaking ceremony for the National Ignition Facility has taken place. Industry has begun delivering the advanced computers required for the Accelerated Strategic Computing Initiative, and record-breaking teraops (one trillion operations per second) operation has already been demonstrated. The first and second subcritical experiments, "Rebound" and "Holog," were successfully completed at the Nevada Test Site on July 2 and September 18, 1997, respectively. A life extension process for the enduring stockpile is being developed, and the dismantlement of U.S. nuclear warheads retired from the stockpile is continuing. The assets of the Stockpile Stewardship Program were applied to a modification of the B61 bomb, and we are on track to restore the nation's capability to produce tritium.

As experience is gained in assessing the safety and reliability of the enduring U.S. nuclear stockpile without nuclear testing, key program strategies of the Stockpile Stewardship Program have evolved and become better focused. In this report, an overview of the current program is presented along with the highlights of the Department of Energy's accomplishments and progress to date.

Maintaining the U.S. nuclear weapons stockpile in this new era will continue to challenge our best capabilities. The Stockpile Stewardship Program must be implemented promptly and fully. In particular, new facilities and capabilities must be developed and validated while personnel with nuclear-test experience are still available. In addition, we will continue to rely on peer review between the three weapons laboratories as a key element of the Stockpile Stewardship Program. Despite the wide-ranging challenges and risks, we are confident that this program provides the framework and capabilities for success.

Victor H. Reis
Assistant Secretary for Defense Programs
U.S. Department of Energy

## Supreme National Interest

"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.

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*

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## Addressing Stockpile Stewardship Program Challenges

Over the past five years, the Department of Energy's Stockpile Stewardship Program has evolved from a vision for the future to an implemented plan of action. While the program's fundamental objective is unchanged from previous years—that is, to maintain high confidence in the safety, reliability, and performance of the U.S. nuclear weapons stockpile—the conditions under which this objective must be accomplished have changed greatly since the early 1990s. The Department of Energy (DOE) is meeting and will continue to meet an unprecedented challenge—namely, to maintain high confidence in the safety, reliability, and performance of the nation's nuclear weapon stockpile by using nonnuclear experiments and computer simulations in lieu of underground nuclear testing.

- *No nuclear testing.* The Comprehensive Test Ban Treaty (CTBT), which was signed by the President in September 1996 and submitted to the Senate for ratification on September 23, 1997, prohibits nuclear testing unless the involved State Party invokes the "supreme national interest" clause and withdraws from the treaty. Currently, there is high confidence in the safety, reliability, and performance of the nuclear warheads in the enduring stockpile. This confidence is based on understanding gained from 50 years experience and more than 1000 nuclear tests, including the results of approximately 150 nuclear tests of modern weapon types during the last 20 years. The President has expressed his confidence in the ability of the Department of Energy to maintain the U.S. nuclear deterrent without nuclear testing. In response, the DOE's nuclear weapons stewards have directed their combined energies to developing new nonnuclear experimental facilities (National Ignition Facility [NIF], Dual-Axis Radiographic Hydrodynamic Test Facility [DARHT]), a world-class computational capability to enable simulation of complex nuclear explosions, and the conduct of subcritical experiments at the Nevada Test Site.

- *Tritium production.* The United States has not produced tritium for nuclear warheads since 1988 and will require a new tritium production source possibly as early as 2005. A dual-track approach using a 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 of these changes do not adversely affect warhead safety, reliability, or performance; but others may, and some are yet unknown. With the average age of the stockpile now being 14 years—older than ever before—it is expected that new problems will arise. In addition, a number of warheads are approaching the end of their originally anticipated deployment period. To meet this challenge, each of the stockpiled warheads 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 workforce. Knowledge preservation programs are under way that include video-recording the experiences of senior designers as well as the 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 at any time since the 1960s. Thus, the U.S. nuclear deterrent is more susceptible to common process and common component failures. A new annual certification process and an enhanced surveillance process have been initiated to ensure that potential problems are found before the safety and reliability of the stockpile is degraded.

- ***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 Department of Energy's base of experience. Without requirements for new warheads, existing warheads will be refurbished and modified to extend their lifetimes. To address this challenge, the capability is being maintained to design and fabricate replacement warhead parts, as well as to design 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 capability-based complex, with its reduced capacity, 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 nuclear weapons complex and the development of an agile, capability-based manufacturing enterprise that will use advanced design and production techniques to respond to both normal and contingency requirements.

The focus of the Stockpile Stewardship Program (SSP) is the U.S. nuclear stockpile. All elements of the program are directed at ensuring the safety, reliability, and performance of this stockpile. As stated in the above responses to each program challenge and as described in more detail throughout this document, we will develop the fundamental understanding needed to ensure the ability to anticipate and fix problems and to deal with future unknowns before they affect stockpile safety or reliability.

At the heart of the Stockpile Stewardship Program is the issue of confidence. Confidence in the weapons is achieved through the effective management of the system that maintains the weapons and the expert judgment of the people who assess them. The ultimate measure of success for the Stockpile Stewardship Program is to certify that the stockpile remains safe and reliable without a recommendation to the President that nuclear testing is required.

The first annual certification of the nuclear weapons stockpile has been completed, and both the Department of Defense (DoD) and DOE have concluded that the stockpile is safe and reliable and that there is no need to conduct a nuclear test. The second annual certification process is currently under way and is on schedule.

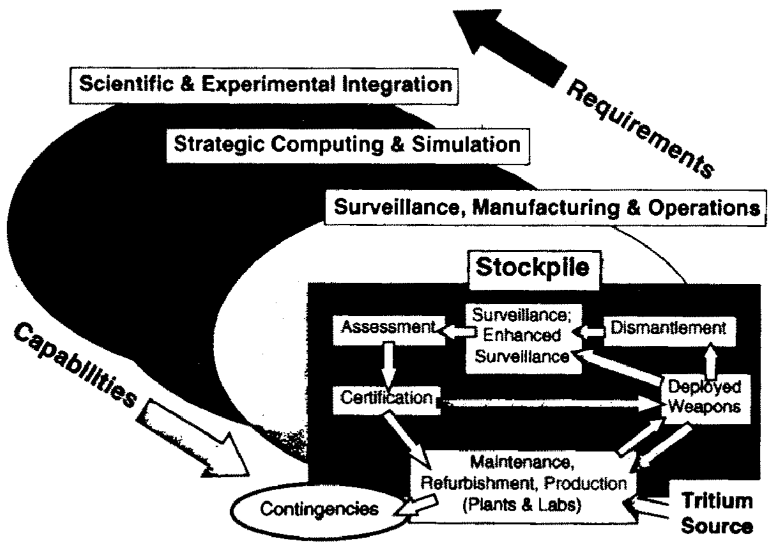
## Stockpile Stewardship Program Integration

A distinguishing feature of the Stockpile Stewardship Program is its integration. As depicted below, the Stockpile Stewardship Program (SSP) has three major elements: Surveillance, Manufacturing and Operations; Scientific and Experimental Integration; and, Strategic Computing and Simulation.

Stockpile Surveillance, Manufacturing and Operations focuses on activities that extend the life of the current stockpile, including surveillance, maintenance, refurbishment, assessment, and annual certification of the warheads. The Scientific and Experimental Integration effort involves developing advanced theoretical, computational, and experimental methods that will enable the continuing assessment and certification of warheads in the enduring stockpile without nuclear testing. The Strategic Computing and Simulation effort supports both Surveillance, Manufacturing and Operations and Scientific and Experimental Integration and includes computation, experimentation, and modeling as well as archiving and analysis of past nuclear test data.

All of the Stockpile Stewardship Program elements are seamless and 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.

Not only are the laboratories and plants working closely together, particularly for surveillance and manufacturing, but the activities under each program are tightly interconnected. High-performance networks linking the advanced computers, coupled with other tools, are essential elements of this effective integration. In addition, the Department of Energy's laboratories and plants work closely with the Department of Defense to make sure that the enduring U.S. nuclear stockpile meets national security requirements.



# Stockpile Stewardship Program Strategies

The goals of the Stockpile Stewardship Program (SSP) will be achieved through an integrated surveillance, assessment, certification, design, and manufacturing process. These activities have remained constant; however, the integrating strategies have evolved as the program has matured. For example, the Stockpile Life Extension Process (SLEP) has been developed as a formal integrated activity through which the Department of Energy, laboratories, plants, and military services evaluate, plan, and schedule the specific refurbishment actions to be conducted on each weapon system. The accelerated and greatly expanded use of strategic computing and simulation tools is the fundamental innovation of this evolution. Today, the program is characterized by three integrated strategies or phases of stockpile stewardship.

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

- *Assessment and Certification: analyzing and evaluating effects of changes on warhead safety and performance.* The effects of identified and predicted age- and environment-related changes in stockpile warheads must be assessed, utilizing in large measure advanced numerical simulations and models to determine whether the changes adversely affect safety, reliability, or performance. Determinations as to whether the degradation is severe enough to require the replacement or rebuilding of warhead components or even entire weapons must be made. Evaluation and certification of new materials, new fabrication techniques, and new manufacturing processes are essential to make sure they are functionally equivalent to the originals.

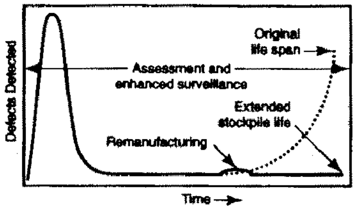
- *Design and Manufacturing: refurbishing stockpile warheads and certifying new parts, materials, and processes.* Periodically replacements must be made for limited-lifetime components (e.g., tritium reservoirs, neutron generators), and other warhead parts must be rebuilt or manufactured to replace those that have experienced or are predicted to experience detrimental aging-related changes. The new components must be certified so that defects that degrade warhead safety, performance, or reliability are not introduced into the stockpile. Advanced simulation and modeling and extensive use of archived data are critical to maintaining confidence in the rebuilt or remanufactured parts.

**The SSP Paradigm.** *The Stockpile Stewardship Program provides confidence in the safety and reliability of the U.S. stockpile through an ongoing and integrated process of surveillance, assessment, certification, design, manufacturing, and computing and simulation.*

## Predicting and Detecting Problems: Surveillance

Stockpile surveillance has been a major component of the U.S. nuclear weapons program ever since the first weapons were put into the stockpile. Approximately 14,000 weapons have been examined and subjected to a variety of nonnuclear laboratory experiments and flight tests since 1958. In cases where these nonnuclear 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 of the warhead types in the




Life Cycle of Manufactured Systems. *The typical life cycle of complex manufactured systems follows a path through initial defects, useful life, and eventual wear-out. The Stockpile Stewardship Program will extend the useful life of U.S. stockpile warheads through enhanced surveillance, assessment, and remanufacturing.*

enduring U.S. stockpile have had repairs or retrofits, and several have required repairs to the nuclear package.

Without the replacement of older warheads with new warheads, the stockpile will age beyond the experience base. The Department of Energy has never before had large numbers of 30-, 40-, or 50-year-old warheads in the stockpile. (The average age of a stockpile warhead has always been less than 13 years.) As a result, new types of aging-related changes and problems in these older warheads are expected to be encountered.

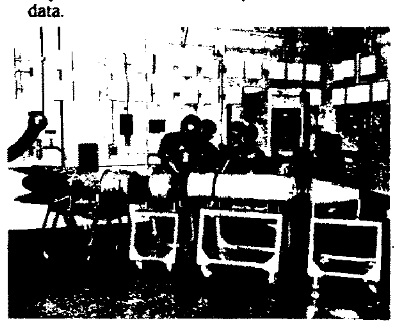
To succeed in this new reality, new surveillance methods and predictive capabilities are needed so that the full range of problems that may arise in the enduring stockpile can be detected. There is also a need to predict and identify aging-related changes and to understand the significance of these changes 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. We have limited experience with the third stage and must develop the capability to predict when it will be reached.

The goal of enhanced surveillance is to predict or detect the precursors and onset of aging-related defects before they jeopardize warhead safety, reliability, or performance. Predictive modeling and simulation are central to this activity. With sufficient lead time, the necessary redesigns, refurbishments, and recertifications can be made efficiently and cost effectively within the capabilities and capacity of the downsized production complex.

An enhanced surveillance process has been established to develop the technologies and methods as well as the fundamental understanding of materials properties and weapons science to significantly improve detection and predictive capabilities. The major activities to be pursued are:

- Testing and researching the aging-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 (i.e., enhanced data acquisition) nonnuclear flight tests to examine the behavior of nearly all actual warhead components in realistic environments. (Historically, most flight tests, for example, did not include realistic simulation of the nuclear package.)
- 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.



Surveillance at Pantex. *During the disassembly and periodic maintenance (e.g., limited-lifetime component exchange) of nuclear warheads at Pantex, surveillance activities are conducted to detect and help predict problems in stockpile warheads.*

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

## Analyzing and Evaluating: Assessment and Certification

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

- Develop an ability to predict and understand the lifetime and aging-related changes that occur in every warhead component.
- Identify and understand significant changes, variables, and processes in terms of warhead safety, reliability, and performance.
- Validate new experimental and computational tools.
- Validate new manufacturing processes and materials to ensure that rebuilt components and warheads are 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, the weapons scientists and engineers 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 the weapons scientists.

Now more than ever before, confidence in the accuracy of the judgment of the weapons scientists and engineers and confidence in the safety and reliability of the U.S. nuclear stockpile are closely linked. In the past, a weapon steward'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.

Subcritical Experiments at the Nevada Test Site. *Streak cameras are used to record data from studies of highly shocked plutonium. These subcritical experiments, conducted underground at the Nevada Test Site, provide essential data about this complex and incompletely understood metal.*

This is being accomplished through the integrated management of computational simulation, applied scientific research, and nonnuclear experiments. In particular, experiments are being designed that test and expand the boundaries of our understanding. There are many areas of warhead operation that cannot be adequately addressed with existing tools and the current knowledge base of the weapons scientists and engineers. To close these gaps, the Stockpile Stewardship Program is making significant investments in enhanced computational capabilities and advanced facilities for above ground experiments.

Of particular concern is the assessment challenge posed by the unrecognized problem—the "unknown unknown." The Department of Energy must have rigorous computational and experimental processes that not only confirm and extend what is known and expected but also to discover gaps in our current understanding. This ability to fill in the gaps is especially important in those areas where previously nuclear testing would have been used to bound the margins of our concerns. Therefore, an aggressive verification and validation process for both the tools and the results is needed.

The Stockpile Stewardship Program provides for demonstration-based assessment and certification of warhead safety and reliability In the absence of nuclear testing, different experiments and tools must be relied on to obtain data relevant to nuclear warhead performance. A suite of enhanced capabilities that are needed to fill in the knowledge gaps and provide data relevant to various stockpile concerns has been identified (see chart below). Advanced experimental facilities will provide high-resolution data on the stages of the nuclear explosion—primary implosion, boost, primary-to-secondary coupling, weapon effects, etc. Wherever possible, the goal is to obtain data experimentally by more than one method.

Under the Stockpile Stewardship Program, computational modeling and numerical simulation provide the critical integration of theory, existing data, new experimental results, and predictions into results that can be verified and validated. Advanced computational capabilities (application codes, computing platforms, and various tools and techniques) are being developed under the Accelerated Strategic Computing Initiative and incorporated into ongoing stockpile computational activities. The weapons scientists and engineers will be focused on numerical simulations and experiments. The goal is to combine past nuclear test data, computational modeling, and new data from current and advanced experimental facilities to fill in knowledge gaps and extend the fundamental understanding in all vital areas.

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

These new capabilities will be used in addition to the experimental and computational capabilities developed during the nuclear testing era. 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, their data will be incorporated into our assessments.

**Capabilities Needed to Ensure High Confidence in Warhead Safety and Reliability**

| Weapon Physics | Computer Simulation | DARHT | Subcritical experiments | NIF | Pulsed power | LANSCE |
|---|---|---|---|---|---|---|
| Improved physical models | X | X | X | X | X | X |
| Early implosion | X | X | X | X | | X |
| Preboost | X | X | X | X | X | X |
| Boost | X | | | X | | |
| Primary–secondary coupling | X | | | X | X | |
| Secondary implosion | X | | | X | X | |
| Weapon Performance | X | | | | | |

This transition period should take several more years.

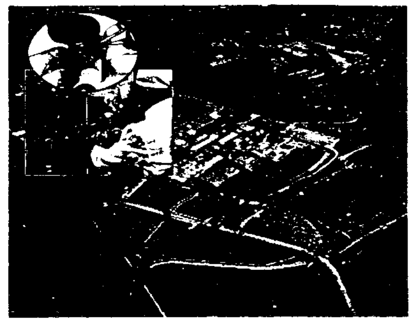
Peer review is a key component of stockpile stewardship. Because assessment and certification of stockpile safety, reliability, and performance rely heavily on expert judgment, it is essential that the assessment process be vetted and validated. Peer review, both formal and informal, takes place among 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: Design and Manufacturing

Nuclear warheads are not static objects. They contain radioactive materials that decay and organic materials that decompose with time. Some materials, like tritium, decay predictably and must be replaced every few years throughout the warhead's lifetime. In addition, radioactive decay produces 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 storage and 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, reliability, and performance, developed through the enhanced surveillance and assessment efforts, the Department of Energy will be able to take a proactive approach to refurbishment. The goal is to replace or fix components systematically, before aging-related changes jeopardize warhead safety or performance.

The Stockpile Life Extension Process (shown graphically on the next page) provides the framework for research and development activities and production planning. To retain confidence in warhead safety, security, and performance, the SLEP risk management strategy addresses three categories of potential refurbishment actions: musts—correct known degradations; shoulds—prevent foreseeable degradations; coulds—enhance safety or



Nonnuclear Components at Kansas City. *With the consolidation of the production complex, Kansas City now has responsibility for the bulk of the nonnuclear component manufacturing. In order to achieve the desired production efficiency and flexibility, the laboratories and plants work closely together in the concurrent design of replacement components and their manufacturing processes.*

Tritium Recycling at the Savannah River Site. *Tritium from dismantled warheads is recycled at Savannah River to provide the tritium needed to maintain the U.S. stockpile. Public Law 104-106 requires that Savannah River be the site for accelerator-produced tritium production, if that technology (currently in R&D) is selected as the nation's principal tritium technology for the future.*

security. A number of specific life extension options are being defined for each warhead type, allowing the laboratories, plants, and the Department of Defense 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.

A new approach to manufacturing is being implemented to fit the capacity of the downsized and consolidated production complex and make full use of its capabilities. Through the Advanced Design and Production Technology (ADAPT) initiative, the laboratories and plants are working together to:

- Integrate product and process design through the concurrent design and development of replacement components and the processes used to manufacture them.
- Develop and qualify new manufacturing processes that produce high production yields, are more efficient, and meet modern environmental, safety, and health requirements.
- Develop and characterize improved materials that are functionally equivalent to the originals.
- Develop agile manufacturing technologies that allow the production complex to gear up rapidly to produce different weapon components.
- Identify, certify, and maximize the use of commercial parts and processes.

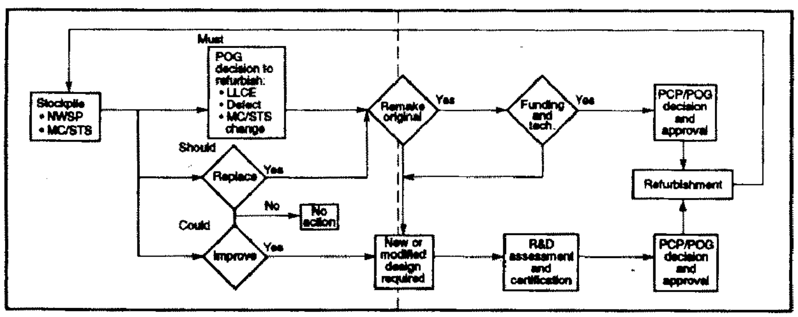
The Department of Energy will continue to meet the day-to-day production requirements for limited-lifetime component exchanges and other replacement components while also continuing to implement the Advanced Design and Production Technology initiative. For example, tritium-containing components must be replaced every few years, and various other parts are needed to reassemble warheads that are removed from the stockpile for routine surveillance and inspection.

## Simulation and Modeling: Strategic Computing and Simulation

Strategic Computing and Simulation is focused on achieving capabilities needed to support the Comprehensive Test Ban Treaty and to implement the Stockpile Stewardship Plan. Currently, there are five major thrusts:

- Accelerated Strategic Computing Initiative (ASCI)
- Stockpile Computing
- Distanced Computing and Distributed Computing for Weapon Simulation (DisCom2)
- Numeric Environment for Weapon Simulations (NEWS)
- Validation and Verification (V&V)

ASCI provides the leading-edge, high-end simulation capabilities needed to meet weapon assessment and certification requirements without nuclear testing. To accomplish this, ASCI integrates the resources of the national




Stockpile Life Extension Process. *The Stockpile Life Extension Process provides a framework for the manufacturing plants and the laboratories and the Department of Defense to establish guidelines for stockpile-related research and development and warhead parts replacement.*

laboratories, computer manufacturers, and academia.

The national laboratories are focused to provide the application codes and related science needed to address weapon safety, reliability, and performance without nuclear testing. They are also developing improved tools and methodologies to utilize this unprecedented volume of data. This involves research and development in the areas of security, extremely high bandwidth transmission, extremely high data rate speeds, and high-fidelity, high-density visualization of dynamic data flows. Even at this early stage in their development, advanced ASCI simulation codes are providing unprecedented capabilities to the weapons program. We are not only doing the same things faster, but performing calculations and simulations that were impossible to contemplate before.

The computer manufacturers are developing the technology and systems needed to operate at 1, 3, 10, 30, and 100 trillion operations per second. This technology is being developed at about twice the rate of commercial advances. ASCI has been highly successful in meeting its milestones and providing highly effective new tools to support stockpile stewardship.

This unprecedented computational power is also being made available to the university community through the Academic Strategic Alliances Initiative. Five universities have received initial research awards to investigate projects in such areas as turbulence and shock physics, astrophysical thermonuclear flashes, and numerical simulation of accidental explosions. This research will have stockpile stewardship, basic science, and civilian applications.


**Academic Strategic Alliances Initiative.** *On July 31, 1997, Secretary Peña announced initial awards to five major U.S. universities—Stanford University, California Institute of Technology, the University of Chicago, the University of Utah at Salt Lake, and the University of Illinois at Urbana/Champaign.*

Stockpile Computing provides weapons designers and analysts with computer center operations, model development, and code maintenance services necessary to support the current Stockpile Stewardship Program (SSP) activities. In particular, Stockpile Computing supports the surveillance, maintenance, refurbishment, assessment, and certification of the existing nuclear weapons stockpile by incremental upgrades to models and computing systems, and infusion of ASCI-proven technologies into routine SSP operations.

Stockpile Stewardship utilizes a diverse and distributed complex of facilities to maintain the safety, reliability, and performance of the nation's nuclear weapons. DisCom2 develops and provides the technology needed to deploy an integrated environment that permits the weapons laboratories and production plants to access computing (from desktop to teraops) across thousands of miles. For example, DisCom2 provides for rapid, secure, and verified transmission of engineering design and change information between laboratory scientists and production plant engineers, enabling teams to work on a common problem in real time, simultaneously, with effective visualization and the ability to make adjustments at a distance.

There is a critical need to upgrade the information architecture at the laboratories to make effective use of ASCI teraops computers. NEWS will provide a local computational environment for large numbers of designers and analysts to use high-end simulation capabilities to simultaneously address time-urgent stockpile issues. NEWS upgrades to data archive, network, off-line processor, and visualization capabilities link ASCI computational resources to designers' and analysts' desktops to allow efficient and productive access to limited teraops computer resources.

In addition to replacing and enhancing previous test-based capabilities, there is also a need to demonstrate that the new tools are providing the correct results. V&V provides the tools, methodologies, and data to ensure that the high-end simulation capabilities accurately model physical phenomena. The Department of Energy will be able to demonstrate in many cases that the complex simulations for national security reasons are reliable, that is, have been verified and validated. Reliability is established by external use of comparable codes, applications, and other methods by the oil industry, the academic astrophysics community, and others.

## 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 tritium production technologies as well as enhanced surveillance, advanced manufacturing, and computational simulation and modeling capabilities. Once the 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.

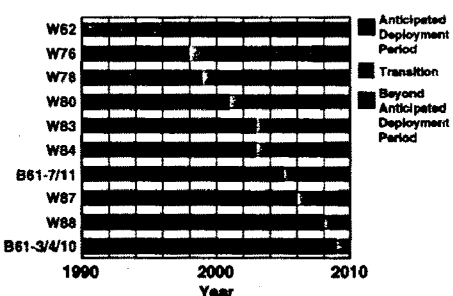
An essential element of maintaining confidence in the stockpile—and in the system that maintains the stockpile—is the informed and vigorous interactions that take place among the laboratories, the Department of Energy, and the Department of Defense and its advisory groups. These include:

- *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 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 the three weapons laboratories, Los Alamos, Livermore, and Sandia—New Mexico and California—independently evaluate the safety and reliability of each warhead. The teams independently review existing calculations and experiments pertaining to the warhead, evaluate relevant stockpile surveillance results and predictive analyses, and perform separate experimental and calculational activities to investigate issues of concern and improve the baseline of understanding. Dual revalidation will be applied to all stockpile warheads, beginning with the W76. The W76 Dual Revalidation is expected to be 2 to 3 years in duration. Upon completion, the DOE and DoD will select the next weapon system for dual revalidation.

- *Stockpile Life Extension Process (SLEP).* The Stockpile Life Extension Process addresses the need to extend 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 refurbishments also provide the opportunity, when 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 Energy and Secretary of Defense formally certify to the President that nuclear testing is not required to assure that the U.S. nuclear




Stockpile Life Extension Process. *Warheads in the enduring U.S. stockpile will be refurbished to extend their stockpile life indefinitely. Life extension options for each warhead type are being defined, allowing the laboratories, plants, and Department of Defense to plan accordingly.*

stockpile is safe and reliable. 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 carries out executive decisions on stockpile actions. The Nuclear Weapons Council, which is supported by a highly specialized staff of military officers, members of the Office of the Secretary of Defense, and the Department of Energy's Assistant Secretary for Defense Programs, also reviews and coordinates the Department of Energy's stockpile plans.

# Stockpile Stewardship Program Accomplishments

More than five years have passed since the last U.S. nuclear test and more than six years since the last new warhead entered the U.S. stockpile. The decision to end nuclear testing and the absence of requirements for production of new warhead designs 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 (SSP).

## Program Architecture: The PEIS

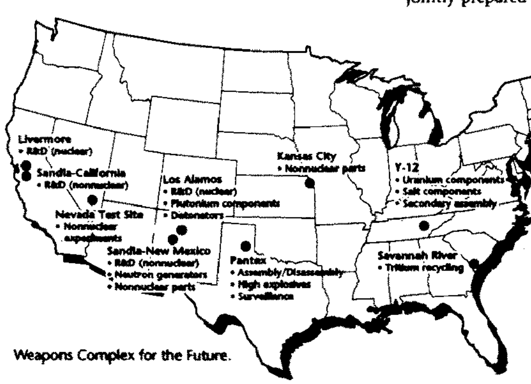
Beginning in May 1995, the Department of Energy held a series of open-to-the-public meetings as part of the process for preparing the Programmatic Environmental Impact Statement (PEIS) for the Stockpile Stewardship Program. Meetings were held at each laboratory and plant site and in Washington, D.C. 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 on December 19, 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 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 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-design warhead production), should future circumstances dictate.

## Implementation Plan: The Green Book

The laboratories and plants have worked with the Department of Energy to develop a detailed implementation strategy for the Stockpile Stewardship Program. This strategy is presented in *The Stockpile Stewardship and Management 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 gaps in necessary capabilities.



Weapons Complex for the Future.

## Administration and Congressional Support: The Budget

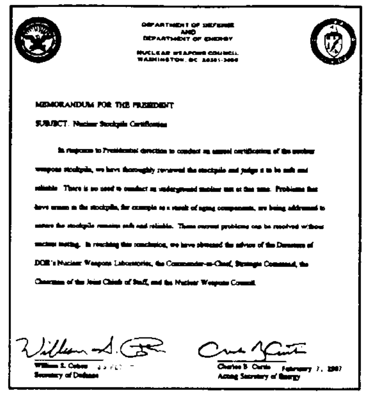
As the President has stated, "In order for this program to succeed, both the Administration and the Congress must provide sustained bipartisan support for the stockpile stewardship program over the next decade and beyond. I am committed to working with the Congress to ensure this support." The President's 1999 budget request will include a five-year plan that meets this commitment. With such budgetary support, the Department of Energy is maintaining confidence in the stockpile while 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 the Department of Energy 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 of Energy 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, the laboratories' Directors, and the Nuclear Weapons Council. The certification that the stockpile is safe and reliable relies on the expert judgment of these senior officials. The first Annual Certification was completed on February 7, 1997. In their letter to the President, the Secretary of Defense and Secretary of Energy stated that they judge the stockpile to be safe and reliable and that there is no need to conduct an underground nuclear test. The second annual certification process is under way and on schedule.

## New Capabilities

Major strides in the development and application of new capabilities to improve stockpile stewardship have been made. 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.



DEPARTMENT OF DEFENSE
AND
DEPARTMENT OF ENERGY

NUCLEAR WEAPONS COUNCIL
WASHINGTON, DC

MEMORANDUM FOR THE PRESIDENT

SUBJECT: Nuclear Stockpile Certification

In response to Presidential direction to conduct an annual certification of the nuclear weapons stockpile, we have thoroughly reviewed the stockpile and judge it to be safe and reliable. There is no need to conduct an underground nuclear test at this time. Problems that have arisen in the stockpile, for example as a result of aging components, are being addressed to ensure the stockpile remains safe and reliable. These current problems can be resolved without nuclear testing. In reaching this conclusion, we have obtained the advice of the Directors of DOE's Nuclear Weapons Laboratories, the Commander-in-Chief, Strategic Command, the Chairman of the Joint Chiefs of Staff, and the Nuclear Weapons Council.

William S. Cohen
Secretary of Defense

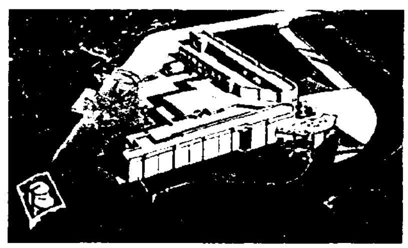
Charles B. Curtis
Acting Secretary of Energy
February 7, 1997

Letter of Certification of the Nuclear Stockpile. *The Secretary of Defense and the Secretary of Energy are required by the President to certify annually the safety and reliability of the U.S. nuclear weapons stockpile.*

**Decisions: DARHT, NIF, Subcritical Experiments, and Tritium Production**

Important decisions were reached regarding two vital new experimental facilities, subcritical experiments, and tritium production.

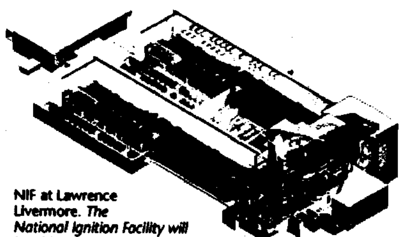
- *DARHT.* The Environmental Impact Statement for the Dual-Axis Radiographic Hydrodynamic Test (DARHT) Facility was completed, and construction is under way at Los Alamos. When completed, DARHT will be the nation's most advanced facility for



DARHT at Los Alamos. *The Dual-Axis Radiographic Hydrodynamic Test Facility, currently under construction, will provide experimental data on the implosion phase of nuclear warhead operation.*

hydrodynamic experiments. These experiments are essential for validating the implosion performance of primaries.

- *NIF.* Lawrence Livermore was selected as the site for the National Ignition Facility (NIF). Engineering design work is under way, and ground was broken for construction on May 29, 1997. This immense laser facility will provide a means for experimentally studying primary boosting. It will also provide important data for assessing secondary performance and weapon effects and for improving and validating new physics models and computer codes.



NIF at Lawrence Livermore. *The National Ignition Facility will be able to simulate weapons-like fusion conditions, a critical experimental capability for maintaining the stockpile without nuclear testing.*

The Department of Energy is also investigating the feasibility of follow-on facilities that may provide additional capabilities to verify and validate the improved simulation models discussed above. To assist in the evaluation of primaries, the Advanced Hydrotest Facility (AHF) is being studied to provide improved understanding of the effects of aging and weaponization features. AHF would expand multipulse, multiaxis radiographic capabilities well beyond those planned for DARHT. To assist in the evaluation of secondaries, a proposed follow-on pulsed-power facility is being studied to extend the range of capabilities for large-scale radiation flow measurements in complex geometries. This builds upon the recent and significant advances in pulsed power resulting from modification of an existing accelerator facility at Sandia National Laboratories. Research on the technology for these facilities is in progress.

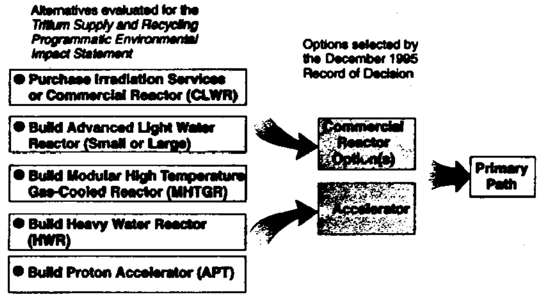
- *Subcritical Experiments.* In April 1997, the Secretary of Energy announced a schedule for subcritical experiments, an essential component of the Stockpile Stewardship Program. The first and second subcritical experiments, "Rebound" and "Holog," were successfully completed at the Nevada Test Site on July 2 and September 18, 1997, respectively. These experiments are providing valuable scientific information about the behavior of nuclear materials during the implosion phase of warhead operation. This information is needed to accurately predict the performance of stockpile warheads as they age.

- *Tritium.* The Department of Energy is pursuing a dual-track production strategy for the most promising tritium supply alternatives: 1) to initiate the purchase of an existing commercial reactor (operating or partially complete) 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 system for tritium production. By late 1998, the Department of Energy plans to select one of the tracks to serve as the primary source of tritium. The other alternative, if feasible, would be developed as a backup tritium source.

Substantial progress has been made for both alternatives since the announcement of the dual-track strategy.

For the Commercial Light Water Reactor Project track: 1) completed and certified the design of Tritium Producing Burnable Absorber Rods, fabricated thirty-two rods, and placed them in the Watts Bar commercial reactor for an 18-month irradiation cycle, 2) the Conceptual Design Report for the Tritium Extraction Facility was completed, independently validated, and issued, and 3) prepared and issued a Request for Proposals from nuclear utilities to sell the Department of Energy a reactor or irradiation services for tritium production. Proposals have been received and are being considered.

For the Accelerator Production of Tritium Project track: 1) the Conceptual Design Report was completed, independently validated, and issued; 2) high-power density irradiation of target/blanket materials was




Dual-Track Tritium Strategy. *The Department of Energy is exploring both an accelerator-based approach and a commercial-nuclear-reactor approach for tritium production for the future.*

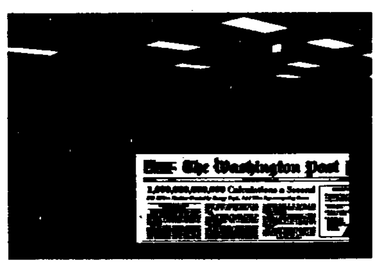
completed; 3) superconducting radio-frequency linear accelerator technology was adopted; and, 4) implementation of a modular approach that allows production flexibility should future tritium requirements change was initiated.

**Strategic Computing and Simulation Advances: Entering the Teraops Era**

Industry has begun delivering the advanced new computers required for ASCI. ASCI's goal is to develop the complex three-dimensional models of weapons operation needed to make the integrated simulations that will provide a digital proxy for nuclear testing as well as provide capabilities needed to address aging and other emerging issues. Intel Corp. and Sandia National Laboratories are working in partnership on the ASCI Red machine, in which thousands of Pentium processors are linked together using a technique known as massively parallel processing. In December 1996, the machine demonstrated record-breaking teraop operation, performing one trillion operations in a second, which made headlines around the world. The system will eventually be made up of more than 9000 processors and will be able to operate at 1.4 teraops.

IBM and Lawrence Livermore National Laboratory are developing the ASCI Blue Pacific machine. Los Alamos National Laboratory and SGI/Cray are developing the ASCI Blue Mountain machine. Both systems are intended to achieve benchmark performance at or above 3 trillion operations per second. At this early stage in their development, advanced ASCI weapons simulation codes are providing unprecedented capabilities to the weapons scientists and engineers. For example, coupled three-dimensional thermal-chemical-hydrodynamic calculations of weapon safety (for example, a weapon in a fire) are now possible. As a practical matter, some standard weapons-related calculations have been performed one hundred times faster than before. Through this initiative, the time it took to run one simulation was reduced from 74 days to 7 hours.

In July 1997, Secretary Peña announced research awards to five major U.S. universities—Stanford University, California Institute of Technology, the University of Chicago, the University of Utah at Salt Lake, and the University of Illinois at Urbana/Champaign. These universities will collaborate with the Los Alamos, Lawrence Livermore, and Sandia National Laboratories on challenging projects that will drive the advancement of large-scale computational modeling.




ASCI Red at Sandia. *The Intel Corporation delivered this advanced, massively parallel processing computer to Sandia National Laboratories in May 1996; in December, it achieved a world-record level of scientific calculational performance.*

## Meeting the Day-to-Day Needs of the Stockpile

The Department of Energy has continued to maintain the U.S. nuclear weapons stockpile. Problems in the stockpile have arisen since the cessation of nuclear testing. Some of these problems are similar to those for which, in the past, nuclear tests were conducted 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.

**Dual Revalidation: The W76**

The W76 dual revalidation is prototyping this formal process for certifying a warhead's conformance with its military characteristics, and obtaining a thorough baseline condition of the weapon. Two separate teams of experts from the weapons laboratories are independently assessing the warhead and combining new computational and experimental investigations with stockpile surveillance results, predictive analyses, and data from past nuclear and nonnuclear tests.

**Stockpile Life Extension Process: The W87**

The W87 life extension process incorporates changes to enhance the structural integrity of the warhead. Engineering development is proceeding and includes above ground experiments high-fidelity flight testing. The effect of the proposed design changes on the warhead's performance is being assessed using the latest computational models, supported by the existing nuclear and nonnuclear test database and laboratory experiments. Experience gained in the W87 and refurbishment will guide future life extension activities for other stockpile warheads.

**New Process Qualification: Gas Reservoirs at Kansas City**

Production of tritium gas reservoirs was moved from the Rocky Flats Plant to the Kansas City Plant. Kansas City is now responsible for manufacturing gas reservoirs for all warheads in the enduring stockpile. Development and qualification of the production processes are under way. This past year, the gas reservoir production programs for two warhead systems—the W76 and the W80—were qualified. Qualification of this critical production capability demonstrates that the risks inherent in consolidating and downsizing the production complex can be successfully managed and mitigated.

**New Production Capability: Neutron Generators at Sandia**

The production responsibility for neutron generators has been successfully transferred from the Pinellas Plant to Sandia–New Mexico. The new production facility was dedicated in July 1996, and approximately 364 units will be recertified in 1997. This new facility will support both production requirements and research and development for new extended-life neutron generators. In support of Sandia production efforts, Los Alamos has developed the capability for tritium loading the targets needed for the neutron tubes.

**New Production Capability: Nonnuclear**

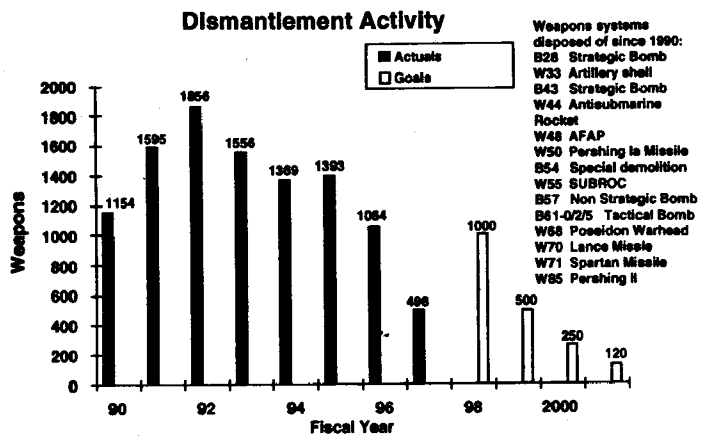
Under the Nonnuclear Reconfiguration Initiative, a number of production responsibilities have been transferred from the Mound, Pinellas, and Rocky Flats plants to Los Alamos National Laboratory in addition to the Neutron Tube Target Loading assignment. The production responsibility for detonators has been successfully transferred and the capability is being installed. Los Alamos also has responsibility for producing beryllium components and nonnuclear pit parts.

**Limited Pit Production Capability at Los Alamos**

The responsibility for pit surveillance and pit manufacture has been transferred from the Rocky Flats Plant to Los Alamos. A pit surveillance capability has been established and pit evaluation was initiated this year. Limited pit manufacturing will now be done at Los Alamos. The first demonstration W88 replacement pit is scheduled to be produced in 1998.

**Weapon Dismantlement**

Dismantlement of the Cold War arsenal is being carried out as the Department of Energy continues to develop the enhanced capabilities and facilities needed to support the enduring U.S. stockpile. As a result of the START I treaty and separate Presidential decisions, thousands of




Weapons Dismantlement at Pantex. *Nuclear warhead assembly and disassembly is performed only at the Pantex Plant.*

weapons have been removed from the U.S. stockpile and are slated for dismantlement. More than 1000 weapons were dismantled in 1996, and nearly 500 weapons will be dismantled in 1997.

### Successful Application of the SSP Model: The B61 Mod 11

Replacement of the B53 with the B61 Mod 11 has improved the inherent safety of the U.S. stockpile. The B53 gravity bomb was the oldest weapon in the stockpile and was produced before modern safety features were developed. By modifying a small fraction of the existing B61 Mod 7 bombs, the Department of Defense can retire the B53 from the stockpile while still meeting its mission requirements.

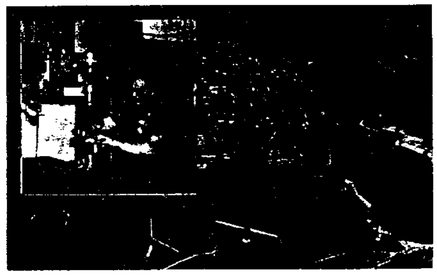
Conversion of B61 Mod 7s to Mod 11s requires replacement of the radar nose and center case with a one-piece hardened steel nose and replacement of the parachute in the bomb's tail assembly with steel ballast parts and a drag flare to change the flight characteristics of the weapon. The Department of Energy authorized these changes in December 1995. The tail case subassembly retrofit was assigned to Kansas City and the nose case replacement to the Oak Ridge Y-12 Plant. A very tight schedule called for delivery of the first conversion kit one year later, in December 1996.

Teams from Los Alamos, Sandia–New Mexico, and the production plants addressed and defined appropriate qualification tests and analyses for certifying the acceptability of the modified bomb and its new delivery conditions. A number of successful flight tests confirmed that the modified warhead will perform as expected and can be deployed as a replacement for the B53.

Because of the tight schedule and an already heavy workload in its machining facilities, Kansas City procured a number of parts for the tail case subassembly from commercial vendors. Assembly of the modified tail case was done at Kansas City. The first conversion kit was delivered ahead of schedule, in November 1996.

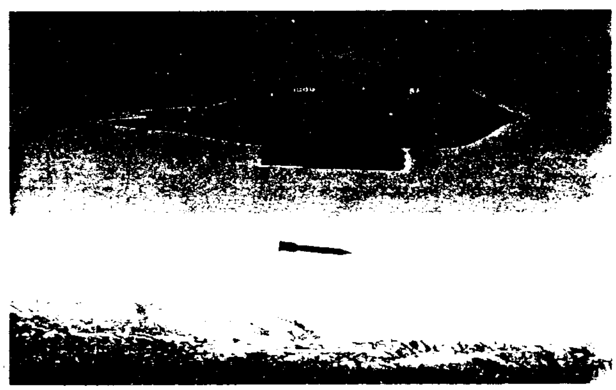
The accelerated schedule presented challenges to the Oak Ridge Y-12 Plant as well, particularly because a number of critical operations had to be restarted from an extended stand-down. Numerous issues related to the replacement nose case had to be resolved during production. The first conversion kit of the replacement nose case was shipped in mid-December 1996, two weeks ahead of schedule.

The conversion of B61 Mod 7s to Mod 11s successfully demonstrated many aspects of the Stockpile Stewardship Program. Integration of design and production engineering was a key factor in meeting the tight schedule. Teamwork between the laboratories and the plants and between the plants and commercial vendors allowed the Department of Energy to deliver the modified warhead in under a year (as opposed to two to three years for a retrofit under the old paradigm). In years past, the Department of Energy would likely have conducted at least one nuclear test to validate the modified bomb. However, because nuclear-test- and design-experienced people and all necessary computer analysis and other required data were available at both the plants and the laboratories, the B61 Mod 11 could be certified and put into the stockpile without a nuclear test.



B61 Mod 11 Nose Case at Oak Ridge Y-12. *The nose case replacement for the B61 Mod 11 was assigned to the Y-12 Plant. Despite the need to restart critical operations from an extended stand-down, Y-12 delivered the first conversion kit of the modified nose case two weeks ahead of schedule.*

With the successful completion of the B61 Mod 11, the Department of Energy has gained experience and confidence in the Stockpile Stewardship Program. This project confirmed the value of the new approach to manufacturing. In particular, it confirmed the feasibility of stockpile modernization via retrofitting and life extension of existing warheads. It also showcased the Department of Energy's ability to respond rapidly across the entire weapons complex to an important stockpile issue.



**The B61 Mod 11.** ***Modifications to the B61 warhead made it possible for the Department of Defense to retire the B53 (the oldest warhead in the stockpile) while still meeting its mission requirements. Validation of this modified warhead provided a model of the use of the stockpile stewardship approach to maintaining a safe and reliable nuclear deterrent without nuclear testing or new-design warhead production.***

## Conclusion

Under the Stockpile Stewardship Program, the Department of Energy's goal is unchanged from previous years—namely, to provide high confidence in the safety, reliability, and performance of the U.S. nuclear warhead 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, the Department of Energy must be able to mitigate the loss of critical expertise that will result from the retirement of nuclear-test- and design-experienced weapons 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.

As previously described, taking full advantage of the capabilities of the Stockpile Stewardship Program, the aged B53 bomb was replaced with a modified B61 equipped with modern safety features, and several other weapons system problems that would have previously required a nuclear test were resolved. These major achievements and the related progress being made to develop nonnuclear experimental facilities and enhanced computational capabilities provide ample evidence that the Stockpile Stewardship Program will be successful and will enable the Department of Energy to continue to maintain high confidence in the safety, reliability, and performance of the enduring U.S. nuclear deterrent.

**Prepared by:**
Office of the Assistant Secretary for Defense Programs
U.S. Department of Energy
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Washington, DC 20585

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# Report to Congress on Stockpile Reliability, Weapon Remanufacture, and the Role of Nuclear Testing

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October 1987

Lawrence Livermore National Laboratory

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## Contents

# Report to Congress on Stockpile Reliability, Weapon Remanufacture, and the Role of Nuclear Testing


## Abstract

This report has been prepared in response to a request from Congressmen L. Aspin, N. D. Dicks, D. B. Fascell, E. J. Markey, and J. M. Spratt, and Senator E. M. Kennedy, to Dr. Roger Batzel, the Director of the Lawrence Livermore National Laboratory (LLNL). Dr. Batzel was asked to make Dr. Ray Kidder available to study two issues: (1) "whether past warhead reliability problems demonstrate that nuclear explosive testing is needed to identify or to correct stockpile reliability," or (2) "whether a program of stockpile inspection, nonnuclear testing, and remanufacture would be sufficient to deal with stockpile reliability problems." In his response, Dr. Batzel indicated that Dr. Kidder would be available to perform the requested study, and that materials would be made available to him for his review. Dr. Batzel also indicated that Dr. George Miller, Associate Director for Defense Systems at LLNL, would prepare a separate report analyzing the issues. This report presents the findings of Dr. Miller and his coauthors.

Chapter 1 examines the reasons for nuclear testing. Although the thrust of the request from Congressman Aspin et al., has to do with the need for nuclear testing as it relates to stockpile reliability and remanufacture, there are other very important reasons for nuclear testing. Since there has been increasing interest in the U.S. Congress for more restrictive nuclear test limits, we have addressed the overall need for nuclear testing and the potential impact of further nuclear test limitations.

Chapter 1 also summarizes the major conclusions of a recent study conducted by the Scientific and Academic Advisory Committee (SAAC) for the President of the University of California; the SAAC report is entitled, "Nuclear Weapon Tests: The Role of the University of California-Department of Energy Laboratories." The SAAC spent many days at LLNL and LANL in direct discussions with numerous experienced weapon design personnel. They received classified briefings and read classified material on the subjects of weapon reliability, the role of nuclear testing, and the measures the Laboratories have been taking to prepare for further nuclear test limitations. There was much interchange and discussion on these topics. The depth of the SAAC study far exceeds that of any other independent review of these topics.

Chapter 2 presents a brief history of stockpile problems that involved post-deployment nuclear testing for their resolution. Chapter 3 addresses the problems involved in remanufacturing nuclear weapons, and Chapter 4 discusses measures that should be taken to prepare for possible future restrictive test limits.

# Executive Summary

This report was prepared in response to a request from Congressmen L. Aspin, N. D. Dicks, D. B. Fascell, E. J. Markey, and J. M. Spratt, and Senator E. M. Kennedy (see Appendices A and B). We address their questions of "whether past warhead reliability problems demonstrate that nuclear explosive testing is needed to identify or to correct stockpile reliability, or alternatively, whether a program of stockpile inspection, nonnuclear testing, and remanufacture would be sufficient to deal with stockpile reliability problems."

The answer to the first question is "yes." Past experience indicates that nuclear testing is necessary to identify and correct problems in the stockpile. Although we have learned from each case, some problems have been very recent. Therefore, we believe that for the foreseeable future, continued nuclear testing will be necessary to maintain stockpile reliability.

The answer to the second question is a qualified "yes" over the short term and a definite "no" over the longer term. Over the short term, experienced scientists and engineers would probably be able to deal with stockpile reliability concerns about as well as they do now; we currently have a high level of confidence in the stockpile, but some problems do arise. The "short term" is the time it takes for the scientific judgment and expert capabilities of weapon scientists and engineers to atrophy in the absence of nuclear test experience. This time may be as short as three to five years, as we found during the Nuclear Test Moratorium of 1958–1961 (Reference 1). Measures taken to prepare for further test restrictions can slow the erosion of capability but they cannot stop it.

Before one can assess whether further nuclear test limitations are advisable, the technical and national security issues involved must be thoroughly addressed. Only then can the risks and benefits of additional nuclear testing constraints be evaluated. In this report, we present our views on the technical issues, supported by historical and technical facts, many of which are presented for the first time in an unclassified publication.

## Nuclear Testing in the Context of U.S. Policy

The debate about nuclear testing has focused mostly on the issue of stockpile reliability. The discussion should, in fact, be much broader and examine the role of nuclear testing in the context of the U.S. policy of deterrence. Current U.S. strategy is to deter nuclear and conventional war by maintaining a credible and effective retaliatory capability that can respond in a limited and proportional way to an act of aggression. Deterrence thus is a dynamic condition and, as such, must be responsive to military and technological developments.

Nuclear testing supports deterrence in four important ways. First, nuclear tests are required to maintain the proper functioning of the stockpile. Second, nuclear tests are needed to modernize the existing stockpile for enhanced safety, security, and effectiveness. The advance of Soviet technologies, most of which are nonnuclear, requires the modernization of U.S. weapon systems to ensure their survivability. Examples of such modernization needs are the mobile small ICBM (SICBM), the longer range Trident II submarine-launched ballistic missile, and the fast, low-flying B-1B bomber; nuclear testing is needed to verify the warheads for these systems. Third, nuclear tests are required to measure the effects of a nuclear weapon environment on U.S. weapon systems and on critical command, control, and communications systems. Finally, nuclear tests make it possible to identify future weapon concepts for U.S. decision-makers and to stay abreast of potential Soviet nuclear weapon developments, thus avoiding technological surprise. While these reasons for testing are all vitally important, in this report we focus on the issues related to stockpile reliability.

## The Need for Nuclear Testing to Resolve Stockpile Problems

The reliability of U.S. nuclear weapons is currently very high because we have been able to sustain a balanced program of weapons physics tests, stockpile confidence tests, and production verification tests. At issue are the conditions for maintaining high confidence in this reliability. Experience has shown that testing is essential. One-third of all the weapon designs placed in the U.S. stockpile since 1958 have required and received post-deployment nuclear tests to resolve problems. In three-quarters of these cases, the problems were identified as a result of nuclear testing. The important point here is that in each case, the weapon was thought to be reliable and adequately tested when it entered the stockpile. Problems resulted from aging, from concerns about safety, from environmental effects, or from a later realization that our understanding of the weapon's physical behavior was incomplete.

Let us emphasize that although a number of weapons in the stockpile have required nuclear tests to evaluate or correct problems, *most* of the problems encountered with the stockpile have been fixed *without* nuclear tests to certify the changes. This has been possible only because the designers and engineers involved could make informed judgments about the problem—judgments that drew on years of experience in actual nuclear testing. Nuclear testing, thus, has a vital role in assuring confidence in *all* U.S. nuclear weapons.

Some have claimed that many of the stockpile problems were the result of deploying weapons that were not "thoroughly tested." There is no such thing as a "thoroughly tested" weapon. Budgetary limitations make it impossible to test nuclear weapon designs under all possible conditions (e.g., delivery environments, defensive threat levels, target requirements, storage histories, safety and security requirements). When a weapon is developed, we test it as thoroughly as we judge to be appropriate to define the boundaries of reliable operation. We conservatively balance factors affecting reliability against those affecting cost. However, not all of the important factors may be known or assessable ahead of time. We test to the level of performance required to meet the military characteristics (MCs) specified by the Department of Defense (DOD).

The military characteristics are prepared by the DOD to specify the requirements for each nuclear warhead. These requirements include, in order of priority, nuclear safety, size and weight, plutonium dispersal safety, operational reliability, yield, conservative use of nuclear materials, and operational simplicity. In the event that compliance with the MCs leads to a design conflict, priorities are to be observed in the order listed, with tradeoffs that allow high-priority MCs to be met while minimizing the degradation of the competing, lower-priority MCs. In 1982, the DOD established an unprioritized MC for stockpile endurance and replicability; these are stated to be *desirable* goals to be achieved to the extent possible while meeting the other MCs.

Claims have been made that the success with which we predict the yield of new nuclear devices in their first nuclear tests indicates the reliability and surety of weapon performance. It would, however, be misleading to judge stockpile reliability on this basis. Our success with first-time predictions is indeed high. There are reasons for this. First, the designers making the predictions either have extensive test experience themselves or their work is reviewed by senior designers with extensive experience. Second, most new designs are based on fairly conservative, previously established technology. For the first test of a variation of this technology, our designers build safe margins into the design. It is later, when the designers begin to optimize a device for its intended weapon application, to study it at environmental extremes, or to incorporate structural, safety, or security features, that margins are reduced and performance sometimes falls short of prediction.

## Weapon Remanufacture and the Need for Nuclear Testing

The difficulties involved in "replica" remanufacture have been faced by all major U.S. industries—aerospace, automobile, chemical and materials, and engineering, as well as nuclear weapon design and fabrication. Experience with attempts at remanufacturing in all these industries can be summarized in three important conclusions.

First, exact replication, especially of older systems, is impossible. Material batches are never the same; some materials become unavailable; equivalent materials are never exactly equivalent; "improved" parts often have new failure modes; different people (not those who did the initial work) are involved in the remanufacturing; vendors go out of business or stop producing some products; new health and safety regulations prohibit the use of certain materials or processes.

Second, documentation has never been sufficiently exact to ensure replication. A perfect specification has never yet been written. We have never known enough about every detail to specify everything that may be important. Individuals in the production plants learn to bridge the gaps in the specifications and to make things work. Even the most complete specifications must leave some things to the individual's common knowledge; it would be an infinite task to attempt to specify all products, processes, and everything involved in their manufacture and use. Experts believe that it would be extremely difficult to improve documentation enough to ensure replication by inexperienced personnel.

Third, testing is the most important step in product certification; it provides the data for valid certification. A nuclear test provides our only data on the performance of the whole nuclear warhead package. Tests, even with the limitations of small numbers and possibly equivocal interpretation, are the final arbiters of the tradeoffs and judgments that have been made. They force people to ask the right questions.

Today, design physicists and engineers *with extensive nuclear test experience* at the relevant yield levels could undertake a weapon remanufacture with confidence that the weapon would perform about as well as the original version. However, even such a group has had difficulty predicting the behavior of some weapons recently manufactured for the stockpile—in particular the W68 Poseidon warhead and the W84 warhead for the ground-launched cruise missile. (The W68 was a remanufactured weapon.) In both cases, measured yields fell short of the predictions made by test-experienced weapon designers on the basis of production specifications. Even in retrospect and taking into account the minor changes known to exist between the development and stockpile hardware, we have not yet been able to explain the causes of these yield degradations. The nuclear tests uncovered gaps in our knowledge and revealed that important and as-yet-unidentified production details should have been specified.

The W68 and W84 are relatively recent weapons. The documentation and specifications for older weapon systems are less complete. Although documentation has improved since the MC for replicability was established in 1982, our experience with the W68 and W84 demonstrates that the specifications are still insufficiently complete to prevent subtle but apparently significant variations from taking place. Improved documentation will be helpful in remanufacturing the newer weapon systems. However, confidence in their performance would be lacking if they are placed in the stockpile without relevant nuclear testing and without certification by test-experienced physicists and engineers.

It is important to emphasize that in the manufacture of nuclear weapons, we are dealing with *practical* problems. Idealized proposals about what we should be able to do, without a proper experience base, are prescriptions for failure.

## The Importance of Scientific Judgment and Continuity of Experience

Nuclear weapons are extremely complicated, and they operate at conditions that are virtually unique—at material velocities of millions of miles per hour, under temperatures and pressures that are hotter and denser than the center of the sun, in time scales as short as a few billionths of a second. Because of the complexity of nuclear weapons and the limited rate at which they are tested, nuclear weapon design is largely an empirical science. Thus assessments of weapon performance—whether for stockpile inspection, new design, or remanufacture—depend primarily on scientific judgment.

It takes years for designers to gain the experience on which they base their scientific judgment. This judgment must be continually cultivated by the application of theory and experiment to device design and refined with data from nuclear tests. We strive to maintain a continuous line of experienced designers, as senior designers pass on their knowledge to younger designers. This continuity of experience is of paramount importance.

We expect, in the event of very restrictive test limits, that in only a few years we would start to lose the test-experienced people. After a while, the people whose judgment has been honed by the realities of nuclear testing would no longer be available—they would have retired or moved on to other fields. We would then be faced with the prospect of asking scientists without nuclear testing experience to make judgments about the inevitable changes that will occur in remanufactured or stockpile weapons. This is a script for failure. If today, test-experienced personnel have difficulty explaining unexpected behaviors in the nuclear weapons they themselves have designed, how in the future will personnel without test experience be able to establish confidence in weapons designed by people long since gone?

## Preparing for Further Nuclear Test Limitations

We are continually studying ways to prepare for further nuclear test limitations so that we can maximize our ability to meet our responsibilities for ensuring the reliability and effectiveness of U.S. nuclear weapons. A number of measures could help alleviate the impact of additional test limitations, if they are vigorously pursued *before* such restrictions are imposed. However, it is important to emphasize that, irrespective of any amount of preparation, further test restrictions will adversely affect confidence in the U.S. nuclear weapon stockpile. In addition, there is no way to ensure that the effect will be symmetric between the U.S. and the Soviet Union. The risk of such a loss in confidence needs to be carefully weighed against the potential political gains of new testing limitations.

Nuclear tests have played a necessary role in helping us meet our responsibilities to ensure the reliability and effectiveness of the stockpile. The need for increased nuclear testing to prepare for new test limits was most recently recognized in 1980 as part of the Augmented Test Program (ATP), planned at the request of the Office of Science and Technology Policy and in response to a memorandum from the National Security Council. The underlying purpose of the ATP was to prepare for a Comprehensive Test Ban (CTB) by placing "early emphasis on those areas of science and technology that contribute most to reliability and confidence of the stockpile."

President Carter approved the ATP in principle, but he did not submit it to Congress for explicit approval and funding. Although in the years since then, there has been some additional funding for nuclear testing, most of this increased funding at LLNL has been earmarked for nuclear-driven directed-energy programs for the Strategic Defense Initiative (SDI); we cannot simultaneously sustain high levels of research on both SDI and weapon physics with the current level of funding. We believe that it would be advisable to consider the equivalent of an ATP at this time. If such a test program is to be successful and avoid the fate of the 1980 ATP, it requires Congressional endorsement, and sustained support will be imperative.

Measures to prepare for more restrictive limits and to help mitigate the problems caused by more restrictive limits include nuclear tests to provide assurance about the reliability of the current stockpile, verify the production of new weapons, and improve our understanding of weapon physics. Expanded nonnuclear experimental facilities, such as expanded hydrodynamic capabilities and a High-Gain Test Facility for fusion research, and advanced computing and numerical modeling capabilities would provide valuable supplements to nuclear test data. Also helpful would be programs to investigate means of certifying nuclear components at reduced yields as well as nonnuclear projects that use some of the same skills as the current nuclear weapon programs. In addition, nuclear weapons might be designed to reduce the likelihood of material degradation with age or to permit modification with less uncertainty about their resulting performance. We are pursuing all of these measures to the extent that funding and the DOD's military characteristics allow.

With the optimized stockpile that we presently possess, nuclear testing has played a key role in maintaining confidence in reliability. It should be mentioned here that with direction, support, and a sustained testing and production program, the stockpile could be reconfigured to be less reliant on (but not totally free from) nuclear testing to maintain reliability. Such an effort would deal only with the testing issues associated with reliability and would not address issues of future modernization. Such a decision would have a significant impact on the cost and capability of the weapon delivery systems since the reconfigured stockpile would generally consist of larger, heavier nuclear systems.

Let us emphasize, however, that in preparing for future, more restrictive test limits, these measures have only limited value. Nonnuclear and low-yield nuclear experiments can maintain some weapon skills but they cannot be used to solve weapon problems. Computer calculations have yet to (and may never) reach the stage where they can replace nuclear tests. These measures provide little guarantee that we will be able to fix future stockpile problems or address new military requirements. They can help slow the erosion of scientific expertise and judgment. They cannot stop it.

## SAAC Review of Nuclear Weapon Testing

The Scientific and Academic Advisory Committee (SAAC) advises the President and the Regents of the University of California on matters concerning the Livermore and Los Alamos National Laboratories. Earlier this year, the SAAC was asked to conduct a study on nuclear weapon tests and the role of the University of California–DOE laboratories (Reference 2). The committee spent many days at both laboratories and met with experienced weapon designers, physicists, and engineers. The SAAC came to a number of major conclusions that independently support the technical points we have made above. In particular, they confirmed the historical need for nuclear testing to maintain confidence in the reliability of the stockpile. They noted the continued occurrence of problems requiring nuclear tests to resolve, and they acknowledged the impossibility of "thoroughly testing" nuclear weapons under current test limits and funding levels. They recognized that the laboratories could develop more robust warheads if the military characteristic for warhead endurance were given a specific high priority. The SAAC acknowledged that the laboratories have been making concerted efforts to prepare for a CTB. They highlighted the serious need to maintain qualified personnel with scientific expertise during a CTB.

## Conclusion

We believe that if further nuclear test limits are determined to be desirable, then a detailed study of the feasibility and impact of reducing our reliance on underground nuclear testing is needed. Such a study should be done in the context of the overall arms control environment. The study would investigate the changes in nuclear design that might have to be made and the military capabilities that might have to be relinquished in order to develop more robust warheads. These issues must be addressed to determine what could or could not be accomplished under more restrictive test limits.

We are not ready today for significantly reduced nuclear test limits. Until we can find ways to meet our responsibilities for ensuring the reliability and effectiveness of U.S. nuclear weapons and ways to prevent the erosion of nuclear weapon expertise and judgment under restrictive nuclear test limits, it would be imprudent to commit this country to a regime of further nuclear test limitations.

# Chapter 1. The Need for Nuclear Testing

For such an important issue as nuclear testing, it is necessary to understand clearly the technical issues so that an appropriate evaluation of the risks and benefits of additional nuclear testing constraints can be evaluated. This report demonstrates, through multiple examples, that to guarantee excellence in our nuclear stockpile, we must maintain an expert group of test-experienced scientists and engineers, well-versed in the practical details of nuclear weapon development and testing.

The issues surrounding further restrictions on nuclear testing must be examined in the context of overall U.S. policy. The present U.S. nuclear policy is fundamentally one of deterrence. There is a lack of consensus as to the nature of deterrence; the spectrum of thought ranges from that of "minimum" deterrence, which proposes that deterrence is maintained by a few survivable nuclear weapons which threaten the opponents' population and industrial centers (Reference 3), to calculated deterrence, which deters limited and full-scale attacks by threatening counters at the appropriate level to acts of aggression (Reference 4). The strategy to implement the latter concept of deterrence is called "Countervailing Strategy," which was stated clearly by Secretary of Defense Harold Brown under President Carter (Reference 5) and later adopted by President Reagan. Deterrence is a very dynamic condition and must be flexible and responsive to nuclear and nonnuclear military and technological developments. Such developments include increased levels of air defenses and antisubmarine warfare, changing target characteristics (like hardening), and threats (like missile accuracy) to the survivability of U.S. forces.

Nuclear weapon testing supports deterrence in four basic ways. First, testing is done to maintain the proper functioning of the current stockpile of weapons. Second, testing is done to modernize the existing stockpile for enhanced safety, security, or effectiveness or in response to the changing Soviet threat. Third, testing is done to measure the effects of nuclear weapons and ensure the survivability of our weapon systems and critical command, control, and communications which might be attacked by adversarial nuclear weapons. Finally, testing is done to avoid technological surprise by analyzing the feasibility of future options to the national decision-makers and to keep abreast of potential nuclear weapon developments of our adversaries.

Modern U.S. nuclear weapons are complex technological objects that have been optimized and tightly integrated into an overall weapon system. Nuclear weapons operate at conditions which are virtually unique: material speeds are millions of miles per hour, the temperatures and pressures are higher than at the center of the sun, and the time scales are billionths of a second. These conditions cannot be generated in the laboratory.

Nuclear warheads are designed to be enduring and robust; however, there is no such thing as a "thoroughly tested" nuclear weapon. Unlike the sampling program that tests thousands of transistors or the continuous exercise of aircraft, a nuclear weapon is usually nuclear tested fewer than ten times during its 20-year lifetime and hopefully is never "operated." The life history of any other piece of military hardware is filled with continual testing followed by small changes to correct deficiencies or to extend its applicability to new systems. Nuclear weapons involve technologies that are very different in character from most modern technology, and the resources have not existed to test them in all of the stressing environments to which they might have to be subjected.

## Stockpile Reliability

The reliability of U.S. nuclear weapons is high compared to most high-technology systems. The issue here is "What are the necessary conditions for maintaining high confidence and reliability?"

Nuclear weapons are fabricated from chemically and radiologically active materials. Much as a piece of plastic becomes brittle when it is left in the sunlight, nuclear weapons age and their characteristics change in subtle, often unpredictable, ways. Testing is sometimes required to find problems and to assess the adequacy of the fixes that are implemented. Experience has shown that testing is essential. One-third of all the weapon designs introduced into the stockpile since 1958 have required and received post-deployment nuclear tests to resolve problems related to deterioration or aging or to correct a design that is found not to work properly under various conditions (see Chapter 2). In three-fourths of these cases, the problems were discovered only because of the ongoing nuclear testing. Because we frequently have difficulty understanding fully the effects of changes, particularly seemingly small changes, on the nuclear performance, nuclear testing has been required to maintain the proper functioning of our nation's deterrent. All systems that have been introduced into the stockpile have required experienced people to assess known or suspected problems.

A fundamental issue is the quality of our scientific judgment. Since nuclear weapon design is still largely an empirical science, a designer's competence is based on years of nuclear test experience in all categories—advanced development, weapon physics and stockpile confidence tests. Without this relevant nuclear test experience, nuclear weapon scientists will lack the necessary information to resolve many kinds of problems that might occur.

There is growing pressure in the Department of Defense (DOD) and the Congress for greater reliability testing of systems such as radar, airplanes, and rockets. At the same time, there have been proposals for much lower nuclear test yield thresholds. Such proposals are somewhat like a limit on solid rocket boosters allowing partial tests of first stages, but only one second stage test per year, and no tests of all three stages. Such a program—whether rockets or warheads—would eventually result in a loss of reliability as well as an exodus of experienced people. Even now, with our limited nuclear test schedule and natural turnover in staff, we suffer from a lack of experienced personnel.

## The Need to Meet the Military Characteristics

Within the constraints of the military requirements, the weapons in the stockpile and currently under development have been conservatively designed to avoid, as best as possible, the adverse effects of aging. Correcting a problem in the stockpile is extremely expensive and time-consuming. Scientists and engineers strive to make their designs durable and robust against foreseeable conditions encountered in the course of a weapon's lifetime. However, tradeoffs must be made to meet the military requirements.

It has been argued that nuclear weapons could be designed to be more robust than they are now to the effects of aging. We have begun a program to study what more could be done. This is difficult since future problems are unknown. In specifying the requirements for new nuclear warheads, the DOD prepares a set of military characteristics (MCs) that define the requirements. These requirements include, first and foremost, nuclear safety, and then, in order of priority, size and weight, plutonium dispersal safety, operational reliability, yield, conservative use of nuclear materials, and operational simplicity. A separate, unprioritized MC for stockpile endurance and replicability was established in 1982. In the event that compliance with the MCs leads to a design conflict, the DOD requires that priorities be observed in the order listed, with considerations given to tradeoffs that allow high-priority MCs to be met while minimizing the degradation of the competing, lower-priority MCs. We have done the best job we can today to meet the MC for stockpile endurance and replicability. We go to great lengths to maximize weapon durability by means of material compatibility studies, accelerated aging tests, and conservative engineering practices. In fact, when asked, we have successfully extended the lifetimes of a number of nuclear weapon systems.

If stockpile endurance had been the highest priority or the only priority, it is likely that the designs would have been different. Changes in priorities could have led to different military systems—missiles or other platforms with different throw-weights, ranges, accuracies, and operational flexibility. The economic impact of these changes would have been substantial. However, different, more conservative designs would fail to provide absolute assurance of avoiding further nuclear testing. On the other hand, they would probably reduce the need for testing or extend the time over which our designers and political leaders retained confidence.

## Modernization

The direction and emphasis of the U.S. modernization program have often been poorly understood. The primary focus of U.S. modernization is on the enhanced safety, security and survivability of our nuclear deterrent forces. Contrary to popular belief, modernization of the U.S. nuclear stockpile has led to a reduction in the numbers of nuclear weapons by nearly 25% and in the total destructive yield by 75% while simultaneously maintaining adequate security for the country. This reduction in numbers and yield, together with enchancements in safety and security, would not have been possible without nuclear testing.

It is obvious that as long as we have nuclear weapons, they must be safe and secure. Yet restrictive nuclear test limitations could preclude needed changes to the stockpile in these important areas. Although there have been no nuclear accidents involving the U.S. stockpile, there have been accidents which involved the detonation of high explosive and dispersal of radioactive plutonium. We have now developed a new high explosive, called insensitive high explosive (IHE), that would not have detonated in these accidents. The U.S. has begun to deploy IHE in stockpiled weapons, but IHE has been incorporated in only one-third of our nuclear systems. Because IHE performs much differently from past explosives, weapons being retrofitted with IHE must be completely redesigned and tested.

Modernization has also been required to develop weapon systems to counter new technological developments, mainly nonnuclear, by our adversaries. For example, Soviet advances in air defense prompted the development of the B-1B bomber, the air-launched cruise missile (ALCM), and a new version of the short-range attack missile (SRAM-II). A new laydown bomb was needed for the B-1B to enable it to drop its payload at low altitudes and high speeds and escape the resulting explosion; the B83 bomb was developed with nuclear testing to satisfy this need. The ALCM was developed to allow U.S. bombers to launch their retaliatory strike outside the perimeter of Soviet air defenses; the ALCM needed a new warhead and this required nuclear testing. The SRAM-II is needed to allow our bombers to more effectively penetrate the Soviet air defenses; its warhead is currently under development and further nuclear testing will be needed.

Soviet advances in antisubmarine warfare prompted the development of the Trident submarine, which is capable of operating in a much larger ocean area than its predecessor, the Poseidon submarine. The Trident needed a new missile, the Trident II, with a longer range commensurate with the submarine's increased operating area. In order to optimize the system, the Trident II missile needed a new warhead which was developed with nuclear testing.

Increased accuracies of Soviet ICBMs have placed our land-based missiles at risk to a Soviet first strike. This has prompted the development of the small ICBM (SICBM), which provides increased survivability through mobility. The current version of the SICBM calls for the missile to carry a single warhead, perhaps a variant of the W87 MX warhead. However, nuclear testing will be needed to certify the variations and the new production lot of the W87. If future versions of the SICBM carry more than one warhead, a new warhead will probably have to be developed to optimize the system and maximize the ground mobility of the missile. The new warhead would also have to meet the mission requirements of the new missile system, and this will require further nuclear testing.

To avoid being caught by technological surprise, we must retain the capability to develop new systems in response to new developments by our adversaries. The new systems will often require nuclear testing. Even if an existing warhead is used in a new system, a nuclear test within current yield limits is extremely important, both to ensure that revised packaging or environmental conditions do not affect warhead function and to verify the adequacy of the new production lot. Restrictive test limitations would limit the evolution of nuclear weapons, including improvements in safety, security, and survivability. We believe that weapon modernization can be stabilizing globally and can be synergistic with major arms reduction agreements.

## Weapons Effects Testing

A critical part of our nuclear test program is testing the effects of nuclear weapons on a vast array of military equipment. Of particular importance are the nonnuclear components of our strategic weapon systems, warning sensors, and communications equipment that might have to work in a nuclear environment. If deterrence is to work, our forces must not present a vulnerable target to the Soviets and perhaps encourage them to take advantage of our vulnerability in a crisis. As in the testing of nuclear weapons themselves, we are frequently surprised by the results of nuclear effects testing on nonnuclear equipment that has previously been exposed to nonnuclear simulations of nuclear effects. Changes and subsequent nuclear testing are often required to certify that these important elements of our deterrent system will indeed be able to function properly. Aboveground nonnuclear simulators attempt to replicate discrete nuclear effects, they cannot replicate the nuclear environment itself. The intensities, spectrum, and the synergistic effects of the various kinds of nuclear and electromagnetic radiation (e.g., EMP) can only be produced by a nuclear explosion.

## Nuclear Testing and SDI

If our deterrent strategy is to provide stability between the U.S. and the Soviet Union, we must avoid technological surprise with respect to the threat we are facing. Nuclear-driven directed-energy weapon (NDEW) research, as part of the Strategic Defense Initiative (SDI), provides insight into this issue.

An NDEW attempts to use a nuclear bomb as a power source to drive a directed-energy device, such as a laser or a particle beam. The primary focus of our current research is to determine the viability of such NDEW concepts in the hands of the Soviets to defeat or significantly alter a U.S. nonnuclear strategic defense system or to attack our strategic retaliatory forces as part of a Soviet first strike. Said another way, the research is directed toward threat definition and avoidance of technological surprise. We do not know how far the Soviet NDEW research has progressed; we need to know what is possible and how to defend against it.

The restrictive test limits that have been proposed would virtually halt progress on investigating the weapon feasibility of the most promising NDEW concepts. Some limited basic physics research would be permitted but not at the level required to evaluate a weapon.

Another important question is whether nonnuclear strategic defense systems are survivable against nuclear attack. As with nuclear effects testing, strategic defense assets will have to be tested in an actual nuclear environment. Nuclear effects testing of SDI-type components at current yield levels will be required until we develop the capabilities to perform the necessary tests at lower yields.

## The Value of Nonnuclear and Very-Low-Yield Testing and Computer Simulation

It has frequently been stated that nonnuclear and very-low-yield (<1-kt) testing and computer simulation would be adequate for maintaining a viable nuclear deterrent. A recent variant of this argument asserts that while such testing and computer simulation may be insufficient for the development of new warheads, they would be adequate for indefinite maintenance of a stockpile of existing weapons. We believe that neither of these assertions can be substantiated.

A computer simulation of a nuclear explosion attempts to provide a detailed physics model for all of the tightly coupled processes that must occur for proper functioning of the device. There are three fundamental issues with computer simulations: (1) the physics is approximated to a varying degree of accuracy by numerical algorithms, (2) not all of the physical processes can be included in fine detail, and (3) experimental data that confirm the appropriateness of the physics are rarely available. Since many of the phenomena are tightly coupled, errors from the simulation of early processes propagate, making subsequent steps progressively more inaccurate. Because most of the physics processes are nonlinear, predictions of full-yield behavior that are based on very-low-yield testing are highly uncertain if not impossible.

The major problem is that a nuclear explosive includes such a wide range of processes and scales that it is impossible to include all the relevant physics and engineering in sufficient detail to provide an accurate representation of the real world. A nuclear explosive contains most of the complicated physics of a supernova explosion—a computational problem whose solution so far has eluded the academic community. It also includes the microscopic detail of engineering and materials—assembly gaps and grain structure. Modern computational facilities cannot provide for this level of simulation. Usually, although not always, the general trends are correctly predicted; sometimes, correct detail and performance can elude us completely.

We attempt to normalize our calculations to experiments to minimize potential errors. In the harsh environment of a nuclear explosion, experiments are very difficult. Much of the information from older experiments, for example, is crude integral data and is of limited use to us now. We simply cannot get the detailed information to tell what is really going on and to identify what might be wrong with our simulations. The conditions that occur in a nuclear explosive are so unique that no experimental facility other than a nuclear explosion can give us data about what actually happens in a nuclear explosion.

We do extensive nonnuclear tests on those parts of the system that are amenable to such tests. The information available from nonnuclear testing, coupled with our most sophisticated calculational procedures, cannot always be extrapolated to predict accurately the behavior of a nuclear device. Our history abounds with such examples, some of them described in this report.

The same is true for modern rockets: small-scale tests and computer simulations do not accurately predict the detailed behavior of solid rocket propellent; full-scale tests and actual rocket launches are necessary to provide assurance of proper function.

Of particular concern is the boosting process in primaries and the fact that this process is not fully understood. For boosting, we incorporate some thermonuclear fuel in the primary. When the fissile material in the primary goes critical, it rapidly heats the thermonuclear fuel, which then burns and emits copious quantities of neutrons. These neutrons, in turn, greatly increase the fission rate, thereby "boosting" the primary yield. If the boosting is less than expected, then the proper ignition and yield of the secondary is in doubt. The achievement of boosting and ignition of the thermonuclear device is all-important in certifying the proper functioning of a strategic primary and secondary. We cannot reliably extrapolate the results of a sub-kiloton test to the full performance of a primary.

A recent example illustrates these points. A final proof test at the specified low-temperature extreme of the W80 (ALCM) was done as the weapon was ready for deployment. The test results were a complete surprise. The primary gave only a small fraction of its expected yield, insufficient to ignite the secondary. The primary had been tested extensively in nonnuclear hydrodynamic tests, including at the low-temperature extreme, with no indication of trouble to the designers. Thus, on the basis of the nonnuclear testing, previous successful nuclear tests, and extensive computer modeling, the weapon designers had every reason to believe that the low-temperature proof test would produce the predicted yield. After extensive post-test analysis, the W80 design was modified and another low-temperature nuclear test was performed; this test was successful, and confidence was established that the warhead would operate properly over its entire temperature range. The production specifications were changed, and the approved warhead entered the stockpile. However, even today we cannot simulate the failure of the first low-temperature test from first principles.

Our experience with the W80 illustrates the inadequacy of nonnuclear and low-yield testing and the need for full-scale nuclear tests to judge the effects of small changes. Even though it has been argued that such a "thorough" test should have occurred earlier, the critical point is that computer simulation, nonnuclear testing, and less-than-full-scale nuclear testing are not always sufficient to assess the effects of deterioration, changes in packaging, or environmental conditions on weapon performance.

Testing of newly produced stockpiled systems has shown a continuing need for nuclear tests. Even an "identical" rebuild should be checked in a nuclear test if we are to have confidence that all the inevitable, small and subtle differences from one production run to the other have not affected the nuclear performance. (See Chapter 3 for a detailed discussion of the issue of weapon remanufacturing.) The current stockpile is extremely reliable, but only because continued nuclear testing at adequate yields has enabled us to properly assess and correct problems as they occur.

## The Impact of Restrictive Test Limits on the Soviets

We do not know how further test limits may affect the Soviet Union. Since 1963, when both the Soviet Union and the United States were restricted to underground testing, we have gained little insight into the Soviet nuclear weapon program. What little we do know shows the Soviets to have an aggressive, well-funded program with impressive technical achievements. We know from their unclassified literature that they understand the physics of many advanced concepts. We know that nuclear weapon technology is not monolithic; thus the Soviet designs could be very different than ours. On the basis of the Chernobyl experience, we can speculate that the Soviets have a very different attitude toward the enhanced safety and security devices that contribute to the complexity of U.S. warheads. The Soviets could use the large throw weight of their missiles to accommodate less technologically sophisticated (and therefore larger) warheads. The technologically sophisticated approach that the U.S. has taken in virtually all of its military equipment has important benefits but it also has attendant costs, among them a greater reliance on testing to ensure proper functioning.

The impact of restrictive test limits could be less on the Soviets than on the U.S. More important, retention of their scientific base could be assured by restrictive state policies while U.S. experts would leave for other fields of endeavor. The difference in the durability of U.S. and Soviet weapons is too often oversimplified. Any differences are probably only a matter of degree. Deterioration of Soviet systems could possibly be less if they indeed do use larger, less sophisticated weapons. Their closed society could allow them to exploit shortcomings in verification and might permit them to secretly prepare for a treaty breakout.

We experienced the serious consequences of secret Soviet preparations during the Nuclear Test Moratorium of 1958–1961. After only three years of the Moratorium, we began to experience a significant loss of skilled personnel. The Soviets, on the other hand, had been preparing for the most complex series of nuclear tests ever conducted by either country. Under the very restrictive test limitations proposed today, we could again expect to see an exodus of skilled U.S. personnel, who would leave the weapon programs for various reasons including inadequate opportunities to verify theory against experiment. The consequences of a Soviet breakout from any restrictive treaty could also be compounded by asymmetries in the two countries' abilities to retain skilled manpower.

## Nuclear Testing and Scientific Judgment

Ultimately, the viability of the U.S. nuclear deterrent rests on the judgments of our nuclear scientists. Weapon scientists cannot adequately address the impact of new technologies, verify that a problem has been properly fixed, or certify that a new weapon design will meet its military requirements on the basis of nonnuclear experiments alone. Neither can they model with computers all the complex physical processes and engineering detail necessary to predict warhead performance with confidence.

Assessments of weapon performance rest on scientific judgment that is based largely on nuclear test experience. This judgment takes considerable time to develop, is cultivated by the application of theory and experiment to device design, and is continually refined with data from nuclear tests. Removing the confirmation and scientific training provided by nuclear tests would result in the overextension of judgment and in the reduced certainty of this nation's deterrent. Such was indeed the case with the 1958–1961 Moratorium (see Chapter 2 for further examples).

Most problems encountered with the stockpile have not required nuclear tests to certify the fixes that were made. In those cases, the fixes were made by competent scientists and engineers who were able to make informed judgments about the problem, judgments based on years of experience in actual nuclear testing. One such problem involved the corrosive oxidation of internal weapon parts in the W58 warhead for the Polaris A3 missile. There was concern that the corrosion would reduce the yield of the device. On the basis of computer calculations and nuclear test experience with a similar situation in another weapon, the designers were able to correct the problem without an additional nuclear test.

Nuclear warheads cannot be "thoroughly" tested; the resources simply are not available. As a result, the functional capabilities of nuclear explosive cannot be fully established without a strong dependence on the scientific judgment of the weapon scientists. It is not feasible to conduct the large number of nuclear tests required to obtain statistically significant data on a given nuclear system. Thus, the variability of a system's nuclear performance with changes in production tolerances, environmental conditions (e.g., temperature extremes), hostile environments (as are encountered in antiballistic missile engagements), and aging effects must be simulated with analytical, computational, and phenomenological models. The relevance and completeness of such models are only as good as the professional judgment of scientific personnel who are involved in the actual physics, design, and analysis of nuclear warheads and who must rely on a relatively small number of tests to explore the margins of weapon operations. Our scientific judgment is broader than just the experience of each individual weapon scientist; the collective judgment of the entire weapon research infrastructure works synergistically to solve the problems we encounter.

Our judgment is aided and constrained by experimental data from testing actual nuclear devices and by data from physics experiments at NTS in the relevant temperature and density regimes. Significant amounts of physics data are currently derived from actual nuclear tests. Our weapon development and physics research tests constantly show us that the more we learn about the weapon physics, the more we must recognize how limited our basic understanding really is. Scientific judgment is needed to bridge the gaps in that understanding. Critical to that scientific judgment is a cadre of experienced people. With our limited test schedule, we already suffer from a lack of experienced designers, and we are most concerned that we might face a permanent loss of capability. Staff maintenance during a Comprehensive Test Ban (CTB) was one of the most important issues addressed by the SAAC report (described below).

## SAAC Review of Nuclear Weapon Testing

The Scientific and Academic Advisory Committee (SAAC) is a standing committee appointed by the President of the University of California (UC) to advise him and the University Regents on matters concerning the Livermore and Los Alamos National Laboratories, which are managed by the University. The members of SAAC who conducted the study are well known in their fields; they have expertise in the sciences, mathematics, engineering, and technical management and are familiar with the nuclear weapon aspects of U.S. forces.

Earlier this year, the SAAC was asked by the President to conduct a study entitled, "Nuclear Weapon Tests: The Role of the University of California-Department of Energy Laboratories" (Reference 2). The study was a response to a number of letters to the UC President from professors expressing concern about the Laboratories' role in nuclear testing. The SAAC spent many days at LLNL and LANL in direct discussions with numerous experienced weapon design personnel. They received classified briefings and read classified material on the subjects of weapon reliability, the role of nuclear testing, and the measures the Laboratories have been taking to prepare for further nuclear test limitations. There was much interchange and discussion on these topics, and the depth of the SAAC study far exceeds that of any other independent review.

The SAAC came to a number of major conclusions that support the technical points we have made above. Some of their conclusions are summarized below:

1. The SAAC reviewed "in some detail" the stockpile problems that involved post-deployment nuclear testing for their resolution. The SAAC concurred that "confidence in reliability could not have been maintained undiminished without nuclear testing" (page 13, last paragraph).

2. The SAAC concluded that the Laboratories have improved their understanding of materials aging and degradation to greatly reduce further occurrences of such problems. "Nevertheless, in recent years sporadic problems of a more subtle nature have arisen, e.g., performance at low temperatures." The SAAC pointed out that sometimes these were recognized based on insights from other nuclear tests, including the Laboratories' weapon physics tests (page 15, last paragraph, and page 16, first paragraph).

3. The SAAC addressed the issue of whether weapons can be "thoroughly tested." The SAAC agreed that limitations on numbers and types of nuclear tests preclude testing of stockpile weapons over the full range of operational parameters. The SAAC stated, "new insight, developed by means of nuclear or laboratory tests, or by calculations, has occasionally raised retrospective questions concerning the ability of the stockpiled weapon to perform" (page 9, paragraph 4).

4. The SAAC agreed that if the military characteristic for warhead endurance were given a specific high priority, the Laboratories could develop more robust designs. This would have attendant penalties in weight, size, and yield, which would appear in increased costs (i.e., special nuclear material) in the warheads and delivery systems (page 14, paragraph 2, and page 16, paragraph 3).

5. The SAAC concluded that the Laboratories have been acting under a plan that emphasizes the necessity to be prepared for a CTB. In responding to an assertion that weapons in stockpile were deliberately designed to require continued nuclear testing to ensure their reliability, the SAAC report stated: "The SAAC concluded that this is not true" (page 2, issue 2, and page 16, issue 3).

6. The SAAC concluded that the Laboratories have designed weapons that are remarkably reliable and long-lived. The Laboratories have always given great attention to stockpile endurance (page 1, issue 1, and page 14, paragraph 2).

7. The SAAC concluded that Laboratory weapon physics programs have resulted in progress toward more enduring designs to prepare for a CTB. The SAAC encourages continuation of these programs (pages 1, 2, issue 1).

8. The SAAC regards as the most serious issue discussed with the Laboratories that of recruitment and staff maintenance during a CTB. The SAAC agrees that this would require "extraordinary" efforts. "The Committee applauds the current efforts of the Laboratories in these directions, and urges increased emphasis in the future" (page 2, issue 3, and page 16, paragraph 7).

## Conclusion

Nuclear weapon research and development, supported by nuclear testing, is essential to maintain the credibility of the U.S. nuclear deterrent. Because the global strategic balance is constantly changing, new weapon systems must be developed to ensure the safety, security, survivability, and military effectiveness of our nuclear deterrent.

The DOE weapon design laboratories have the responsibility of ensuring that the weapons currently in the stockpile are safe and reliable, of developing warheads for new systems as they are needed, and of exploring what is possible in order to avoid technological surprise.

Nuclear testing is essential if the Laboratories are to meet these responsibilities successfully. Nonnuclear tests and computer simulations are very valuable tools but there is no substitute for the experimental data from nuclear tests. In many instances, weapon scientists must rely on technical judgment to make decisions regarding problems that arise in the stockpile, in recommending changes in weapon systems, and in developing new warheads—judgment that can only derive from and be refined with actual data from nuclear tests.

Without nuclear testing, deterrence would still be based on nuclear weapons. However the costs would likely be higher, the uncertainties would be greater, and our options for maintaining stability would be limited.

# Chapter 2. History of Stockpile Problems and Post-Deployment Nuclear Testing

In the 26 years since testing resumed after the 1958–1961 Nuclear Test Moratorium, post-deployment nuclear testing of U.S. nuclear weapon designs has been required to assure continued confidence in the performance of the nuclear weapon stockpile. Major weapon systems (e.g., Polaris and Poseidon) have been involved in these tests. A majority of the problems would not have been discovered if the nuclear test program had been discontinued. Specifically, if the stockpile had been frozen by a test ban treaty early in this period, many of the weapon designs could have been found to be seriously deficient, had their use become necessary. Some of the problems were the consequences of the Moratorium, which was in effect a *de facto* Comprehensive Test Ban (CTB). Early problems have long since been resolved and we have learned from these experiences, but others have arisen, some very recently. One-third of all modern nuclear weapon designs in the U.S. stockpile have received post-deployment nuclear tests to resolve serious problems; in three-fourths of these cases, the problems were identified only because of the on-going nuclear testing. Many thousands of deployed weapons have been affected.

While only one-third of the deployed designs required testing to discover, evaluate, or fix problems, nuclear testing has been required to retain confidence for *all* U.S. systems. *All* systems have experienced some problems, and the assessment of these problems was made by people experienced in nuclear design and testing.

The U.S. weapon stockpile is highly reliable today. However, weapon certification by the weapon design laboratories has never been unconditional. Some conditions placed on certification are explicit: for example, limited lifetime component exchanges must be as specified, and exposures to defensive threats or adverse environments during the stockpile-to-target sequence (STS) must lie within limits specified in the military characteristics (MCs) for each weapon. Generally, these conditions are clearly stated. However, certain other conditions are less obvious, seldom clearly articulated, and equally vital; for example, there must be adequate programs for the identification, assessment, and resolution of stockpile problems. What is adequate, in turn, can only be determined by those few experts who are directly responsible for weapon certification. Experience has demonstrated that the above conditions cannot be met indefinitely without nuclear testing. Experience has also shown that while testing has been permitted, U.S. nuclear weapons have been dependable for long periods with high confidence.

## Historical Background

Few problems arose in the U.S. weapon stockpile before the 1958–1961 Nuclear Test Moratorium. There were several reasons for this. First, by 1958, 11 weapon designs had been retired at an average age of less than 4.5 years; little time had passed for problems to develop or be recognized. There were 14 designs remaining that would attain slightly more than twice that average age before they, too, would be retired. The life of four weapons, in which the designs were not very complex, was to be much longer. The U.S. had a rapidly developing technology, a need to respond to a constantly changing threat from the Soviet Union, and in particular, relative simplicity in its early nuclear weapon designs. There was a rapid turnover in weapon systems. These factors, combined with less stringent safety and security requirements (by today's standards) made the development of stockpile problems very unlikely.

The first modern weapon design appeared with the first thermonuclear weapon, the Mk 14, deployed and quickly retired in 1954. More significant was the development, starting in 1955, of small and efficient "boosted" fission devices for use as single-stage weapons or as primaries (fission triggers) for thermonuclear weapons. During the late 1950s, the size of future U.S. strategic delivery systems began to be determined by attainable yield-to-weight ratios, and high ratios depended on the new boosting and thermonuclear technologies. At the same time, concerns increased regarding safety and security, and these concerns placed increasing constraints on the weapon designs.

When the United States entered the Moratorium in 1958, the first thermonuclear weapons based on the new boosted primary technology (the Mk 27 warhead for the Regulus missile and the B28 bomb) were ready to begin deployment, as a result of tests completed in 1956. In 1958, there were no recognized problems with weapons in stockpile. Concerns soon developed, however, regarding the safety of one of the new thermonuclear weapons, the B28. Although more than one-third of the tests of boosted primaries done to that date had been tests of one-point safety, it was discovered through analysis of the latest data that these had not been worst-case tests and that a significant safety problem might still remain. (In a one-point-safe design, the accidental detonation of the high explosive at a single point does not result in any significant nuclear yield.) Production and delivery of the B28 were slowed drastically. Strategic Air Command (SAC) missions in Europe were put on hold at a time of high international tension; in effect, the B28 was grounded. On the basis of data from an earlier test, weapon scientists were able to shift B28 production to a different, safer design. Without this retrofit, which would not have been possible without data from the earlier nuclear test, the deployed weapon would have had to remain subjected to onerous operational restrictions.

When the U.S. resumed testing in 1961, the situation was changing rapidly, although the implications of the changes were not yet fully recognized. Of the 18 weapon designs that had constituted the 1958 stockpile, only one had been retired. Seven new designs had entered the stockpile during the Moratorium. As a result of the stockpile surveillance program, and particularly as a result of the resumption of nuclear tests in late 1961, it was realized that four of the 24 weapon designs in the 1961 stockpile had problems that could be resolved only by additional nuclear tests.

The number of new designs in stockpile grew rapidly after 1961. Of 10 new designs deployed by 1964, half developed problems (discussed later in this chapter) that would be resolvable only by further testing. Some weapons required redesign whereas others only required assessment, through additional testing, and appropriate stockpile management.

By 1970, 10 of the 27 designs then composing the stockpile (23 from the 1964 stockpile, and four newer designs) were weapons whose continued availability had depended, or would soon depend, on post-deployment testing. By now, many earlier problems had been corrected. However, one of the two newest designs in the 1970 stockpile required further testing, as would one of the older designs. At the same time, it began to be clear that stockpile lifetimes were lengthening.

There now are 28 designs in the U.S. arsenal, 17 from the 1970 stockpile and 11 new designs. Of the 11 new designs, three (W79, W80, W84) have required additional nuclear testing, and a fourth (B61), whose reliability has not been in question, has required substantial redesign and modernization to meet current safety, security, and economy requirements.

The history presented here demonstrates the essential role of nuclear testing in preserving confidence in the reliability of U.S. deployed nuclear weapons. At no time has it been possible to dispense with the knowledge and judgment, based on current test experience, of the weapon scientists.

To understand the path that has been followed, it is useful to recall the commitments made to the nation in 1963 by President John F. Kennedy, presented as safeguards for the treaty limiting the U.S. to underground testing. The most important of these safeguards were (A) the maintenance of modern nuclear laboratory facilities and programs in theoretical and exploratory nuclear technology, to ensure continued progress in that technology, and (B) the conduct of comprehensive, aggressive, and continuing underground nuclear test programs to add to our knowledge and to improve our weapons in all areas of our military posture for the future. President Kennedy also declared (Reference 6) that "While we must all hope that at some future time a more comprehensive treaty may become possible by changes in the policies of other nations, until that time our underground testing program will continue."

## Stockpile Reliability

The maintenance of confidence in the reliability of our weapon stockpile depends on the continuing stockpile surveillance program, the quality assurance and reliability testing of nonnuclear components, and the nuclear testing of warhead components and similar nuclear devices in the on-going nuclear weapon development program. The continuing nuclear test program serves to confirm, and occasionally to call into question, the design choices made in the stockpiled weapons. It trains and provides experience to new designers who will eventually be called upon to evaluate stockpile reliability problems. Identified stockpile problems have sometimes required nuclear tests to guarantee acceptable weapon performance. Had nuclear tests not been available, the stockpile problems would have forced unacceptable reductions in yield and/or reliability, unacceptable operational limitations, or replacement with a design with much greater uncertainty in performance.

Nuclear tests can be necessary to confirm the proper resolution of a stockpile problem or to determine whether the problem will adversely affect the performance of the weapon. Such tests are needed because some of the physical phenomena occurring in weapons are so complicated that it is impossible to model them completely or to evaluate them adequately with only calculations and nonnuclear tests. Nuclear tests are also necessary to verify the judgment of the weapon designer and the "realism" of models and calculations.

Our design calculations are the result of many assumptions about how materials behave at the extreme conditions of a nuclear explosion. These assumptions often are based on limited experimental data and on theoretical predictions that are difficult if not impossible to verify in sufficient detail. As a result, design calculations must be compared with actual test results; like many assumptions made in other extremely complex technologies, they sometimes are found to be incorrect, incomplete, or inadequate.

The phrase "thoroughly tested" has recently received considerable attention. It has been claimed that a large fraction of stockpile problems were the result of deploying weapons which were not "thoroughly tested." It has also been assumed by some that our new weapons are "thoroughly tested." This phrase is misleading. It is impossible, in a real world with budgetary limitations, to test nuclear weapon designs under all foreseeable STS conditions, including exposure to adverse storage or delivery environments, expected defensive threat levels, and changing target requirements. It is impossible to do a statistically meaningful number of tests. It also is impossible to know or foresee all future safety and security requirements at the time weapons enter the stockpile. Safety criteria (e.g., criteria on one-point safety, safety against accidental plutonium dispersal by high-explosive detonation, and safe levels of intrinsic radiation) and security requirements can and do change. Expected threat levels or other STS parameters change as the Soviets acquire new capabilities. The acceptability or availability of certain materials originally used in weapon fabrication may change as a result of factors entirely beyond the control of the weapon scientists. Finally, it may be discovered, sometimes in the course of subsequent testing of similar designs, that design errors were made, that basic physical data are in error, or that understanding of the physics itself has changed. The term "thoroughly tested" implies a comprehensiveness that is impossible in practice. Designer judgment, validated by ongoing testing, is vital both in determining what tests are most essential at the time of certification and in evaluating problems or changing requirements that arise later.

The bottom line is that there is no such thing as a "thoroughly tested" weapon. In developing a weapon, we test it as thoroughly as we can under a variety of conditions. In the development process, we attempt to define the boundaries of reliable operation, and we back away from these boundaries in a way that conservatively balances factors affecting reliability and factors affecting cost.

It has been noted recently that weapon designers have been quite successful in first-time predictions of the yields of new devices in nuclear tests. Claims have been made that this high rate of successful prediction is an indicator of reliability and of surety of performance if remanufacture is necessary. Evaluating stockpile reliability on the basis of such statistics is extremely misleading.

Our success rate of first-time yield predictions is high for good reasons. First, the designers making the predictions have extensive test experience themselves or their work is reviewed by senior designers who have such experience. Second, most of the designs are based on fairly conservative, well-established technology. The first time a variant of this technology is tested, our designers use their knowledge to build safe margins into the designs. Essentially, they put "fat" into the system. It is when the designers begin to fine-tune a device to optimize it for its intended weapon application, to study the device at environmental extremes, or to incorporate engineering details like structural, safety, and security features that performance margins are reduced and uncertainties creep into their predictive capabilities.

There is an important common message in the stockpile difficulties described below: the weapon was thought by the experts to be adequately tested and reliable at the time when it entered the stockpile. However, problems occurred as a result of materials aging, changes in safety concerns, environmental effects, or a later realization that our understanding of the physical performance was incomplete. Nuclear testing was done to properly identify the effects of these problems on weapon performance or to evaluate the validity of solutions to problems. It should be noted that even if an identical rebuild is chosen as the solution to a problem, a nuclear test should be done to ensure the adequacy of the production process. (See Chapter 3 for a detailed discussion of weapon remanufacturing.)

Because of budgetary and manpower constraints, a weapon in the stockpile is usually nuclear-tested fewer than ten times during its development and subsequent lifetime. Obviously, it is impossible to test every conceivable condition and eventuality. The stockpile is reliable because we test for the worst conditions that we expect, and we can fix problems if they occur or if we discover later that our expectations were wrong. In this regard, nuclear weapons are like most other modern, high-technology systems (e.g., rockets, airplanes, computers). The effects of time, environment, and chemical degradation often require testing to identify and fix sometimes subtle design and materials problems.

While not all solutions to stockpile problems require certification by full-scale nuclear tests, all rely on data obtained in nuclear tests and, most critically, on the judgment and insight that the scientists and engineers acquire on the basis of such data. If we stopped nuclear testing, such experimental data would no longer be obtained, and the pool of specialists whose judgment was validated by nuclear test experience would decline and, finally, no longer exist.

## Stockpile Problems Involving Post-Deployment Nuclear Testing

In the remainder of this chapter, we give a brief unclassified description of stockpile problems that involved post-deployment nuclear testing for their identification or resolution. We address those designs developed both by LLNL and by LANL (see Table 1).

### LLNL Designs

Of the 16 LLNL-developed warhead designs that entered the stockpile after 1958, several were subsequently found to have problems. For six of these (WXX, W84, W79, W68, W47, and W45), the resolution of the problems involved nuclear testing. In three of the weapons (W84, W47, W45), some problems were discovered by nuclear testing and further nuclear tests were necessary to resolve the problems. All of these problems have been corrected.

All of the designs placed in the stockpile were extensively tested beforehand. More than one-third of the weapon designs that LLNL has placed in the stockpile have experienced problems that involved nuclear testing. Some of the systems had multiple problems.

**WXX.** A problem recently occurred with an LLNL weapon which cannot be identified or discussed in detail on an unclassified basis. The problem involved a new concern about one-point safety of the device under certain conditions. A nuclear test was necessary to eliminate the concern.

**W84.** The W84 is the warhead for the ground-launched cruise missile (GLCM) and is tailored to applications in the European theater. Accordingly, it was developed to a set of stringent requirements emphasizing safety, security, and flexibility. A number of seemingly minor changes were made in the stockpile hardware as compared with the hardware used in the development tests, as is usually done for complex systems. When a stockpile confidence test was conducted on a unit that had been deployed for a year (and modified slightly to simulate certain aged conditions), a lower-than-expected yield was obtained. There was concern that the low yield was indicative of possible marginal operation of the device. Another nuclear test was necessary to evaluate the source of the yield degradation, to certify a fix to the problem, and to determine that there were indeed no problems with marginality. This stockpile confidence test is typical of the tests we now do to certify the production versions of all systems that enter the stockpile. They are dual-purpose tests in that they verify that the production process has not introduced unacceptable systematic perturbations into the weapons and they serve to determine the effects of some stockpile exposure and handling on the weapons.

**W79.** The W79 is the warhead for the 8-inch artillery shell. A problem was encountered in manufacturing a component needed to meet the weapon's operational requirements. The component involved a complex design, and a satisfactory design could not be achieved within the specified development time scale. Hence, the W79 was deployed with a simpler design that allowed the weapon to meet a modified operational capability. Ultimately, after the weapon was deployed, a different approach was devised to satisfy the operational requirements. This different approach required a design change that meant that the physics behavior of the device had to be altered, and a nuclear test was required to certify the design change. The W79 problem differs from the other problems described in this report in the sense that the W79 was *knowingly* placed in the stockpile with a different capability than originally required. We were unable to develop an engineering solution to solve the problem, and an

**Table 1. Fifteen U.S. nuclear weapon systems have required post-deployment nuclear testing to identify or resolve problems. All the listed problems have been resolved.**

| Warhead | Problem | Responsible laboratory | Identified or evaluated by nuclear testing | Resolved by nuclear testing |
|---|---|---|---|---|
| WXX | One-point-safety concerns | LLNL | X | |
| W84 | Concern about marginal behavior at aged conditions | LLNL | X | X |
| W79 | No practical manufacture of a complex part; different approach required altering the physics behavior | LLNL | | X |
| W80 | Failure at low temperature | LANL | X | X |
| B61 | Replacement of HE with IHE for safety | LANL | | X |
| | Concern about low-temperature performance | | X | |
| W68 | Degradation of HE | LLNL | | X |
| W47 | Corroding fissile material | LLNL | X | |
| | Vulnerability in simulated ABM environment | | X | X |
| | Improvement of one-point safety | | | X |
| W45 | Mechanical change of HE | LLNL | | X |
| | Performance under aged conditions | | X | X |
| W52 | Replacement of HE because original wasn't safe enough for handling | LANL | X | X |
| B43 | Improvement of one-point safety | LANL | | X |
| | Performance under aged conditions | | X | X |
| B28/W49 | Performance under aged conditions | LANL | X | X |
| W44 | Improvement of one-point saftey | LANL | | X |
| | Performance under aged conditions | | X | X |
| W50 | Improvement of one-point safety | LANL | | X |
| | Performance under aged conditions | | X | X |
| B57 | Performance under aged conditions | LANL | X | X |
| | Improvement of one-point safety | | | X |
| W59 | Improvement of one-point safety | LANL | | X |
| | Performance under aged conditions | | X | X |

alternate physics solution was used to allow the W79 to meet its full requirements. Continued nuclear testing was necessary to certify the solution.

**W68.** The W68 is the warhead for the Poseidon submarine-launched ballistic missile (SLBM). In routine stockpile surveillance, the high explosive (HE) in the W68 was found to be decomposing and the decomposition products were causing deterioration of the detonators. We judged that it was only a matter of time before the W68 weapons in stockpile would be inoperable. We could have repeatedly rebuilt the W68 warheads using the same type of HE that was decomposing, at tremendous expense and with large operational impact on the U.S. Navy. Instead, we chose a more cost-effective and technically sensible approach and rebuilt each warhead with a more chemically stable HE.

Even though a version of the W68 with the more stable HE had been tested in initial development, we judged that a nuclear test was necessary to certify the design. The production verification test was done at certain simulated extreme conditions of the STS. We were surprised when the resulting yield was degraded beyond what we expected based on the earlier test with the new HE. Besides changing the HE, there had been a number of other changes in warhead parts. For example, certain warhead materials had to be changed because the vendors of the original materials had gone out of business.

We have not yet been able to explain the cause of the observed yield degradation. Although the new HE was supposed to be the same as that tested earlier, there may have been subtle changes in its formulation. We do not know whether the degradation was caused by the new HE, the other changes, or some combination. We might even have experienced yield degradation had we rebuilt the warhead with a fresh batch of the same chemically unstable HE.

Although the yield of the W68 was considered to be acceptable, it has been necessary to emphasize certain maintenance procedures to allow the warhead to meet its intended function at certain STS extreme operational conditions. When the Navy asked if the time for doing these maintenance procedures could be relaxed because of the large impact on their operational work load and associated costs, we emphasized the importance of doing the procedures in a timely manner. Our advice to the Navy was significantly influenced by the unexpected result in the production verification test.

While some have stated that a production verification test of the rebuilt W68 was not necessary, the above results showed that the test was needed both to certify the adequacy of the production rebuild and to allow us to provide accurate advice to the Navy on required maintenance and operational restrictions. It is clear that the rebuilt version of the W68 is different in substantive ways from the original.

It is important to recognize that the HE decomposition and its effects on the detonator caused considerable concern. A test of the remanufactured warhead was necessary to restore our confidence and that of our leadership. The Poseidon warhead was too important to our national security to leave our leaders in a position of doubt.

**W47.** The W47 was the warhead for the Polaris SLBM. Several problems were encountered with the W47 that required post-deployment nuclear testing for their resolution. One of these problems was discovered in a nuclear test.

First, corrosion of the fissile material was observed during stockpile maintenance. A test of a unit simulating the problem defined the acceptable corrosion limits, and those weapons that exceeded these limits were removed from the stockpile.

A nuclear effects test showed that material in the W47 primary was vulnerable to effects encountered in a potential antiballistic missile environment. The design was modified to cure this deficiency, and a nuclear test was needed to insure that the modified design performed adequately.

Another problem with a safety device required the development and testing of a new primary. Before the Moratorium, we were unable to make the W47 inherently one-point safe (i.e., incapable of producing any nuclear yield in the event of accidental detonation at a single point of its HE). The Moratorium prevented us from performing the necessary tests to develop an inherently one-point safe design. Instead we incorporated a mechanical safing device in the W47 to provide the necessary one-point safety. Use of such a device was not a novel idea at the time and such devices had been successfully used in other systems and are still used in some. The designers of the W47 had every confidence that the weapon would meet its intended mission. However, chemical corrosion in the W47 eventually caused a serious reliability problem in the safing mechanism that did not lend itself to a viable engineering solution. The mechanism would not fully complete its arming operation in a large number of the sampled warheads, indicating that a large fraction of the W47 warheads would be duds and that the number of dud warheads was increasing with age. This problem was solved by replacing the primary with one known to be one-point safe, and a nuclear test was required to certify the new design.

**W45.** The W45 is the warhead for the Navy's Terrier missile, the now-retired medium atomic demolition munition, and the Army's now-retired Little John missile. The W45 was developed in part during the 1958–1961 Moratorium and entered the stockpile in 1962. There were two W45 reliability problems that required post-deployment nuclear testing.

One involved unexpected effects of radioactive aging of a warhead component. When the W45 entered the stockpile, our weapon scientists had no reason to believe its operability would be unacceptably affected under aged conditions. They believed the weapon had been well tested before entering the stockpile. When the weapon was tested under aged conditions, after the Moratorium, it gave only half its expected yield. To respond to this unexpected result, it was necessary to conduct a number of nuclear tests to certify all versions of the W45 in the stockpile. Five tests were required establish yield values and changes in the maintenance procedure for the weapon. The issue here is that although it was relatively simple to calculate or measure radioactive decay rates, it was much more difficult to estimate the effects of radioactive decay on the complex operation of this sensitive weapon.

The second problem, a permanent deformation of the explosive after aging, also required a nuclear test to certify a new design with a modified chemical explosive.

### LANL Designs

Of 25 Los Alamos weapon designs that have been deployed since 1958, one-third have required post-deployment nuclear testing. The W80 warhead was ready for deployment when a probable flaw in the primary design was discovered. A new modification of the B61 was in production, but not yet deployed, when new nuclear safety requirements caused production to be terminated pending development, through additional tests, of an alternative safer primary design. Seven other designs (B28/W49, B43, W44, W50, W52, and W59) developed one or more problems whose recognition and resolution required further nuclear tests.

**W80.** The W80 is the warhead for the air-launched cruise missile (ALCM). A test at the low-temperature extreme of the temperature range of the W80's STS was done just as the weapon was ready for deployment. The test results were a complete surprise. The primary gave only a small fraction of its expected yield, insufficient to drive the secondary. The weapon had been tested extensively in nonnuclear hydrodynamic tests, even at the low-temperature extreme with no indication of trouble. Thus, on the basis of nonnuclear testing and previous successful nuclear tests, the weapon designers had every reason to believe that the low-temperature proof test would produce the predicted yield. After extensive post-test analysis, the design was modified and another low-temperature nuclear test was performed. The test of the modified design was successful, and confidence was established that the warhead would operate properly over its entire temperature range. The production specifications were changed accordingly, and the approved warhead entered the stockpile. Because of concerns about performance at extreme temperatures raised by the low-temperature test, a nuclear test at the high-temperature extreme was performed later.

This example illustrates again the inadequacy of nonnuclear testing and the need for nuclear tests. Without the disastrous result of the low-temperature nuclear test, the weapon designers would have judged, on the basis of the nonnuclear tests, that the system would perform properly. As a result of the experience with the W80, similar low-temperature nuclear tests have been done for several other weapon systems, including the B61.

**B61.** The B61 is a strategic bomb that entered the stockpile in 1968. By 1971, a modification to the design was required, and, more important, the safety and security features of the older design did not meet current standards. A new series of B61 designs was produced with various modifications containing improved safety and security features and, in one, insensitive high explosive (IHE). Incorporation of all modern technology except the IHE was accomplished without nuclear testing; nuclear testing was required to make the change to IHE. In the early 1980s, a nuclear test revealed that the B61 had a cold-temperature sensitivity similar to though less severe than that exhibited by the W80. Because of this, a further design change had to be implemented.

In reviewing the history of the B61, it is important to note that the original design was never judged to be unreliable; it did not meet modern performance criteria. Modern versions of the B61 incorporate IHE, permissive action links (PALs), command disablement, and other use-control features.

**W52.** The W52 was the nuclear warhead for the Army's now-retired Sergeant surface-to-surface missile. In 1959, the warhead was nearly ready for production when two explosive accidents occurred at Los Alamos, killing six people. The explosions were due to the unexpected susceptibility to accidental detonation of the type of high explosive used in the W52's fission trigger. Los Alamos had to change the explosive used in the W52 to a safer, less sensitive, and somewhat less energetic explosive. This decision was made during the Moratorium when the new design could not be verified in a nuclear test. The redesign was based on nonnuclear hydrodynamic tests and on computer design calculations. Because of the high confidence the Los Alamos scientists had in their redesign, they did not immediately test the W52 when the Moratorium ended in 1961. The W52 entered the stockpile in April 1962. When Los Alamos finally tested the device, the weapon gave only a fraction of its expected yield. The W52, as delivered, had too low a yield to be militarily acceptable. Los Alamos scientists made a rapid redesign, and within three months of the test failure, they successfully conducted a nuclear test of the new design, which was then incorporated into the stockpile.

The W52 dramatically illustrates the limitations of nonnuclear experiments and computer calculations to evaluate seemingly moderate changes in warhead designs. Although the problem with the W52 occurred in the early 1960s and our capabilities in computer modeling and nonnuclear experiments have improved significantly since then, experienced designers today would not undertake to change the HE in a weapon without nuclear testing. Even with modern capabilities, this is a very major change and the risks of errors are too high.

**B43.** The B43 is a tactical and strategic thermonuclear bomb. It experienced several post-deployment problems. In 1961, Los Alamos scientists concluded that the primary for the B43 was not one-point safe under all conditions. A long series of tests was required to develop an adequately safe version.

In a second problem, a radioactive aging problem like that noted above for LLNL's W45 was recognized in a test of the B43. To investigate whether it might be possible to extend the lifetime of the B43 weapons in the stockpile, a test of an aged B43 was fired. The test gave only half its expected yield. After further nuclear testing and increased theoretical understanding, LANL was able to establish appropriate B43 maintenance procedures for aged weapons.

The low yield was a shock, in part because its results applied not just to the B43 but to all similar weapons in the stockpile. Weapon scientists were more concerned about some systems than others, depending on application. Under a continued Moratorium, maintenance procedures might have been used that would have allowed weapons to remain in service beyond their useful lives.

**B28/W49.** The B28 is a tactical and strategic thermonuclear bomb. The W49 version was the warhead for the Thor and Jupiter intermediate-range ballistic missiles and the Atlas D ICBM. The B28 had a problem with warhead aging like that experienced by the B43. A nuclear test of an aged B28/W49 warhead was required to certify the existing maintenance procedures for the weapon. As the behavior of the warhead was better understood, through computer modeling and confirmed by nuclear testing, the maintenance procedure for the B28 was further modified.

**W44.** The W44 is the warhead for the antisubmarine rocket (ASROC) missile. The W44 had the same problems as seen with the B43 with respect to one-point safety and radioactive aging. The same solutions were employed.

**W50.** The W50 is the warhead for the Pershing I missile and for the now-retired Nike Zeus missile. The W50 had a one-point-safety problem and there were the same concerns about radioactive aging as with the B43. The same solutions were employed as for the B43.

**B57.** The B57 is a tactical and a strategic bomb. The B57 experienced the same radioactive aging problem as the B43. It was also found to have a one-point-safety problem. A nuclear test was done to certify a new version of the B57 primary that was one-point safe. The same solutions to the radioactive aging problem were used as for the B43.

**W59.** The W59 was a warhead for the Minuteman I missile. The W59 had a one-point-safety problem and there were the same concerns about radioactive aging as with the B43. The same solutions to these problems were used as for the B43.

### General Comment

LANL's B28/W49, B43, W44, W50, W57, and W59, and LLNL's W45 were all affected by the same problem—unexpected sensitivity to the radioactive aging of the warheads. We have gained considerable experience since the 1960s and believe that such a common-mode problem is much less likely now than it was then. This particular problem has long since been solved. It has been stated that any one problem in a single system does not pose a threat to the entire nuclear stockpile, since other systems can fill the gap left by the faulty system. However, modern designs do have a great deal of commonality (e.g., high explosive, detonators, security features, etc.) and a common-mode problem could affect a large fraction of the stockpile. We must protect ourselves against such problems, and nuclear tests are of vital importance in recognizing and solving them when they occur.

## Vulnerability Problems

The vulnerability of U.S. strategic nuclear weapon systems as well as nonnuclear assets like warning sensors and communications equipment to nuclear effects is a matter of extreme importance. Underground nuclear tests are used by the

Defense Nuclear Agency (DNA) to assess the vulnerability of U.S. systems. There are many uncertainties in the codes and calculations that are done to predict vulnerability to nuclear effects. These uncertainties are largely due to the difficulty in accurately modeling a complex real weapon system and the fact that one is attempting to calculate the response of materials in a very difficult regime of equation-of-state. Although aboveground testing is conducted with various accelerators and nuclear reactors, the fluences and deposition times are far removed from those in an actual nuclear explosion and there is no way to assess combinations of effects. In addition, the size of the sample that can be exposed is often limited, making it impossible to assess the vulnerability of complete systems.

Surprises have been found in the underground vulnerability testing of all U.S. strategic nuclear systems except the Minuteman II. Effects tests are vital to ensuring the survivability of nonnuclear systems, including space-based command, control, and communications assets. Effects tests will also be necessary to ensure the survivability of space-based SDI assets.

Figure 1 shows the various U.S. strategic systems and their years of testing and/or deployment. It is interesting to note the frequency with which unexpected test results occur and the number of instances where a number of tests were required to obtain satisfactory results. In some cases, system characteristics had to be altered. (The DNA should be consulted for specific information on these results.)

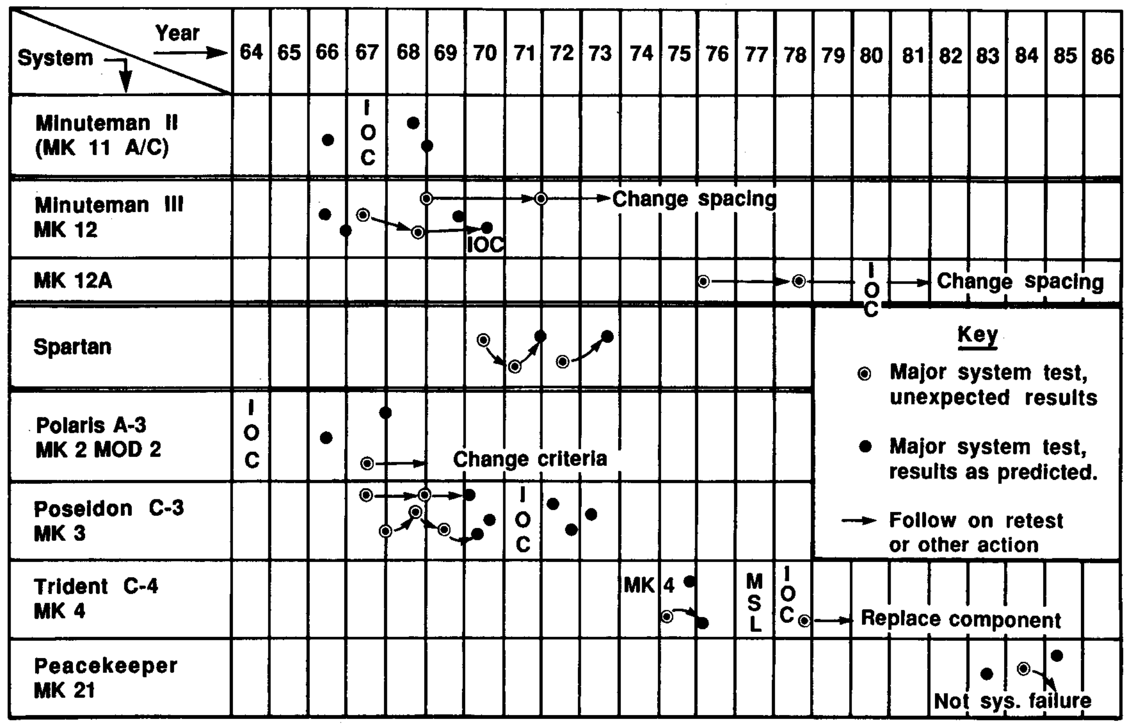


Figure 1. Results of underground nuclear tests of U.S. nuclear missile warheads. Note the number of tests in which results did not match predictions.

# Chapter 3. Weapon Remanufacture

The issue of "replica" remanufacture is familiar to engineers in all major U.S. industries. Although tests of a complex system are expensive and time-consuming, one is hard-put to find an example anywhere in U.S. industry where a major production line was reopened and requalified without tests. We have discussed remanufacturing with many people experienced in materials research, aerospace, engineering, and private industry, as well as in nuclear weapon design and fabrication. The aerospace industry has many parallels to nuclear weapon development. Two particularly instructive cases are the Polaris A3 missile remanufacture and the proposed remanufacture of the Saturn V rocket. In both cases, we consulted with the responsible engineers—top people with firsthand experience and direct responsibility for remanufacturing a complex technology with hundreds of separate parts, each with its own special design and purpose. Their experiences are detailed in Appendix C.

The body of opinion from these experienced people can be summarized as follows:

- *Exact replication, especially of older systems, is impossible.* Material batches are never quite the same, some materials become unavailable, and equivalent materials are never exactly equivalent. "Improved" parts often have new, unexpected failure modes. Vendors go out of business or stop producing critical products. New health and safety regulations rule out previously used materials or processes. Different people—not those who did the initial work—do the remanufacturing.

- *Documentation has never been sufficiently exact to ensure replication.* A perfect specification has never yet been written. We have never known enough about every detail to specify everything that may be important. Even "perfect" specifications are changed many times after they are formulated and certified. Individuals in the production plants learn how to bridge the gaps in the specifications and to make things work. Even the most complete specifications must leave some things to the individual's common knowledge; it would be an infinite task to attempt to specify all products, processes, and everything involved in their manufacture and use. Experts believe that it would be extremely difficult to improve documentation enough to ensure replication by inexperienced personnel.

- ***The most important aspect of any product certification is testing; it provides the data for valid certification.*** A nuclear test provides our only data on the nuclear performance of the whole nuclear warhead package. Tests, even with the limitations of small numbers and possibly equivocal interpretation of results, are the final arbiters of the tradeoffs and judgments that have been made. We are concerned that, if responsible engineers and scientists were to refuse to certify a remanufactured weapon, pressures could produce individuals who would. The Challenger accident resulted from such a situation and highlights an all-too-common tendency of human nature to override judgment in favor of expediency.

## Weapon Remanufacture and the Need for Experienced Personnel

Remanufacture of a nuclear warhead is often asserted to be a straightforward exercise in engineering and material science, and simply involves following well-established specifications to make identical copies. In the real world, however, there are many examples where weapon parts cannot be duplicated because of outmoded technologies, health hazards, unprofitable operations, out-of-business vendors, irreproducible materials, lack of documentation, and myriad other reasons. Every time we encounter such a problem in duplication, we have to rely on the experience of our weapon engineers, material scientists, and design physicists to carefully analyze and approve any deviations from the specifications.

When we find that a weapon cannot be manufactured precisely to its original specifications, someone has to determine "Does it really matter?" Only weapon designers, engineers, and material scientists *with nuclear test experience* are qualified to answer this question with any degree of confidence. Most of the changes made during remanufacture do not need to be certified in a nuclear test. It is usually sufficient to rely on nonnuclear tests and computer simulations, together with the judgments made by experienced scientists and engineers, to determine whether or not a change is acceptable. In some cases, nuclear tests have been required to certify a change, and most of these tests have been successful, determining that a change was satisfactory or revealing the need for further modifications. Hindsight shows that we could have avoided those nuclear tests that were successful, because they were successful. However, without these tests, we would not have had the confidence that the change was satisfactory and would not affect the performance of the remanufactured device.

Today, design physicists and engineers *with extensive nuclear test experience* at the relevant yield levels could undertake a weapon remanufacture with confidence that the weapon would perform about as well as the original version. However, even such a group has had difficulty in predicting the behavior of some weapons recently remanufactured for the stockpile. Not only must remanufacturing attempt to replicate the construction of the original weapon, it must also duplicate the performance of the original weapon.

Two aspects of our current weapon design process are primarily responsible for the success with which our designers are able to predict the performance of nuclear weapon designs, under the range of yields that are within our predictive capabilities. Both rely on experience. The first is the actual nuclear test experience of our present staff of designers, physicists, and engineers. The second is the critical review to which each new design or modification is subjected.

Because of the complexity of nuclear weapons and the limited rate at which they are tested, nuclear weapon design is largely an empirical science. Assessments of weapon performance—whether for stockpile inspection or remanufacture—depend on scientific judgment, and it takes years for designers to acquire the experience on which they base their scientific judgments. New designers must gather their knowledge and experience directly from nuclear tests and indirectly from the senior designers.

Currently, our nuclear test schedule is very limited, and it is taking longer for the newer designers to develop test-based experience. Thus the indirect route to experience is more important than ever, as younger designers take the output from their computer simulations and their interpretations of experimental results to test-seasoned senior designers for review and confirmation. This *continuity of experience* is indispensible.

Today, the first tests of a new design (most frequently a variation on a previously tested and certified design) are usually successful because our designers have the necessary experience to be able to build safe margins into the nuclear tests. It is when they incorporate engineering details or test at environmental extremes—necessary steps in turning a "device" into a weapon—that actual performance can fall short of predictions. If today, test-experienced personnel sometimes have difficulty predicting device performance or explaining unexpected behavior, how could a designer without actual nuclear test experience and without experienced coworkers to consult be able to design or modify a weapon with success or confidence?

We expect that, in the event of very restrictive test limits, in only a few years, we would start to lose our test-experienced people. They would leave to work on other, less restrictive, more productive projects. After a while, the people whose judgment had been honed by the realities of nuclear testing would no longer be available. We would then be faced with the prospect of asking scientists without nuclear testing experience to make judgments about the inevitable changes that will occur in remanufactured or stockpiled weapons.

## Examples of the Need for Nuclear Testing in Remanufacture

When faced with the inevitable changes encountered in weapon remanufacture, the crucial question is "Will this change affect the weapon's performance?" A "yes" answer means that we must then determine how to fix the problem and if a nuclear test is needed to certify the fix. Experience plays a crucial role in these decisions. Here, we give a number of examples where changes did matter and where nuclear tests were needed. Some of these are actual weapon remanufactures, and others involve situations almost identical to what we might encounter in weapon remanufacture. Most of these examples involved stockpile problems and have been discussed in that light in Chapter 2.

#### Remanufacture of the W68 Poseidon Warhead

Routine stockpile surveillance revealed that the high explosive (HE) in the W68 was decomposing and the decomposition products were causing deterioration of the detonators. We judged that it was only a matter of time before the weapons would be inoperable. One "solution" would have been to rebuild the W68 warheads every five years, using the same type of HE that was decomposing. This would have been extremely costly and would have had a large operational impact on the U.S. Navy. Instead, we chose the more cost-effective and technically sound solution of replacing the deteriorating HE with a more chemically stable formulation; this HE had, in fact, already been tested in the W68 development program. This fix entailed a remanufacture of the W68.

The W68 was a critical part of the U.S. deterrent forces and the DOD was quite sensitive to the urgency of the changeout. Thus we judged that a nuclear test—a production verification test under simulated aged conditions—was necessary to certify the modified design to the Navy. We were surprised when the resulting yield was degraded beyond what we expected on the basis of the earlier test with the new HE. We knew that in addition to changing the HE, a number of other changes in warhead parts had been made during this remanufacture. For example, certain warhead materials had to be changed because the vendors of the originals had gone out of business. However, none of these other changes had been thought to be significant.

It is often argued that replacement materials can be stockpiled. One of the W68 materials that was no longer available was an organic material that had to be formulated at the time of use (much as epoxy cement available at any hardware store is formulated by mixing the contents from two different tubes). The raw materials used to make the final material for the W68 began to show significant changes after only two years of storage, even when refrigerated.

We have not yet been able to explain the cause of the yield degradation. Although the new HE was supposed to be the same as the material tested in the original W68 development program, there may have been subtle changes in its formulation. We do not know whether the yield degradation was caused by the new HE, by other part changes, or by some combination of changes. It is entirely possible that we might even have experienced yield degradation had we simply replicated the warhead with a fresh batch of the same chemically unstable HE. As discussed in Appendix D, we have experienced a number of problems in replicating HE.

Although the degraded yield of the W68 with the new HE was considered to be acceptable, it was necessary to modify the maintenance procedures and some conditions of the warhead's stockpile-to-target sequence. When the Navy asked for a relaxation of these procedures because of the large impact on their operations and associated costs, we emphasized the importance of following the procedures as specified. Our advice was significantly influenced by the unexpected result in the production verification test.

It is clear that the rebuilt W68 is different in substantial ways from the original. While some have stated that a production verification test of the rebuilt W68 was not necessary, we believe that the results show that the test was indeed necessary, both to certify the adequacy of the production rebuild and to enable us to provide accurate advice to the Navy on maintenance and operational procedures. The W68 production verification test is a definite example of the need for nuclear tests when remanufacturing a warhead.

**Development vs Stockpile Versions of the W84 GLCM Warhead**

The W84 experience illustrates the impact of seemingly small and insignificant changes that occurred as the development warhead was turned into the stockpile weapon. The types of changes are virtually idential to those that would be encountered in remanufacturing a warhead.

During the engineering of the W84 warhead, a number of small changes were made between the final development hardware and the production hardware. At the time they were made, each of these changes was judged to have no impact on warhead performance. When a stockpile confidence test was conducted on a unit that had been deployed for a year and modified slightly to simulate certain aged conditions, a lower-than-expected yield was obtained. We were concerned that this low yield was indicative of possible marginal operation of the device. Another nuclear test was necessary to evaluate the source of the yield degradation, to certify a fix to the problem, and to determine that there were indeed no problems with marginal operation.

Although the problem we experienced with the W84 has since been resolved, the experience we gained is directly relevant to remanufacturing a warhead. None of the seemingly minor changes made between the final development version and the production version, taken singly or together, can account for the observed yield degradation. Since we can account for the known changes in the specifications between the development and production versions, we conclude that we lack the necessary knowledge about what other things should have been specified. Evidently, we did not specify and control all the factors that mattered.

Only three years elapsed from the final yield certification test of the final development version of the W84 to the test of the production version (and less than two years from the tests of the development hardware at the high- and low-temperature extremes). Knowing that something significant changed in the fabrication process in this short time, we must wonder what sorts of changes might take place between now and some future time when a decision might be made to remanufacture the warhead. Until we learn the answer to this question, we believe that production verification nuclear tests will be needed to certify remanufactured warheads. In fact, if the production of a warhead extends over very many years, more than one production verification test may be advisable.

**Sensitivity of Primary Performance to IHE Properties**

The safety features of insensitive high explosive (IHE) are very important for the peacetime storage and transport of U.S. nuclear weapons. While IHE weapons are virtually impervious to accidental HE detonation under extreme conditions of shock, impact, and fire, there are manufacturing problems associated with this material that make it difficult to replicate from batch to batch.

In the early 1980s, an in-production warhead was fired in a nuclear test to determine the sensitivity of its IHE primary to certain environmental conditions. The effects of environmental conditions on IHE are of concern since the same properties that make IHE safe to accidental detonation also make it difficult to initiate detonation in actual use. In this nuclear test, the measured primary yield was 25% lower than expected. Extensive post-test analysis of the experiment revealed a number of possible causes of the primary yield reduction.

One possible cause involved the particle-size distribution of the specific IHE lot used to manufacture the weapon; some particle-size distributions make the IHE more difficult to initiate. A research program was begun to study the sensitivity of IHE initiation to various factors, including particle-size distribution. As a result of this research, the production specifications of the IHE were changed to ensure consistent detonation performance under all expected conditions. Had it not been for the nuclear test, the production specifications might have gone unchanged, with possible serious consequences for future weapon builds. It should be noted that the IHE batch used in the nuclear test had a particle-size distribution that was worse than in any of the units that had already been deployed; thus the already produced units were judged to be acceptable. The fact remains, however, that it was only in the nuclear test that the extent of the IHE's sensitivity to particle-size distribution was discovered, and only then could the necessary particle-size distribution specifications be implemented.

This example illustrates the variabilities possible in HE manufacture. Even with detailed specifications, it may be extremely difficult to produce consistent and reproducible batches of HE since many aspects of HE manufacture are as much an art as a science. Just as important, while we believe we know today what to specify, there may be some unspecified but important characteristic that we know nothing about.

In a future remanufacture, we would extensively check the HE components in nonnuclear experiments. We would estimate the effects on nuclear performance of any differences that might arise in behavior between the new and original systems. However, without a nuclear test to verify the magnitude of these effects, considerable uncertainty in performance could result.

**New High Explosive for the W52 Sergeant Warhead**

The redesign of the W52 warhead was a remanufacturing-like situation required for reasons of safety. In 1959, the W52 warhead was nearly ready for production when two explosive accidents occurred at LANL, killing six people. The explosions were due to the unexpected susceptibility to accidental detonation of the HE used in the W52 primary. Los Alamos scientists had to change the explosive used in the warhead to a safer and less sensitive explosive, which was also somewhat less energetic. This decision was made during the Nuclear Test Moratorium of 1958–1961, when the new design could not be verified in a nuclear test. The redesign was based on nonnuclear hydrodynamic tests and computer design calculations. Because of the high confidence that LANL scientists had in their redesign, they did not immediately test the W52 when the Moratorium ended in 1961. The W52 entered the stockpile in April 1962. When the device was finally tested, it gave only a fraction of its expected yield. The W52, as delivered, was militarily unacceptable. Los Alamos scientists made a rapid redesign; within three months of the test failure, they conducted a successful nuclear test of the new design, which was subsequently incorporated into the stockpile.

The W52 is an example of a weapon design that *had* to be changed because of safety reasons. Nonnuclear experiments and computer calculations were inadequate, and nuclear testing was essential to verify the design. Although this was not literally a weapon "remanufacture," it might well have been if the fatal accidents had occurred *after* deployment of the original W52. The W52 case also illustrates how pressures in the system can contribute to recertification, even though there should be reservations about doing so.

**Problems with the W47 Polaris Warhead**

Three problems were identified with the W47 warhead: corroding fissile material, vulnerability of a material to an ABM environment, and a defect in a mechanical safing device. Remanufacturing issues were associated with the second and third problems, and nuclear testing played a necessary role in correcting them.

A modified design was needed to correct the ABM vulnerability problem. The extent of the design modification was large enough to require a nuclear test to certify the change, and weapons were rebuilt with the modification.

A mechanical safing device was used in the W47 warhead to make it safe to one-point detonation. However, chemical corrosion in the W47 caused a serious reliability problem in the safing mechanism that did not lend itself to a viable engineering solution. In a large fraction of the sampled warheads, the mechanism would not fully complete its arming operation; this indicated that a large fraction of the W47 warheads would be duds, and the number of duds was increasing with age. Rather than remanufacture the warheads with rebuilt safing mechanisms that would fail again, we solved the problem by replacing the primary with one known to be inherently one-point safe. A nuclear test was required to certify this new design. All W47 warheads in the stockpile were retrofitted with the new primary.

Although these problems with the W47 did not involve exact replication of the warhead, they all involved dismantling warheads and rebuilding them with improvements. Each of the improvements was necessitated by serious unforeseen changes in vulnerability or reliability. The W47 illustrates that in order to maintain the capability of a weapon, exact replication may not be desirable or even possible.

## Repackaging Warheads

It has been suggested that, in the event of future restrictive test limitations that preclude the design of new warheads, it would be possible to repackage existing warheads in new delivery systems. Note that repackaging is considerably different than remanufacturing. Repackaging would involve taking a warhead designed for one application (i.e., delivery vehicle and mission) and, without redesigning it, adapt it for another use.

U.S. warheads and delivery vehicles are tightly integrated into weapon systems; each warhead is optimized for its specific missile and each missile is optimized for its warhead. The warhead is designed to withstand conditions unique to the mission of the delivery vehicle, and thus is designed to meet specific targeting requirements, transportation environments, hostile (e.g., ABM intercept) environments, etc. It would be extremely imprudent to adapt an existing warhead to a new application without nuclear testing if the conditions of the new application are much different from the "as designed" environments.

If we cease nuclear testing, we would have to freeze certain aspects of the packaging system and significantly limit warhead options for new delivery systems. Such a limitation on future defense systems could prove to be extremely costly and inhibitive since changes in the warhead could cause major changes in the whole system. The overall effect would likely be one of increasing the effective warhead mass and volume. For example, we would need a stay-out zone between the warhead and certain missile components; we would not be able to qualify a new weapon electrical system (WES); we would have to freeze the electromagnetic pulse (EMP) specifications; and generally we would require more volume to repackage.

Historically, warheads and missiles have been designed as an integrated system, with features in one affecting or dictating features in the other. For example, in order to increase range and decrease cost, we have often designed our warheads on the margin in terms of the yield-to-weight ratio or other especially important military requirements. Our designers have worked to reduce the system weight (often by reducing the warhead dimensions) while maintaining warhead yield. This approach is very cost-effective in terms of delivery systems, enabling aircraft and submarines to carry more missiles. On the other hand, it has meant that our warheads are more complex and thus more dependent on nuclear testing. We have paid for this system integration and efficiency with a warhead complexity that has increased our reliance on nuclear tests for certification.

The priorities among competing military characteristics are not carved in stone; they change as new contingencies arise. For example, in recent years we have accepted a less-than-optimum yield-to-weight ratio in order to install

IHE and to reduce oralloy usage. Similar changes in priorities will certainly occur in the future; for example, successful development of a directed-energy weapon (DEW) by an adversary would force us to give high priority to a requirement for DEW-vulnerability protection.

It may indeed be possible to design a more "robust" nuclear warhead, as is discussed in Chapter 4. Such a device could be based on very conservative design practices and probably would be heavier and larger than its optimized modern counterpart. It would probably have a decreased yield-to-weight ratio; it would also have to provide for the required stay-out zones for electronics. Before these warheads could be incorporated into existing delivery systems, many of the systems would have to be redesigned and retrofitted—a time-consuming and extremely expensive undertaking.

Thus a freeze in packaging options, due to restrictive nuclear limitations, or a decrease in the yield-to-weight ratio, due to extremely conservative warhead designs, would lead to a need to reconfigure existing delivery systems to accept larger diameter warheads (assuming this would be possible; for many systems it is not), a probable increase in the total number of delivery systems, and possibly the development and production of new delivery systems. This situation calls to mind comments from Lockheed engineers about remanufacturing a rocket motor in the absence of testing—they might have been able to do it with a very conservative design, but the end product would not have fit into the existing submarine launch tubes!

The strategic balance often depends on our ability to make critical changes in missile configurations. Testing gives us the ability to certify efficient warheads in new configurations. Without testing, we foreclose on our options to make those changes.

## Conclusion

When we examine the issue of remanufacture, our most important conclusion is that *test experience is vital.* Even with the limited nuclear testing permitted today (limited both in yield and in number of tests), the day-to-day decisions that must be made in the weapon production process can be handled, in large part, using the judgment of test-experienced scientists and engineers. This brings us face to face with a major concern when we consider remanufacturing nuclear warheads without testing. The experience base essential for making these decisions will deteriorate without testing, and yet, without testing, there will be an even greater need for these judgments. The end result will be a product—a nuclear weapon—with reduced credibility. The uncertainty in the warhead's performance (difficult or impossible to quantify without knowing the detailed nature of a possible problem) might become great enough that its deterrent value would be significantly reduced.

Our *current* test-experienced engineers and scientists could undertake a remanufacture with confidence that the weapon would perform about as well as the original weapon. However, experience has shown that, even now, we might have difficulty in matching earlier performance. It is difficult to be quantitative about how close we can come to exact replication since we cannot know the nature of future problems. Without nuclear certification tests of remanufactured weapons, there will undoubtedly be greater uncertainties. Perhaps, the uncertainties can be mitigated by more conservative designs or by more conservative operational limitations on the deployed weapons. Whether the resulting uncertainties in deterrent value are acceptable is a question for the policy-makers.

A major problem in remanufacturing a weapon is the available documentation. The documentation for older weapon systems is inadequate and many of the specifications are unknown. Documentation has improved since the military characteristic for replicability was established in 1982, and we now have significantly improved specifications for the more recent weapon systems. However, as we learned from the W68 and W84, the specifications for even these recent systems may be incomplete and we lack the knowledge to make them complete. While, in the future, it should be more feasible to remanufacture these modern weapon systems than the older systems, the uncertainties in performance of the remanufactured weapons could be significantly greater without nuclear certification tests and in the absence of design physicists and engineers with test experience.

It is important to emphasize that in weapon remanufacture we are dealing with a *practical* problem. Idealized proposals and statements that we "should be able to remanufacture without testing because expertise is not essential" are a prescription for failure.

## Chapter 4. Preparing for Further Nuclear Test Limitations

It is difficult to predict when, if, or in what form we will see further limitations on nuclear testing. In the face of more restrictive test limits, the weapon laboratories would still be responsible for ensuring the reliability and effectiveness of U.S. nuclear weapons. Thus it behooves us to take the necessary steps now to prepare for such a situation. The technical impacts would be less severe if the limitations took effect gradually, in phase with other arms limitations and technology controls. The President has proposed such an approach to the Soviets. He has called for step-by-step progress toward further test limitations in parallel with major arms reductions, with the ultimate goal of a complete cessation of nuclear testing.

Since the 1958–1961 Nuclear Test Moratorium, we have been acutely aware of the potential impact of a Comprehensive Test Ban (CTB). On many occasions, the Laboratory has been requested by the U.S. government to assess the consequences of more restrictive test limits or a CTB.

What will be our ability to carry out our responsibilities if testing is severely limited? At the very least, these responsibilities would include ensuring the reliability of the existing stockpile, assessing changes in weapons caused by stockpile aging, overseeing corrections to potential problems, and evaluating the inclusion of previously designed weapons into new delivery systems. It appears likely that under restrictive test limits, many of these responsibilities could not be met with today's level of confidence. Upgrades and improvements, however minor or reasonable, would have to be carefully examined to ensure that they would not introduce unacceptable uncertainties.

In the earlier chapters of this report, we have discussed how changes in weapon design are dictated by safety and security considerations, use of new materials, new configurations, or new military requirements. Although not all of these changes must be certified in full-scale nuclear tests, they all rely on data obtained in nuclear tests and, most critically, on the judgment and insight that scientists and engineers acquire on the basis of such data. Depending on the specific test limits, experimental data from testing could be very limited or nonexistent. Thus the pool of experienced specialists would decline and the skills of those that remain would diminish.

Although we see no satisfactory way to solve the problems involved in meeting our responsibilities under a regime of very restrictive nuclear test limitations (e.g., a CTB or a very low yield threshold), we have identified several measures by which they may be mitigated. Measures we could employ *before* new test limitations go into effect include stockpile confidence tests of existing warheads, production verification tests of new weapons, developing backup warheads for various weapon systems, improving our understanding of weapon physics by nuclear and nonnuclear tests, finding ways to certify thermonuclear components at reduced yields, and designing weapons less likely to suffer material degradation or more suited to modification than current designs.

Other measures could continue *after* test limitations have gone into effect. These include acquiring more extensive nonnuclear experimental facilities, developing advanced supercomputers and numerical modeling capabilities, pursuing nonnuclear programs (e.g., advanced conventional munitions) that use many of the same skills as the current nuclear weapon program, and taking deliberate steps to maintain the capability to produce existing weapon designs.

We are pursuing all of these measures to the extent that funding and the military characteristics (MCs) allow. Our efforts in this area were recently attested to by the University of California Scientific and Academic Advisory Committee (SAAC); the findings of the committee are reported in Reference 2 and are summarized in Chapter 1.

### The Augmented Nuclear Test Program

Laboratory programs in support of these measures were mapped out, more than five years ago, at the time of the Augmented Nuclear Test Program. In 1980, at the request of President Carter's Office of Science and Technology Policy and in response to a memorandum from the National Security Council, the Departments of Energy and Defense developed a plan for an Augmented Test Program (ATP) for underground nuclear testing. The ATP called for a 50% increase in the number of nuclear tests for the first two years, followed by an additional 25% increase in succeeding years. The purpose of the ATP was to "place the U.S. in a more sound national security posture." In addition, the ATP report stated that:

"The program places early emphasis on those areas of science and technology that contribute most to reliability and confidence of the stockpile.

In this regard, the program supports as a first priority CTB readiness objectives in the short term while continuing to provide for orderly reestablishment in the longer term of the nuclear science and technology base which is the bedrock of the U.S. nuclear deterrent."

The ATP set a high priority on the nuclear tests required to complete the current and projected military requirements. Plans were made for other nuclear tests to address the issues of alternative warheads, longevity, assessability, and reliability. Research was to continue on improving the safety and security of the stockpile and on assuring the survivability of U.S. systems exposed to nuclear weapon effects. In addition, a large fraction of the tests were to be devoted to enhancing our fundamental knowledge of nuclear weapon design physics.

The Office of Science and Technology Policy convened a panel (Solomon Buchsbaum, Harold Agnew, John Foster, Gerald Johnson, Carson Mark, Ernest Martinelli, and Wolfgang Panofsky) to review and provide input to the ATP plans. The Panel made the following observations:

"In general, the Panel is favorably impressed by most parts of the Program, in particular those parts that address fundamental nuclear design questions. It is important to remove the physics uncertainties in device designs, which are now compensated for empirically, so that designers can predict performance from first principles.

"In the absence of ability to test, confidence in the reliability of the stockpile ultimately rests on availability of people who are intimately knowledgable of the design of the warheads in the stockpile and who, on examining a particular warhead, can judge its capability to perform according to its design. A key objective of any expanded program should be to help retain a cadre of such people and attract new ones.

"The Panel agrees that the ATP as proposed would make an important contribution to increased confidence in the reliability of the U.S. nuclear weapon stockpile under a CTB. The ATP cannot, however, eliminate all concerns about stockpile reliability especially under a protracted CTB."

The Panel recommended a number of changes that were incorporated in the ATP plans. These included provisions to allow for more stockpile confidence tests of key systems, development of alternative warheads for important strategic systems, and a recommendation to improve our understanding of the performance of primaries. Accordingly, the ATP called for a series of boost physics experiments. Regarding alternative warheads, the ATP intended that alternative designs would be developed and placed "on the shelf" to provide backups to systems then under development. Such backups could be used if an unresolvable problem arose with the preferred warhead. In particular, the panel recommended the development of conventional high-explosive backups to primaries using insensitive high explosive (IHE), owing to the newness of IHE designs at that time.

What was the outcome of the ATP? President Carter approved the ATP in principle. Although he did not submit the ATP to Congress for their explicit approval, he requested and obtained additional funding for nuclear testing. President Reagan has continued to seek more funds for testing in his budget requests.

At the time the ATP was planned, we had already started to work on many of its suggested measures. Beginning in 1980, the weapon laboratories began to do more stockpile confidence tests. One such test that is now done regularly on new stockpile systems is a production verification test; in this test, a unit is brought back for a proof test after it has been exposed to field conditions for a short time. We have also tested a number of older systems. We recognized that more nuclear tests were needed for weapon physics research (described below). In addition, we instituted a boost physics research program, one of the specific ATP goals. Although we have fallen short of the goal of developing alternative or backup warheads for all important systems, some alternatives are available if an unresolvable problem arises with a particular warhead. For example, the Mk 12A/W78 conventional HE warhead could be used in place of the Mk 21/W87 IHE warhead for the Peacekeeper (MX) missile. The GLCM (W84), ALCM (W80), and Pershing II (W85) warheads might also be adapted to other systems if needed, although penalties in operational capability and military performance would probably be incurred.

Our weapon physics research and stockpile confidence tests are continuing, but not under the name of the ATP. The redirection of effort to nuclear-driven directed-energy weapon (NDEW) programs for the Strategic Defense Initiative (SDI) has absorbed most of our additional nuclear testing resources for the last seven years. We cannot simultaneously sustain high levels of research on SDI and on weapon physics with the current funding levels. Although we have accomplished much, because of limited funding, only a fraction of the goals set by the ATP in 1980 have been met.

It would be advisable to institute an ATP. As part of our five-year planning of nuclear test activity, we have detailed additional testing along these lines, including several tests relevant to stockpile confidence at lower yield thresholds. If a new ATP is to be successful and avoid the fate of its predecessor, a future ATP will require Congressional endorsement and adequate sustained support will be imperative.

## Laboratory Efforts to Prepare for Further Test Limitations

We are already taking steps to prepare for future limits on nuclear testing and have identified a number of ways in which these measures could be enhanced.

### Weapon Physics Experiments

We regularly conduct weapon physics experiments as part of nuclear tests fielded for other purposes. Since 1981, one or two additional nuclear tests have been dedicated specifically to weapon physics research under the heading of "fundamentals of reliability." The knowledge gained from these tests has already been used to develop more conservative and more reliable designs. We have improved our understanding of the boosting process, reduced the uncertainties involved in thermonuclear energy production, and enlarged our knowledge of aspects of radiation hydrodynamics. However, we still have a long way to go before our understanding of these complex physics processes is complete enough to substantially reduce our dependence on nuclear testing. In recent years, as a result of programmatic requirements for NDEW research, we have had to scale back on the number of dedicated weapon physics tests. There is also a limit to how rapidly the results of weapon physics experiments can be interpreted and computational models developed or modified as theory and experiment are integrated.

Weapon physics experiments are also done at our nonnuclear and high-explosives experimental facilities. With the Nova laser, we have measured the x-ray opacity in materials, providing the first laboratory-gathered data crucial to thermonuclear design. With the Flash X-Ray facility, we are exploiting recent advances in radiography and ultrafast (10-nanosecond) photography to take pictures of spallation from explosively driven metal shells characteristic of fission triggers. We are also constructing the High-Explosives Applications Facility (HEAF), with which we will investigate the nonideal properties of insensitive high explosives and to characterize more completely the safety of "ideal" (but sensitive) explosives.

An important commentary on our weapon physics research was provided by the SAAC as they examined the role of these tests in the resolution of problems encountered with stockpile weapons:

"It is evident from the results of these physics tests that they have contributed to a better general understanding of this technology. ... the increased number of weapons physics tests since 1981 has both helped to identify these problems and has contributed to an understanding that will be instrumental in reducing their number in the future."

With continued research in weapon physics, we should be able to improve our understanding even further. This would allow us to place less reliance on nuclear testing for the identification, evaluation, and resolution of physics problems. Recently, however, the DOE has submitted budgets to Congress with *decreased* funding for "core" testing (i.e., tests other than for NDEW research). This will seriously reduce the level of our research effort into the "fundamentals of reliability."

### Advanced Nonnuclear Experimental Facilities

We are continually searching for nonnuclear experimental facilities that could come close to duplicating the conditions created in a nuclear test. The various existing nonnuclear experimental facilities and the facilities envisioned for the future do not come close enough to simulating the conditions in a nuclear explosion and thus could not take the place of nuclear testing. They can, however, provide valuable weapon physics data, help experimenters maintain some level of relevant skills, and provide a test bed for designers to verify some theoretical aspects of weapon physics. This might enable us to maintain a certain level of nuclear weapon expertise, but such facilities might also have a lulling effect on our capabilities. Focusing attention on areas only partially relevant to nuclear weapons could lead to errors in judgment about actual nuclear design matters.

Major extensions of existing nonnuclear facilities would be required to enhance our capabilities in nonnuclear testing. For example, a High-Gain Test Facility (HGTF), using a multimegajoule laser for research on inertial confinement fusion (ICF), would provide more intense conditions than are available with the Nova facility. The HGTF would allow us to make studies on 1000-MJ ICF capsules.

The conditions produced at such yields would be relevant to some aspects of nuclear weapons design and diagnostics and would provide a source for some tests on military vulnerability, lethality, and exposure. However, many aspects of the physical performance of nuclear weapons (e.g., the behavior of fission primaries) could not be addressed by the HGTF.

Enhancements in the capabilities of the above-mentioned FXR facility at Site 300 would be valuable. Advances in accelerator technology leading to higher x-ray intensities would provide the improved resolution needed to explore the late-time implosion behavior of primaries. Progress in acquiring such improved or new facilities is very much limited by available funding.

### Low-Yield Fission Explosions

A CTB might be configured to allow very-low-yield fission explosions, below the verification threshold. These explosions would have some value for maintaining minimal experience with fission weapons but they would be of little help in resolving stockpile problems.

We have conducted a preliminary study of the role of low-yield nuclear tests (under 100 tons total yield) in maintaining a nuclear design capability. We attempted to identify what nuclear explosives technologies could be maintained under such a highly restrictive limit and what weapon physics experiments could be performed that would contribute to our understanding of higher-yield weapons. The report of the results of this study is classified; an unclassified version is available, although it lacks much of the technical reasoning and detail presented in the full report.

We reached several conclusions about the impact of a very-low-yield nuclear test threshold. We concluded that tests at low yields add little or nothing at all to our confidence in the performance of nuclear weapons systems. Neither do they contribute significantly to the maintenance of the essential, critical design skills relevant to today's stockpile. The reason for this is that stockpile devices use a number of different physical processes to achieve their yield, and some of these processes cannot be simulated at very low yields. We did identify several weapon physics experiments that would add to our technology base for understanding the general operation of nuclear explosives and could be conducted at low yields.

One of the most critical aspects of a low-yield test limit or a CTB would be the difficulty in training new weapon designers and engineering personnel and in maintaining the competence of the existing staff in technologies relevant to the existing stockpile. During an extended absence from nuclear testing at relevant yields, we would expect an inexorable deterioration of our understanding of the nuclear weapon stockpile.

### Advanced Computational Capability

The Laboratory continues to acquire the most advanced supercomputers available. The Livermore Computer Center currently has two CDC 7600 computers, four Cray-1 computers, a Cray-XMP/48, and a Cray-XMP/416. We devote much research to developing improved computational methods to take full advantage of the advanced computer architectures and to improve the accuracy of the physics models in our weapon design codes. We have made large gains over the years in our ability to model nuclear explosions, but we are still far from being able to give up our reliance on nuclear tests. In fact, historically, computational modeling has been intended to supplement nuclear tests, not eliminate them.

The cost of modern computers is high enough that equipment funding of the national laboratories limits the acquisition of a new mainframe replacement to one every two years. This is not rapid enough to enable us to make the potential gains inherent in advanced computational capability.

### Certifying Nuclear Components at Reduced Yields

We have been studying the possibility of certifying the full-scale yield of weapons at test yields below 150 kt. The fundamental issues are whether devices with large quantities of inert materials will produce diagnostic data that are representative of the full-yield device, and whether we can extrapolate, with confidence, the full-scale yields from small fractional yields. Computational studies indicate that often-suggested thresholds below 15 kt are inadequate for full certification. We are investigating the adequacy of thresholds at and above 15 kt. Preliminary analytical results, yet to be confirmed by experiments, indicate that yields beyond 15 kt are needed to provide definitive data from largely inert secondaries. Our research to date indicates that it would not be possible to certify new-type, high-yield thermonuclear devices at any of these reduced test yields. Also, these levels would not enable us to determine full yields to the accuracy now available.

We are investigating what can be learned about the boosting process at low test yields. Our experimental data in this area are extremely limited. More nuclear tests are needed before we can determine the value of low-yield testing to studies of the very complex boosting processes present in current primaries.

Reduced-yield studies are vitally important, and we are planning several nuclear tests as part of this research. The rate at which we do these experiments is limited by the funding available for our core programs.

**Nonnuclear Weapon Programs**

During a CTB, work on advanced conventional munitions would help to maintain some of the skills relevant to primaries. These munitions use many of the same technologies—in particular, hydrodynamics, materials science, high-explosive chemistry, and high-speed diagnostics—that are required in the development of the fission triggers for nuclear weapons. We have sought a stable, block-funded program in conventional munitions and, most recently, a joint DOE-DOD-funded Energetic Materials Center (for the study of explosives and rocket propellants). DOD funding cutbacks in the 6.2 category have limited the former program and precluded the latter.

The ICF program uses skills relevant to the physics of secondaries. When ICF capsules are imploded, much of the same physics is involved as in secondaries (e.g., radiation hydrodynamics, thermonuclear reactions, radiation opacities, and hydrodynamic instabilities), albeit on a much smaller scale. While physics skills may be exercised in such ICF studies, the development of nuclear weapons and the solution of stockpile reliability problems require full-scale nuclear tests. Although ICF capsules involve much of the physics of secondaries, an examination of the prospects for achieving ICF has forced us to conclude that even though ICF is both technically interesting and challenging, it does not address many critical issues of weapons design and thus would not be adequate to enable us to maintain a competent nuclear design capability during a protracted nuclear test ban.

There are some nonnuclear programs that exercise skills relevant to NDEW research. The ICF facilities can be used in such research. In fact, the Nova laser is currently being used in the laboratory x-ray laser program. Some laboratory research is also possible on microwave weapons.

We must emphasize that the role of these nonnuclear programs is quite limited. They can be used to help maintain some relevant physics skills but they cannot be used to solve weapon problems. They can help to slow the erosion of capability but they cannot stop it. Unless these programs have an important national mission, they will not attract the top people. Even with very limited nuclear testing and with generous funding for nonnuclear facilities, it will be hard to get and keep top people. Expertise on real weapon problems will decline, and depending on the allowed level of testing, personnel knowledgable about nuclear test operations and diagnostics will leave.

Another major concern is that weapon physics draws heavily on such basic scientific disciplines as atomic physics and the theory of hot dense plasmas. The research base in the U.S. in these area is almost nonexistent. In contrast, these subjects are strongly emphasized in foreign countries, especially the in Soviet Union. For example, there are no Assistant Professors of Atomic Physics Theory in the U.S. It will take many years and tens of millions of dollars for university research facilities to redress this problem. Since the Mansfield amendment disallowed DOD's application of 6.1 funds, atomic physics has not had a principal sponsor among the federal agencies. We suggest that the DOE establish a Division of Atomic and Dense Plasma Physics to parallel the Division of Nuclear and Particle Physics.

**"More Robust" Weapons**

We could design and manufacture weapons that are less likely to suffer degradation with time. However, because of the configuration of the present stockpile and delivery systems and because we cannot anticipate what problems will develop, this would be an expensive and difficult undertaking. For example, larger primaries containing more nuclear material are seen by some as less demanding and more robust. Since we often cannot judge ahead of time which components will degrade, we still could not make absolute guarantees about the longevity or durability of these "more robust" weapons. The addition of 10% more high explosive or more fissionable material might provide some assurance against the effects of minor deterioration in the future; however, this would not have prevented some of the problems encountered in the past.

For any of these changes to be incorporated in U.S. nuclear weapons, the MCs would have to be changed. If they are changed, we might be forced to give up improvements in weapon technology that provide increased safety, security, survivability, and military effectiveness. Without carefully studying each proposed new weapon system, we could not know what specific technological improvements would have to be sacrificed in any one system. For example, while unlikely, we might forego the use of IHE in favor of conventional high explosive, since IHE is more difficult to initiate and thus potentially more sensitive to some stockpile aging effects.

The size and weight of the warheads might also be increased. We have learned from experience that larger systems are less sensitive to small design changes and, for this reason, would be expected to be less prone to some effects of stockpile aging. The increased size and weight of the warhead could also generate the need for larger missile systems. Adapting DOD delivery systems to the available DOE warheads, rather than optimizing the warheads for the delivery systems, is likely to increase overall weapon systems costs substantially.

Similarly, the more nuclear material, such as plutonium and tritium, that a weapon contains, the more robust it normally is to parametric changes and consequently to some of the effects of stockpile aging. A thorough study would be required to account for the increased nuclear material needs of more robust designs and to determine whether the production reactors can meet these needs in a timely manner.

Other improvements that might be relinquished in an attempt to make weapons more robust include certain built-in security features and structural features required for specialized missions. For example, the construction features that allow earth penetrator weapons, artillery shells, and laydown bombs to withstand extremely high accelerations and decelerations can affect the operation of the nuclear warhead and could be the source of uncertainty in the event of a stockpile aging problem. Thus we might have to forego the development and deployment of systems that depend on these features for their effectiveness.

A more detailed description of the nuclear design changes that might be involved and the military capabilities that might have to be relinquished in order to develop more robust warheads has been requested by the Senate Armed Services Committee (SASC) in the FY 1988 Defense Authorization Bill. This study would direct the DOE to examine the feasibility of reduced reliance on underground nuclear testing (Appendix E). If it is decided that further nuclear test limits are a desirable goal, we believe that the approach suggested in the SASC language is the correct one. Rather than making assertions about what can be accomplished under more restrictive test limits, the SASC language poses questions that must be answered before agreeing to additional testing limits. We certainly are not ready today for significantly reduced limits, and a thorough preparation and investigation, including nuclear tests, is needed before this country commits to a new regime of greatly increased test restrictions.

## Enhancing Our Ability to Remanufacture Weapons

We are placing major emphasis on 25-year objectives, materials compatibility, and engineering durability in order to maintain the capability to remanufacture weapons. At the government's request, we have already judged it acceptable to extend the lifetimes of a number of systems in the stockpile. Although we rigidly document production procedures and materials, there is no guarantee that remanufacturing will be easy; indeed, there is ample evidence to the contrary (see Chapter 3 and Appendix D).

### Continued Production at Low Rates

Production of weapons could be continued at low rates. It would be quite expensive to do this, since we would have to maintain a complete manufacturing infrastructure for each weapon (of which there are currently 28 types), even though the build rates would be small. A very high premium might have to be paid to keep small vendors involved in the process. Tremendous loads would be placed on existing production facilities, and extra facilities might have to be built.

It is also not clear that continuing production will indeed maintain capabilities. Consider, for example, the W68 Poseidon warhead. During the very early production of the W68 at the Burlington AEC (Atomic Energy Commission) plant the quality of the product was very high. As the build rate increased and new assembly people were brought into the program, the quality dropped to an unacceptably low level. To correct this problem, production had to be stopped and the new operators educated in both procedure and design intent (i.e., operation of the warhead) by the experienced engineering team responsible for overseeing the production.

### Maintaining Critical Processes

It has been suggested that we maintain certain critical processes, manufacturing technologies, and production plants on a stand-by status in the event that remanufacturing becomes a necessity. This might be accomplished for a few high-priority systems and selected technologies. The risk is that we will preserve unneeded technologies and ignore the critical ones. We would have to deal with the problems of maintaining a highly trained, knowledgable cadre who would not be doing anything "productive." In addition, the processes and technologies would have to be continuously monitored to make sure that they did not change with time, either through lack of attention from a potentially bored staff or, conversely, through their creative efforts to "improve" the processes and product.

**Improved Documentation**

A major problem in remanufacturing a weapon is the documentation. The documentation of older weapon systems is inadequate, and many of the specifications are unknown. Documentation has improved since 1982 when the DOD added an MC for warhead endurance and replicability, in which these features are stated to be *desirable* goals consistent with meeting the other MCs:

"It is desired that the warhead have an inherent endurance obtained as a result of design considerations that address: a maximum warhead lifetime, maximizing the ability to replicate the warhead at a future date, and maximizing the ability to incorporate this warhead in other weapon delivery systems. Therefore, the design, development, and production of the warhead must be well documented and involve processes that to the extent possible allow replication at a future date."

Since then, we have significantly improved the documentation and specifications for the more recent systems that have gone into the stockpile. However, as experience with the W68 and W84 revealed (see Chapter 3), the specifications for even the more recent systems may be incomplete and we lack the knowledge to make them complete. While the improved documentation should make it more feasible to remanufacture modern weapon systems in the future, the uncertainties in performance of the remanufactured weapons could be great in the absence of nuclear certification tests and without test-experienced design physicists and engineers.

Today, we are providing adequate documentation for our current job-shop methods of weapon development, production, and stockpile surveillance. Current and past documentation is not and never was intended to cover the possibility of *inexperienced* personnel attempting a weapon remanufacture. We could prepare still more detailed specifications and documentation, given substantially increased resources. However, the experts with practical remanufacturing experience in both the weapons complex and private industry warn that there is a practical limit to the level of detail that can be included in production specifications.

**Stockpiling Materials**

It has been suggested that weapon materials be stockpiled for possible future rebuilds. Indeed, this can be and is being done for some materials. Appendix D gives examples of the problems we have already faced with replicating batches of high explosive, procuring metals with the right mechanical or chemical property, locating a source of a material with the required uniformity and strength, and discovering that materials have become obsolete for reasons of economy or because of new health and safety standards. Many of the materials used in *existing* weapons—materials that are critical to the correct functioning of the weapons—would take much effort and expense (and testing) to replicate, and we would have to solve the problems of replicating the material before it could be stockpiled.

Stockpiling large amounts of weapon materials would be expensive and, in some cases, would require special handling of hazardous materials. The availability of safe and secure storage space is already limited, as are the funds required to operate the production plants. Even assuming that we can stockpile a given material to replace identical material that has aged in a weapon, there is no guarantee that the stored material will be in better shape than the aged material in the weapon. Therefore, although stockpiling materials may seem to be an ideal solution to the problem of remanufacturing a weapon, it may actually be more practical and effective to remake the material or to find a suitable substitute at the time we need it. This will of course require testing, possibly even a nuclear test. In fact, a substitute material that will age well is likely to be preferred over a material that has aged badly if, through proper testing, we can demonstrate that the substitute is satisfactory.

## Conclusion

The Laboratory is committed to fully meeting its responsibilities for ensuring the reliability and effectiveness of U.S. nuclear weapons both today and in the event of future, more restrictive limitations on nuclear testing. We have identified and are already taking a number of steps to prepare for more restrictive test limitations. We are continually seeking new and better ways to preserve the nuclear weapon expertise and judgment so critical to meeting our responsibilities. Until we accomplish this, it would be imprudent to agree to further limitations and restrictions on nuclear testing.

## Acknowledgments

Many expert scientists and engineers were consulted in the preparation of this report. Certain sections of the report were written by Herman Leider and Charles Wraith of Lawrence Livermore National Laboratory (LLNL). Particularly valuable input came from John Immele, Eugene Burke, William Zagotta, Steve Younger, Bill Inouye, and Warren Heckrotte of LLNL, and David Watkins, Don Westervelt, Delmar Bergen, and Robert Osborne of Los Alamos National Laboratory (LANL). Some sections of the report were adapted from draft material written by Don Westervelt of LANL. We thank the Strategic Systems Program Office of the U.S. Navy for allowing us to include the information on the experience of the Lockheed Missiles and Space Company on the remanufacture of the Polaris A3 missile. We also thank the many weapon designers, engineers, physicists, materials scientists, and technical managers at LLNL and LANL who provided their expert opinions in numerous discussions and manuscript reviews. We particularly want to thank Lauren de Vore for her expert editing and for providing valuable suggestions for this manuscript.

## References

1. R. D. Woodruff, Testimony Before the Subcommittee on Arms Control and Disarmament, Armed Services Committee, U.S. House of Representatives (September 20, 1985); also, R. N. Thorn, testimony on same date.
2. The Scientific and Academic Advisory Committee; Lew Allen, E. L. Goldwasser, A. J. Goodpaster, A. K. Kerman, M. B. Maple, K. McKay, W. G. McMillan, F. Reines, H. F. York, and R. E. Vogt, *Nuclear Weapons Tests: The Role of the University of California–Department of Energy Laboratories, A Report to the President and the Regents of the University of California* (July 1987).
3. Robert S. McNamara, *Blundering into Disaster, Surviving the First Century of the Nuclear Age* (Pantheon Books, New York, 1986).
4. See for example, Secretary of Defense Harold Brown's Posture Statements, *Department of Defense Annual Report, FY 1979 and FY 1980.*
5. Harold Brown, *Report of the Secretary of Defense to the Congress on the FY 1982 Budget* (January 19, 1981).
6. State Department Special Report regarding U.S. Policy Regarding Limitations in Nuclear Testing (August 1986).

**Appendix A. Letter from Congressmen L. Aspin, N. D. Dicks, D. B. Fascell, E. J. Markey, J. M. Spratt, and Senator E. M. Kennedy to Director Roger Batzel, dated March 30, 1987.**

# Congress of the United States
**Washington, DC 20515**

March 30, 1987

Dr. Roger Batzel
Lawrence Livermore Laboratory
P.O. Box 808
Livermore, CA 94500

Dear Dr. Batzel:

As you are aware, in recent months Administration officials have argued that the United States should not negotiate a Comprehensive Test Ban Treaty with the Soviet Union because such an agreement would prevent us from conducting explosive reliability or "proof" tests of existing nuclear warheads.

One of the key technical questions that has to be answered in assessing the validity of this argument is whether it is possible to assure the reliability of the existing nuclear stockpile through non-nuclear explosive testing and remanufacture of new warheads using the original design and product specifications of existing, thoroughly tested warheads.

It has been argued that previous examples of problems with stockpile reliability indicate that nuclear explosive testing will continue to be necessary in order to identify and correct stockpile problems. Examples of such stockpile problems have been cited in a number of unclassified and classified documents, as follows:

1. Jack W. Rosengren, Some Little-Publicized Difficulties with a Nuclear Freeze, R&D Associates. Report RDA-TR-122116-001, October, 1983. (Unclassified)

2. Jack W. Rosengren, Reliability of the Nuclear Stockpile under a CTB. R&D Associates. RDA-TR-122100-001-Rev. 1, December 1982. (Secret/Restricted Data)

3. Jack W. Rosengren, Stockpile Reliability and Nuclear Test Bans: A Reply to a Critic's Comments. R&D Associates. Report RDA-TR-138522-001, November, 1986 (Unclassified)

3. Dr. Roger Batzel, Classified Addendum. Submitted into record of the September 18, 1985 Hearing of the Special Panel on Arms Control and Disarmament of the Procurement and Nuclear Systems Subcommittee of the House Armed Services Committee. (Secret/Restricted Data)

4. Admiral Sylvester R. Foley, Jr. Assistant Secretary for Defense Programs, Department of Energy. Answers to questions asked in Congressman Edward J. Markey's letter of April 17, 1986. (Secret/Restricted Data)

As we will be considering nuclear testing legislation this session, we wish to have an independent and comprehensive technical review of the information that has been made available to the Congress on the reliability issue. We wish Dr. Ray Kidder of the

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Lawrence Livermore National Laboratory to prepare such a technical review.

While our request may on the surface appear somewhat unusual, in the past Congress has often relied on the special technical and scientific expertise of employees of the national laboratories to provide advice on nuclear weapons issues. The House Armed Services Committee, for example, has made special note of this fact on a number of occasions. In its report on the FY86 DOE Authorization Bill, the Committee noted that it did not want the Congress to be "isolate(d)...from the technical and scientific advice of experts employed by contractors carrying out DOE defense programs." In its report on the FY87 DOD Authorization, the Committee indicated that it had never been the "intention of the Congress that the employees of the Department of Energy national laboratories should be discouraged from responding to oral or written inquries from Members of Congress or the chairman, the ranking minority member, or a member of the staff of the appropriate committees."

It is our understanding that Dr. Kidder has been involved in the preparation of classified technical reviews of a number of on-going nuclear weapons programs. We also understand that Dr. Kidder has previously prepared short analyses of both the unclassified Rosengren Report (UCID-20804) and the Classified Addendum you submitted to the House Armed Services Committee. But these analyses do not cover all of the examples (or all of the issues) that have been raised in the other documents we have mentioned. For this reason, we would like Dr. Kidder to carefully review all of the aforementioned documents and prepare for us a comprehensive report (in both classified and unclassified form) which addresses the issue of whether past warhead reliability problems demonstrate that nuclear explosive testing is needed to identify or to correct stockpile reliability, or alternatively, whether a program of stockpile inspection, non-nuclear testing, and remanufacture would be sufficient to deal with stockpile reliability problems.

We would therefore appreciate your cooperation in making the above-mentioned materials available to Dr. Kidder and making arrangements for the prompt transmittal of his analysis to us upon its completion.

With best wishes,

Sincerely,

Edward J. Markey, M.C.

Les Aspin, M.C.

Norman D. Dicks, M.C.

Edward M. Kennedy, U.S.S.

John M. Spratt, M.C.

Dante B. Fascell, M.C.

**Appendix B. Letter from Director Roger Batzel to Congressman L. Aspin, dated April 17, 1987.**

April 17, 1987

The Honorable Les Aspin
U.S. House of Representatives
1118 Longworth House Office Building
Washington, D.C. 20515

Dear Congressman Aspin:

You have asked that the Laboratory make available Dr. Ray Kidder to prepare a comprehensive report which addresses the issue of whether past warhead reliability problems demonstrate that nuclear explosive testing is needed to identify or to correct stockpile reliability, or alternatively, whether a program of stockpile inspection, non-nuclear testing, and remanufacture would be sufficient to deal with stockpile reliability problems. While it is indeed unusual that we are asked to make available a particular Laboratory staff member for a particular, independent study, we will honor your request if he wishes to perform this review. Of course, stockpile reliability is only one of many reasons why nuclear testing is necessary.

Dr. Ray Kidder has available to him the technical information he should need to analyze this question and has been encouraged by Laboratory staff members to become informed, as this subject is not one on which Dr. Kidder has had extensive experience. The Laboratory will cooperate in making materials available to him for the review you have requested. With respect to Reference 4 in your letter of March 30, 1987, that is material which was provided to the House Armed Services Committee in response to Mr. Markey's questions by Admiral Foley, and Dr. Kidder will need to obtain that from him. He is, of course, free to reply to your inquiry both in classified and unclassified form, and may submit his findings to you at any time that he feels he has finished his analysis.

Dr. Kidder is a respected theoretical physicist at the Laboratory with considerable experience in several of the Laboratory's programs. However, he has not had recent, direct responsibility or experience as a nuclear weapons designer, nor experience in the weaponization of nuclear weapon systems, nor responsibility for evaluating the reliability of stockpiled nuclear systems or the problems that can arise therein.

In order to provide the Congress with the technical information it should have, I have asked Dr. George H. Miller, Associate Director for Defense Systems, to provide you with a separate analysis of the issues which you have raised. In his

Congressman Les Aspin
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April 17, 1987

position at the Laboratory, Dr. Miller has direct responsibility for all nuclear weapons activities, including stockpile reliability, maintenance and manufacturing issues which arise in the DOE production complex. Dr. Miller and his staff have the experience base to make the necessary judgements and can provide you with background and details on all of the many aspects of this important question.

By identical copy of this letter, I am responding to Senator Kennedy and the other Members of Congress who were cosigners with you of your letter.

Sincerely,

Roger Batzel

Roger E. Batzel
Director

# Appendix C. The Polaris A3 and the Saturn V Remanufacture Experiences

The difficulties involved in "replica" remanufacture have been faced by all major U.S. industries—aerospace, automobile, chemical and materials, and engineering, as well as nuclear weapons. The aerospace industry has many parallels with nuclear weapon development and production. The Polaris A3 missile remanufacture and the proposed remanufacture of the Saturn V rocket illustrate the difficulties encountered when attempting to remanufacture technologically complex systems.

## The U.S. Navy Polaris A3 Experience

In 1982, the U.S. Navy's Strategic Systems Program Office (SSPO) contracted with Lockheed, on behalf of the United Kingdom, to do a "replica" rebuild of the Polaris A3 first- and second-stage rocket motors. These motors were designed and built in the 1960s for the U.S. and U.K. programs by Aerojet and Hercules, respectively; production of these motors ceased 19 years ago. To minimize technical risks, the U.K. requested the rebuild to be as close a replica of the first build as possible. The intent was to maximize assurance that the same reliability and performance of the original motors would be achieved, and at the same time provide the most expedient means of providing replacement motors. Time was critical; the U.K. needed more assets on a short time scale, and wanted to maintain their deterrence credibility throughout. The U.K. Polaris SLBMs are scheduled to remain deployed until the late 1990s.

Recently, we visited Lockheed, the prime contractor for the rebuild program, to learn more about this remanufacturing effort, and talked with personnel who had been involved with the A3 moror remanufacture program. Some of their observations and commentaries are described below.

The motor rebuilds were successfully accomplished by Aerojet and Hercules, but only with an extensive test program. It was found that true replication is impossible to achieve, because (a) "same" materials are frequently not the same, sometimes in unknown ways, (b) "equivalent" materials seldom are equivalent, sometimes in unknown ways, (c) "better" parts often introduce new failure modes, sometimes undetected, and (d) documentation, however rigorous, sometimes is not adequate to reproduce actual on-the-job operations. Because of these problems with replication, a successful rebuild of the A3 motors required extensive testing, including full-scale motor tests at NWC/China Lake and flight demonstration tests on the Eastern Test Range.

This was a true replication attempt. One of the precepts was not to change the original design unless it was absolutely necessary and the change could be shown to have no adverse influences on the performance of the new motors. The motor subcontractors tried to exactly duplicate the history of the original build, including all the documented design alterations approved since completion of the original build program.

In an effort of this magnitude and complexity, a great deal of lower level testing can be performed to determine material properties and to approximate performance characteristics. However, it is not until full-scale tests of the complete rocket motors are performed that an evaluation of the "all-up" configuration is possible. Specific points to illustrate this follow.

### Material Replication

Original supplier unavailability required qualifying an alternate source. There were some surprises, however. A case in point was the first-stage rocket motor chamber insulator material. Material from the original source was no longer available and a material from an alternate source was selected. This material met the original specification requirements, but when it was used in a full-scale motor, a significantly different (more rapid) erosion rate occurred. A design change was required (increased insulator thickness) to achieve acceptable motor chamber insulation. This is perhaps the best example to illustrate the need for full-scale testing of the remanufactured motors. Had this not been discovered following the rocket motor test firing, it could have resulted in motors being produced with a performance weakness that could have manifested itself in a similar manner to the problem experienced in the aged motors being replaced.

One of the aluminum forgings used was Alcoa 7075-T6. It was the "same" alloy as used in the original manufacture according to Alcoa. In the interim, however, due to Alcoa facility changes and process improvements, the time from forging to quench had changed significantly. This resulted in forgings with higher internal stress characteristics, causing cracks in the forgings and subsequent rejections when the forgings were machined into adapters. Although this problem was identified and corrected at the component level, it illustrates the type of problem that can occur in a replica program from a subtle process change.

**Documentation**

The problem with materials specifications was that, in some cases, the engineers needed a parametric performance specification as well, and this is usually not available. A full parametric evaluation of specification allowables is needed for a fully adequate "how to" specification. This would have to be achieved from numerous and expensive tests. Simply tightening tolerances does not control the product sufficiently, and makes processing more difficult.

**Procedures**

Management's major concerns were the following: documentation, tooling and facilities, materials, suppliers, safety requirements, reacquiring experienced personnel, and adverse effects of changes, both direct and synergistic, immediate and long range. Procedurally, a review board was set up to pass on any changes. It was composed of U.S. government, Lockheed, and vendor representatives. The board's charter was to fully scrutinize any proposed changes and only pass those that were mandated by safety, tooling or facility changes, or material unavailability. Still, some propsed changes that were approved had to eventually be revised as a result of subsequent processing and testing experiences.

**Testing**

Each approved change required some level of testing/evaluation. One cannot look only at what has been changed; the whole system must be retested because of synergism. Full-up flight tests were needed to determine if the design and performance requirements were met. There is a difference between what can be learned from static tests and what can be learned from flight tests. They needed them both. Most experienced and knowledgable engineers would refuse to certify without testing. They view flight-test data as necessarily representative to provide true replica certification; the test program provides the major indicators for areas of concern.

In addition to the full-scale motor firings of units selected at regular intervals from the production sequence, assessment of motor performance is made from nondestructive tests (radiographic) and static test firings of motors retained in an aging program. Nondestructive tests are also periodically performed on motors returned to field facilities from operational tactical submarine deployment. Complete weapon-system level tests, i.e., flight tests, are periodically conducted by the U.K. at the U.S. Eastern Test Range. In the aggregate, the information obtained from these various test programs is used to assess system reliability and to monitor aging characteristics. Data is compared to manufacturing baseline and original motor experience.

**Experience**

The first-stage motor is a more complex design, and therefore more difficult to replicate; the second-stage motor is a simpler design, but replication was process-dependent, thereby requiring involvement of some of the original experienced people. If Lockheed and Hercules hadn't had the Poseidon Program, which maintained the experience base for the "equivalent" second-stage propellant, there would have been significantly more difficulties. Their decisions were based heavily on the judgments of experienced people, and were influenced by what they did before and the knowledge that extensive tests were going to be conducted.

Motors/missiles are rarely fired to demonstrate a failure; they are normally fired to confirm expected performance characteristics. Tests are needed for the user's confidence in the performance and reliability of the product. The technical management team on this rebuild program believes that they would never have done this rebuild successfully without full-scale testing.

The U.S. Navy's SSPO, its prime missile subsystem contractor, Lockheed, and the Lockheed motor subcontractor suppliers, Aerojet and Hercules, with the support of many other material suppliers and test agencies, did an admirably thorough and professional job of carrying out this successful rebuild. It is clear that they encountered many problems, even with extensive testing. There are close parallels between the problems they encountered and the problems our engineers and scientists predict would occur with the remanufacture of older stockpiled nuclear weapons, even with testing.

**Similarities between the Polaris A3 Rebuild and Nuclear Weapon Remanufacture**

Material replication problems are very similar; there is even some direct overlap in material usage (for example, Alcoa 7075-T6 is used in some weapon parts). Just as Lockheed worries about the shelf life of consumable materials, so do we—especially radioactive materials like tritium, complex explosives and rubbers, and electronics components. General remanufacturing experience, illustrated by Lockheed's experience above, has shown that exact replication of complex materials usually is not possible (see also Appendix D). Thus, the purpose of testing is to verify that the necessary changes are acceptable.

Inadequate specifications will always be a problem, and part fabrication problems are essentially the same whether one is building rocket motors, nuclear warheads, or automobiles. With foresight, some of these problems can be avoided by keeping plants open, retaining tools, stockpiling parts, etc. Other problems, like material aging, safety issues, and the retirement of experienced people, probably cannot be avoided.

Electronics parts represent a deep worry. They are not easily replicated, and even when they are stockpiled, the aging characteristics of electronics are largely unknown. In addition, the electronics packages for nuclear warheads must survive the high electromagnetic pulse (EMP) environment of neighboring warheads (fratricide) and unfriendly warheads.

Computer modeling has the same goals and problems for rocket motors as for warhead designs. In both cases, the physical process is a rapid, destructive, and dynamic fuel burn. In both cases, the computer codes are scaled to match the results of tests. In both cases, some of the physics must be approximated, and the codes are not accurate or complete enough to make correct first-principles predictions. We also lack the extensive set of measurements that would allow confident scaling over a wide region of the warhead or rocket motor parameter space.

Time frames were a worry for Lockheed, and would be a similar worry for the U.S. nuclear stockpile. Remanufacture takes many years. Unanticipated common-mode problems are unacceptable for warheads and missile motors alike.

Documentation problems are the same for nuclear warheads and rocket motors. The problem has to do with human nature and imperfect knowledge. Only by carrying out an unrealistically large number of tests could a full parametric specification become possible.

Certification, of course, is different. Lockheed was able to do extensive full-up testing of the rebuilt rocket motors, but we cannot do "full-up" testing of nuclear weapons. For rebuilt nuclear warheads, we would of course do extensive nonnuclear tests of the components. Lockheed's flight tests are the equivalent of the production verification tests currently done for nuclear weapons. Just as Lockheed identified several problems during full-up flight tests, so might we need full nuclear tests to find possible problems. We could "certify" a rebuilt warhead without nuclear testing but with significantly reduced confidence.

Experience is a major concern in both cases. No matter what the product, remanufacture requires decisions based on the judgment of test-experienced people. At both Lockheed and the weapon laboratories, there is a consensus that test experience is absolutely necessary.

Testing is essential in almost all remanufacture efforts of complex technologies. With nuclear weapons, we must make a distinction between nonnuclear and nuclear tests. One can question whether the full-up flight tests of the rebuilt rocket motors were required. Lockheed's engineers believed they were necessary because of the synergistic effects that can show up only in flight tests. With a robust motor design, relaxed performance requirements, separate component tests, and new launch tubes in the submarines, Lockheed might have produced a successful motor without full-up flight tests. Similarly, if warhead yield certification requirements were reduced, we could probably rebuild some nuclear warheads without testing, at least while test-experienced designers are available. However, we would pay a price in terms of greater uncertainty about warhead performance.

(Note: The May 28, 1987, edition of *Aerospace Daily* published an article on the launch trials for the U.K. Polaris SLBMs from Royal Navy submarines. Of 12 launch trials, three resulted in failures. In the most recent trial, a missile launched from the U.K. submarine Repulse off Cape Canaveral veered off course and had to be destroyed. *Aerospace Daily* reported that "the ejection and first-stage firing modes were satisfactory. The fault was attributed to the motor despite a recent update program, costing around $610 million or more, to improve the propulsion system.")

## The Saturn V Rocket Experience

Recently, because of the Challenger Space Shuttle disaster, American companies proposed to rebuild several Saturn V rockets to fill the gap (Reference A1); the Saturn V is capable of launching a 100,000-pound payload, compared to 65,000 pounds for the Space Shuttle. In particular, they wished to rebuild the Saturn F-1 engines, each of which has one million pounds of thrust. Five of these engines make up the Saturn V first stage. Seven F-1 engines were located, and plans were made to refurbish them.

Fifteen Saturn V rockets were built in the 1960s, and all but two had been fired into space by 1980. The remaining two are on display at NASA's space museums at the Kennedy Space Center and the Johnson Space Center.

Hughes Aircraft and Boeing Aerospace recently considered collaborating on a rocket using two F-1 engines that could deploy 85,000 pounds into a low orbit. Upon investigation, they found that the infrastructure no longer existed. The tools, dies, and jigs had been sold for scrap metal as a part of a regular government disposal program. Many of the vendors no longer existed, most of the F-1 experts were gone, and many drawings and documents were scattered or lost. In their opinion, it was too risky to try to rebuild the F-1 engine and they abandoned the project.

Rockwell International, the company that originally built the F-1 engines, has assessed the F-1 documentation. They believe that most of it exists in boxes stored at a depository in Atlanta, Georgia, but acknowledge that some of the blueprints are undoubtedly missing or inaccurate. As with other U.S. industries, it would be difficult at this late date to certify most of the specifications.

Hughes considered having designers draw up new plans from the existing F-1 engines. They concluded that it would be highly impractical to have engineers attempt to measure all the pieces with micrometer calipers; none of their engineers would certify this as a reasonable process.

Dr. J. R. Thompson, the director of Marshall Space Flight Center, recently told a meeting of the American Institute of Aeronautics and Astronautics that, assuming all the documentation could be found, it would take four to six years to rebuild the F-1 engineers and another four years to test to assure reliability. No one in the system was considering remanufacturing the F-1 without flight testing.

## Reference

A1. W. J. Broad, "Hunt is on for Scattered Blueprints of Powerful Saturn Moon Rocket," *New York Times* (July 15, 1987).

# Appendix D. Materials Science and Engineering Considerations in Weapon Manufacture

The particular problems in this section are typical of the type of materials science and engineering problems that can arise in the manufacture of nuclear weapons. All of these problems were solved by experienced materials scientists and engineers, either through consultation with the design physicists or through their own knowledge about the operational requirements of the weapon. Most materials science and engineering problems can be fixed without a nuclear test. Those cases where nuclear testing has been necessary are discussed in Chapters 2 and 3.

The general nature of the problems, not the specific details, is important, since similar problems could occur in the future. It is important to note that when such problems arise today, they are resolved by engineers and scientists with nuclear test experience.

## Materials Science Considerations

Circumstances affecting materials science can arise and significantly interfere with the manufacture, remanufacture, or renovation of a nuclear weapon. By "significant" we mean that delays of more than a year between the decision to build is made and the time actual production can take place.

### New Regulations

New governmental regulations (OSHA, EPA, NRC, FDA, etc.) have been enacted that interfere with nuclear weapon manufacture. In these instances, it is not simply a question of getting a waiver of the rules. Once materials have been determined to be dangerous, the plants refuse to work with them, and rightly so.

For example, in 1973, OSHA determined that the crosslinking agent (the amine "MOCA") in Adiprene/MOCA was carcinogenic. Adiprene/MOCA was an almost universal adhesive used in the assembly of nuclear weapons at that time. Thus the OSHA ruling required that either the entire DOE complex provide acceptable protective handling capabilities for this material or that an adequate substitute be found and qualified. Both options were estimated to require several years to implement, and it was decided to develop a substitute material. A development effort was begun at LLNL, and after several years the Halthane adhesives were introduced into the production process at Pantex, Y-12, and Bendix.

### Discontinued Speciality Materials

The weapons complex is often the major or sole user of specialty materials. Production of these substances is not profitable, and an industry may do so only because they have been defined as critical defense materials. However, the DOE has limited economic leverage as a customer. Materials that we have widely used have been discontinued by the manufacturer,forcing us to obtain the needed technology and transfer it to another vendor.

A good example is the discontinued manufacture of a basic silicone gum used to make stress cushions for several weapons. Union Carbide was the original manufacturer, but they discontinued the material. A French company made the "same" gum, but it proved to be highly variable and the products made with it had a very large rejection rate. General Electric made a similar gum with different mechanical properties, which we used as a stop gap. In the meantime, we obtained the rights for the original silicone gum from Union Carbide and transferred the technology to a smaller company, McGhann-Nusil, our present supplier. Presently, Bendix manufactures the stress cushions and oversees this material. Because they had to understand the technology involved, they first set up a pilot plant, and this took the better part of four years. Extensive product testing was involved, and the new product was included in nuclear tests.

In another case, Dow Corning stopped manufacturing a silicone addition potting compound in 1977. This material was also widely used in weapons. At the time, Pantex was planning the W68 retrofit and the W79 production. They were able to purchase and stockpile enough material from Dow Corning to finish the W79 production, but new materials had to be qualified for the W68 retrofit. Pantex also had to obtain and learn the process for the future. This took about three years, even with LLNL help.

**Material Variability**

Another issue is the variability of certain materials. We experienced this with the use of Kevlar, a high-performance polyaramid fiber, in nuclear weapons. Kevlar yarn was chosen for making a part in a nuclear artillery shell. This DuPont material had been used for automobile tires as Kevlar-29. A LLNL study on fiber composites led to the recommendation that the somewhat stronger material, Kevlar-49, be used for the weapon. Since the material obtained from DuPont was found to have statistically significant batch-to-batch variations, we decided to obtain enough Kevlar-49 from a single batch to complete the build. However, even with this single-batch material, the spool-to-spool variation in properties was troubling with regard to weapon lifetime predictions.

DuPont considered their Kevlar production details to be proprietary, but they shared some of them with us. It turns out that the order in which the polymer is put together (the so-called block copolymer arrangement) affects its engineering properties. Since our business was minor compared to the industrial market, it was uneconomical for DuPont to develop the specifications that would be needed for weapon remanufacture. Thus it may prove to be impossible to make new Kevlar parts years from now. We have Kevlar stored in the dark, but we don't know its storage-life characteristics; thus stockpiling of this material may or may not be effective.

**Foreign Sources**

A particularly disturbing situation weapon rebuilds is that some necessary materials have been available only from foreign sources. In fact, we do not always know the country of origin of some materials we procure. Clearly, we cannot face a rebuild in the future without the necessary manufacturing capabilities in the U.S.

**High Explosives**

High explosives (HE) are of particular concern for weapon remanufacture. HE technology is as much an art as a science. We have experienced a number of problems with explosives over the years. Recently, we have introduced insensitive high explosive (IHE) into the U.S. inventory. A major component of IHE is TATB (triamino-trinitrobenzene). TATB's safety advantages are very important for the peacetime storage and transportation of U.S. nuclear weapons. TATB weapons will not accidentally detonate even under extreme conditions of impact, shock, and fire. There is no other material of this type known. However, TATB has posed a number of manufacturing problems.

For example, wet- and dry-aminated TATB batches have different mechanical properties, with batch-to-batch variations. The manufacturers and the designers decided to change the process from a so-called "dry" amination to "wet" amination. The addition of water was beneficial, raising the energy of the explosive and eliminating a potentially corrosive chlorine ion. But recent lots of wet-aminated TATB have shown higher growth of one of the components, higher initial density, and reduced mechanical properties; these factors may adversely affect the performance of a weapon.

The dependence of the performance of primaries on the manufacture of such explosives mandates that a remanufactured design receive a nuclear test. There is no way to test the nuclear processes in a nonnuclear facility. We have developed confidence in the new manufacturing techniques only as a result of nuclear tests. Tests of a new explosive need not be stockpile confidence tests—we can test the performance of the explosive in development tests of other weapons.

In another example, we designed the W87 warhead to use an ultrafine TATB booster to ignite the main HE charge. We attempted to match the same TATB that had been used in the W84, produced only a few years earlier. The blender batches for the W87, however, were put together with different starting materials. Initial attempts at process verification lots of material failed to reproduce the W84 material. It became clear that we would not be able to duplicate the W84 material, and we had to find an acceptable substitute. A total of 97 process verification lots of ultrafine TATB were produced. Variables examined in these lots included TATB residence time in the grinder, mass flow rate through the grinder, amount of material stabilizer, time the stabilizer was added, washing process, and drying process. We even found that a new pump (a seemingly minor change) affected the mixing of the material and the resulting grain size enough to alter the burn properties of the material. From these 97 lots, we were able to select a process for producing the W87 ultrafine TATB. Each step of this process required extensive testing, including determination of particle-size distributions, surface area analysis, and test firings of standardized pellets for detonation divergence studies. The W87 TATB batch, as produced, demonstrated different yet acceptable detonation characteristics when compared to the W84 material. The new material was included in a nuclear test to verify its acceptability. Future attempts to duplicate either the W84 or W87 TATB material will probably encounter similar difficulties. We probably would again require a full process development of verification lots, subbatches, blending, and all associated testing to obtain a new "master" batch of ultrafine TATB.

## Engineering Considerations

Warhead production is not an assembly-line or production-line procedure; it is more a job-shop process. Currently we accept materials and piece part deviations on the basis of experience and judgment. In the real world, we have rarely done a nuclear test or built a weapon that rigidly met our nominal specifications. Our engineers frequently make cost-effective decisions about parts that are outside the specifications. Without the experience of testing, the engineers probably would no longer be able to accept such parts. As a result, the production criteria would probably become very exacting and more expensive.

### Documentation

The present quality of our specifications is about the same as in an industrial job shop. As in any such industry, a "perfect" specification manual does not exist. Even after the specifications have been carefully formulated and certified, they are changed many times to reflect the lessons learned during actual production. In the real production world, individual operators learn how to make things work "regardless of what the instructions say."

The issue of remanufacturing weapons is difficult to address generically. Rather, we must consider specific weapon systems at specific points in time. The time since last manufacture often sets the criteria for the availability of documentation, critical processes and materials, and knowledgable personnel.

A necessary requirement for the restart of manufacturing is the completeness of the documentation: specifications, drawings, manufacturing steps, assembly procedures, inspection procedures, quality assurance requirements, sampling plans, and—possibly the most important—identification of critical engineering and physics requirements. Historical documentation, in the detail required to enable relatively unknowledgable and untrained personnel fabricate an existing warhead, is a monumental task, and will probably never be adequate.

Modern MCs contain a request for adequate documentation for a future rebuild, within the tradeoff limits of higher priority MCs and available resources. In the real world, even with documentation (including specifications, drawings, historical records, etc.) in sufficient detail to allow restart of manufacturing, we would still require significant "reinventing" of processes and materials. This would take years to accomplish, assuming it is possible at all. We could do more from the beginning of an original build to aid the rebuild process. Early in the design process, additional team members could become documentarians to record the significant design features and the reasons why they were so designed. They could also document, summarize, and make clear the results of the test program that selected each material or design feature and carefully record what was known and not known. We do much of this documentation today, and we could do more. With such data in hand, we could then go to the production agencies with the details of each process and procedure documented in a way to facilitate future implementation. Whether such a procedure would work for nuclear weapons is unknown. It does not seem to have worked well in other industries.

Today, manufacturing procedures rely on a large number of commonly accepted standards. In addition, documentation may refer to existing equipment and current materials, which may or may not be available in the future. Some procedures are considered to be common knowledge are not documented. Documentation must address the desired end result or product, not just the procedures. Jargon must be avoided. When a manufacturer's proprietary material is specified, the desired properties of that material should also be documented. The manufacture may no longer be producing that material when we want it in the future, or he may have "improved it." Obviously, it will take considerable foresight to anticipate future questions, ambiguities, and problems to the degree needed to produce the proper documentation for a future weapon rebuild.

**Continuity of Experience**

Plant operators and design engineers and scientists interact almost daily about part tolerances, material properties, and assessments of minor deviations from specifications. Product experience is crucial because the performance of a weapon is sensitive to subtle details and interrelated effects. However, even today, many of our most experienced designers and engineers have already retired or moved on to other fields. Also, the rate of nuclear testing has dropped steadily over the years. This deterioration of our experience base is a concern, even at the current level of nuclear testing.

In our current production approach, a small design team is formed at the onset of potential production (Phase 3). Ideally, this team stays with the design until production is well under way. The team performs research and development, does production design, works with the plants to get the design into production, and troubleshoots the design during initial production. Once the weapon is in production, engineers trained by the design team follow the weapon until production is complete. These people provide a foundation for the future as they conduct the stockpile surveillance and material compatibility tests. Thus, the system establishes that people knowledgable in that particular weapon will follow it throughout its life, assuming they remain with the program. While there is substantial documentation in this process, it was never intended to enable relatively unknowledgable and untrained personnel to fabricate the warhead.

**Actual Experiences**

**Impact of Inexperienced Personnel.** During the very early production of the W68 at the Burlington AEC plant, the product quality was very high. However, as the production rate increased and new assembly people were brought into the program, the quality dropped to an unacceptably low level. To correct this situation, production had to be stopped and the new operators educated in both procedure and design intent (i.e., operation of the warhead).

**Need for Personal Interactions.** Personal interactions between design engineers and the production engineers are necessary for developing fabrication and acceptance procedures. Of key importance here is that the production engineer is knowledgable about the function of the components from both an engineering and a physics view and he can consult with test-experienced design physicists when necessary.

For example, Rocky Flats wanted Y-12 (at Oak Ridge) to machine a B83 oralloy part on the negative side of the allowed tolerances to facilitate its fit with another part. However, when this is done, the oralloy parts tended to be low in mass, which would affect the physics performance of the device. LLNL design engineers were called on to provide guidance on this subject.

Another example from the B83 build involved the laydown design of the bomb. The impact load from laydown travels through the outer mitigator; the load is partially transmitted to the internal components at very specific locations by slight variations in the way the mating parts interact. It would take a very detailed study of these mating parts to understand how this design works. LLNL engineers understand how the design works; they know that certain types of machining errors, although acceptable in one region, are unacceptable in others because they might adversely affect the load path.

**Materials Selection.** In many cases, weapon manufacture is driven by physics or engineering requirements synthesized, but not necessarily understood, from years of nuclear test experience. This can produce specifications for which detailed justifications do not exist, other than the observed fact that such details lead to successful tests. This commonly occurs in the selection of materials for a particular application.

For example, welding of thin stainless steel is necessary to make a part for the B83. The process is very sensitive to the specific chemical and mechanical characteristics of the metal. Attempts to characterize the metal have been only partially successful. Although we believe we now understand the important parameters (three years into production), we bought material from two lots of rolled sheet steel so that we would have enough material for the entire B83 build.

In another example, the thin-walled tubing used to make a part for the W84 proved to be very sensitive to the process used for making the tubing. After trying tubing from several vendors, we decided to buy from a single vendor. Even so, we must inspect every inch of the tubing, rejecting more than 50%. We do not know what makes tubing from this vendor work well; we just know from our tests that it does.

It should be noted that material specifications are based on quantitative analysis using techniques accepted today. They are truly applicable only when comparing materials, and should not be regarded as an absolute specification. Ten or twenty years from now, analysis techniques then may reveal that what appears today to be the same material may not be.

**Handling Deviations from Specifications.** Warhead requirements are sometimes driven by physics or engineering issues that are too complex to be detailed in a production specification or are not fully understood but have been proven successful through nuclear testing. Hence, the acceptance criteria may be very tight (due to lack of understanding of what the requirement should be), and deviations are expected. These are handled in the production process through a deviation request system that requires evaluation by a knowledgable designer. The designers and the manufacturers of weapons parts will not always know the details of what will be troublesome to manufacture when production starts. We may have to take a "see what happens" approach in early production. As carefully designed tooling and processes prove not to work exactly as predicted, the question of changing the process or tooling becomes one of both cost and schedule. Only by knowing the engineering and physics function or by redoing physics calculations or engineering tests can decisions be made that do not compromise the design. Test-experienced people are needed to make these decisions.

A large number of the deviations are small nicks and scratches on parts that come from normal handling. In some cases, such scratches can affect the performance of a weapon; in most cases, the designers know from test experience whether the nicks will matter. Our procedures require that each such instance be evaluated and a decision made on the individual item. Without these personal interactions, the reject rate would be excessively high or the product faulty. We currently process about 150 to 200 evaluation requests per system per month for all production plants. This number seems large until one considers the total number of individual features that must be assessed; the B83 and W84 each have nearly 1000 features to be checked on LLNL parts at the Y-12 plant alone!

Sometimes designer judgment and computer calculations are not sufficient to determine the effect of a defect. For example, in making the device for a development nuclear test for the B83, a gap in a crucial part developed during fabrication. Several experienced designers ran hundreds of hours of computer calculations to determine whether the crack would affect warhead performance, but they could not come to a clear consensus. Up to the time of the actual nuclear test, there were worries that the crack might substantially degrade the device performance; no one could certify with certainty that it would not. Due to time pressures, it was not expedient to reject the device and build another. In this case, the judgment made by test-experienced designers proved to be correct as the warhead performed as designed. However, without the nuclear test, we would have not been able to certify with confidence the performance of this particular device.

**Specifying the Art of Certain Processes.** Many processes, although covered by specifications, are more of an art than a science. These are quite often developed (if not invented) at the design laboratories and must be monitored during production by knowledgable people.

An example of this is a recent problem with a W84 component. A solid-state bonding process is used to join dissimilar metals. The quality of the product is critically dependent on good process control and the close attention of well-trained personnel because there is no adequate nondestructive testing technique that can evaluate the quality of the bonds. Failure of these bonds is a time-dependent mechanism that has been observed in some early production units. To prevent failures, the process must be carefully managed.

One of the key features of this process is the assured removal of all oxide from the surface before a layer of another metal is applied. Etching of the base metal and the deposition of the other metal take place in a vacuum chamber. Although we have established parameters to remove all the oxide, simple things such as the way in which the part is clamped in its holding fixture can affect the rate of oxide removal. Thus, some evaluation must be made on each part to assure that it is indeed oxide-free before the deposition of the other metal is begun. Although we have tried several techniques to make this evaluation with instrumentation, we have found none equal the human eye (two pairs, actually, as we ask for verification by an inspector as well as the operator) for detecting the change to a shiny, then slightly hazy, appearance that indicates a clean surface.

**Complex Manufacturing Processes.** Estimates of the time to restart production are weapon-specific and depend on the time since last manufacture. Given the highest priorities, sufficient resources, and adequate documentation, the issue becomes one of requalifying old and unique processes. A significant part of the problem is that the documentation for older systems is much less extensive than that for new systems. For relatively simple warheads that do not depend on unique or obsolete processes, about a year from authorization of the rebuild to first production unit may be reasonable. However, some weapons may involve processes that take many years to develop for production, and it could take a significant amount of development time to requalify them.

For instance, the fabrication of some parts for the W70 and W71 required the development of a complex process of part fabrication, special material procurement and certification, assembly by automated equipment and technician handicraft, inspection, test firing and statistical data evaluation, and finally, iterations of the above steps until a satisfactory product was obtained. The parts were fabricated by injection-molding of plastic into a complex die. The injection-molding process, used in toy making, had to be upgraded beyond the state of the art. Contour tolerances of this complex shape were tighter by a factor of ten than those required in industry. Fabrication of these components required the efforts of three of the production plants, which created a complex problem in coordination, both during development and in production.

In the case of a part for the W79, it took about five years to transfer an aqueous plating process developed at LLNL to the production complex. Requirements for scratch-free and flaw-free surfaces required the development of special handling and inspection processes that yielded a product with only a 30% acceptance rate. Even though each step of the process had a yield of better than 90%, the large number of steps resulted in the low final yield. It took about a year from the start of production to the completion of a part.

**Possible Near-Future Remanufacturing Need.** A situation is now occurring that may provide direct experience with remanufacturing. Three systems (the WYY, W62, and the W56) use some similar parts in which a time- and temperature-dependent reaction is apparently occurring. (Note: the WYY cannot be identified for classification reasons.) These systems are being monitored and, unless they are retired first, they will have to be retrofitted. Retrofit of these systems will vary from minor disassembly and reassembly of the WYY to a major disassembly and reassembly of the W56. If this is required for the W56, it will test many of the issues of remanufacturing, particularly material availability, expertise, and the need for nuclear testing. Such a retrofit of the W62 would be very difficult because of the way the weapon has been assembled and would involve major elements of remanufacture.

## Conclusion

The reliability of remanufactured warheads is the fundamental issue. The remanufacturing of warheads, in itself, does not automatically reestablish confidence in the reliability of the system. With testing and verification, old systems and their reliabilities can be rejuvenated. However, testing is often essential to establish the reliability of the remanufactured product. Testing is the essence of any quality-assurance program, whether it be for automobiles, rocket motors, or nuclear weapons.

## Appendix E. Senate Armed Services Committee Language for the FY 1988 Authorization Bill

### STUDY OF THE FEASIBILITY OF REDUCED RELIANCE ON UNDERGROUND NUCLEAR TESTING

The Committee notes that on a number of occasions, Congress has expressed the sense that it is desirable, from the point of view of arms control, to place further limitations on the size and/or number of nuclear tests. The Committee believes that nuclear test limitations should be an integral part of a comprehensive approach to arms control, with further limitations on nuclear testing established in conjunction with further progress in other areas of arms control.

The Committee notes also the continuing controversy over the extent to which the reliability of the nuclear weapon stockpile, or our confidence in it, would be affected during a prolonged period of substantial limits on testing beyond those in the Threshold Test Ban Treaty. While there is a range of opinion expressed by the expert community on this subject, the Committee believes that the gravity of the issue is such that a conservative position should be taken. That is the Committee believes that we must understand how to deal with some degree of unreliability that might develop over time.

The Committee also notes that there is disagreement in the expert community as to the yield above which nuclear tests can be reliably identified as such -- the range of disagreement extending approximately between 1 kiloton and 10 kilotons.

Finally, the Committee notes the salutary precedent, established at the time of the TTBT, of providing safeguards concomitant to nuclear testing limitations. The Committee continues to support the ratification and entry into force of the TTBT and PNET, subject to improved verification procedures.

In light of these several considerations, the Committee believes that, as a safeguard against the implementation at some future date of further test limitations, the Administration should begin to assess the feasibility of modifying the nuclear stockpile in ways which would minimize both the likelihood and the impact of unreliability which might develop during a period of further restricted testing. If such measures are feasible, DoD and DoE should undertake a program to evaluate the cost and timetable to prepare a more durable stockpile and to implement such changes as may be needed to delivery systems. That is, the Committee seeks to understand the feasibility of a posture for the nation's nuclear weapon stockpile which, in the face of long-term and substantial further limitations on testing, would be as well suited as possible to preserving the essential elements of our national security.

To this end, therefore:

I. The Nuclear Weapons Council (NWC) shall direct the Department of Energy (DoE) to study the extent to which it is feasible to prepare the stockpile to be less susceptible to unreliability during long periods of substantially limited testing. The DoE shall report its findings through the NWC to the Committees on Armed Services and Appropriations of the Senate and the House of Representatives not later than 1 July 1988. This report shall include an assessment of the feasibility of developing and stockpiling nuclear warheads which would be either
   a) less subject than current warheads to degradation while in stockpile for long periods of time; or
   b) more amenable than current warheads to realiability assessment and, where necessary, to reliable repair, both accomplished without nuclear testing; or both.

   The report should describe ways in which existing and/or new types of calculations, non-nuclear testing, and permissible but infrequent low yield nuclear testing might be used to move toward these objectives. To the extent it is determined feasible in this study to achieve these objectives, the report should describe the scope and nature of the research, development and testing program needed, first, to fully assess this issue and then to prepare designs for more durable warheads, including:
      1. any nuclear testing required before further limits are imposed;
      2. the type and cost of any additional facilities, such as non-nuclear or allowed low-yield nuclear testing facilities, which would be required either before or after the commencement of further limits on testing; and
      3. the lead-time required to move to a regime of fewer tests.

   Finally, the report should estimate the penalties in size, weight, safety, or other characteristics that more durable warheads would impose on the military systems of which they might be a part.

II. Concurrent with this tasking, the NWC shall direct the DoD to study the following:
   a) the extent to which the military capabilities of the nuclear warhead stockpile might be affected by incorporation of such more durable warhead designs;
   b) the extent to which commonality among such designs in the stockpile (i.e., using the same warhead design for more than one system application) might be desirable or feasible, considering advantages

and disadvantages of commonality both for durability and for minimizing degradation of military characteristics;

c) ways in which such possible degradation of military characteristics might be partly or fully compensated for by changes in other nuclear weapon system characteristics; and

d) whether there could be degradation of weapon system survivability in ways similar to those which might produce warhead reliability degradation during prolonged further nuclear test limitation, and, if so, whether there are ways to provide additional durability of survivabiltiy of measures put in place either before or after commencement of such further test limitations.

The DoD shall report its findings on the above through the NWC to the Committees on Armed Services and Appropriations of the Senate and the House of Representatives not later than 1 July 1988.

For the purposes of the reports of Sections 1 and II, the Departments shall assume that the further test limits would preclude nuclear tests above a) 1 kiloton or b) 10 kilotons.

III. Concurrently with the above reports, the President shall report to the Congress on considerations pertaining to the relationship between:

a) various types and degrees of progress in other areas of arms control -- for example, further limitations on the number or characteristics of nuclear weapons systems, their geographical deployment, or limitations on other military systems such as chemical weapons or conventional forces; and

b) progressively more stringent limitations on nuclear testing, such as reductions in yield threshold below the TTBT, limitations on numbers of tests, or combinations of these, including, but not limited to, limitations as stringent as a complete ban on tests above 1 kiloton.