THE COMPREHENSIVE TEST BAN TREATY:

LAWRENCE LIVERMORE NATIONAL LABORATORY'S IMPACT ON U.S.NUCLEAR POLICY FROM 1958 TO 2000

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Paul Brown

Lawrence Livermore National Laboratory
P.O. Box 808, Livermore, CA 94551
(925) 424-6325

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Technical comments and queries are encouraged and should be directed to Dr. Craig R. Wuest, (925) 423-2909, wuest1@llnl.gov.

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Acronyms

AFTAC	Air Force Technical Applications Center
ABM	Anti-ballistic missile
ACDA	Arms Control and Disarmament Agency
AEC	Atomic Energy Commission
CINCPAC	Commander in chief of the Pacific
CTB	Comprehensive test ban
CTBT	Comprehensive Test Ban Treaty
CTBTO	Comprehensive Test Ban Treaty Organization
CD	Conference on Disarmament
DARPA	Defense Advanced Research Projects Agency
DDR&E	Department of Defense Research and Engineering
DNA	Defense Nuclear Agency
DoD	Department of Defense
DOE	Department of Energy
DP	Defense Programs
ENDC	Eighteen Nation Disarmament Committee
FLR	Federal Laboratory Review
GSE	Group of Scientific Experts
HASC	House Armed Services Committee
HEDEF	High-energy-density experimental facility
HE	High explosive
HASC	House Armed Services Committee
ICF	Inertial confinement fusion
IFE	Integrated field exercise
JVE	Joint Verification Experiment
LLNL	Lawrence Livermore National Laboratory
LEP	Life extension program
LTBT	Limited Test Ban Treaty
LANL	Los Alamos National Laboratory
LYNM	Low-yield nuclear monitoring
NAS	National Academy of Sciences
NDC	National Data Center
NIF	National Ignition Facility
NNSA	National Nuclear Security Administration
NSC	National Security Council
NSS	National seismic station
NTS	Nevada Test Site
NPT	Nuclear Nonproliferation Treaty
NTEM	Nuclear Test Experts Meeting
OTA	Office of Technology Assessment
OSI	Onsite inspection
PNE	Peaceful Nuclear Explosion
PDD	Presidential Decision Directive
PNET	Peaceful Nuclear Explosions Treaty
PRM	Presidential Review Memorandum
PSAC	President's Science Advisory Committee
RSTN	Regional Seismic Test Network
RRW	Reliable Replacement Warhead
SNL	Sandia National Laboratories
SASC	Senate Armed Services Committee
SFRC	Senate Foreign Relations Committee
SVA	Separate Verification Agreement
SSMP	Stockpile Stewardship Management Plan
SSP	Stockpile Stewardship Program
SALT	Strategic Arms Limitation Talks/Treaty
SDI	Strategic Defense Initiative
START	Strategic Arms Reduction Treaty
TTBT	Threshold Test Ban Treaty
U.C.	University of California

The author, Paul Brown.

Foreword and Acknowledgments

This history is the final work of Dr. Paul S. Brown, who served in a variety of technical and management positions at Lawrence Livermore National Laboratory (LLNL) for more than 50 years. In this work, Paul focuses on aspects of arms control during the timeframe of 1958 to 2000, particularly on issues related to the need for nuclear testing and the efforts that would eventually bring about its end as a result of U.S. policy actions in light of the changing geopolitical and technical drivers and constraints. Paul's history provides a perspective of how the issues surrounding nuclear testing evolved, with an emphasis on LLNL's participation over the years. He describes key events as they relate to nuclear testing and its ban, such as the development of the stockpile stewardship program.

This represents a mostly finished effort, with some final editing. Unfortunately for the Laboratory and the nation, Paul passed away before this work was completed. However, he was active in shaping the final draft up until the time of his death, while valiantly fighting a host of medical challenges. This work is a fitting tribute to Paul's dedication and service to the country, and it is hoped that technologists, scholars, and policy makers can learn from the events described herein as the U.S. navigates its challenging national security course for the 21st century.

A variety of sources were used to provide an accounting of some of the Laboratory's contributions over the decades relating to the events surrounding the Comprehensive Test Ban Treaty (CTBT). Sources include excerpts from previous LLNL publications such as *Energy and Technology Review*, and the Laboratory's 40th anniversary publication;* Dr. Milo Nordyke's unpublished draft history of the Laboratory's involvement in the nuclear test ban negotiations (Nordyke was LLNL's treaty verification program leader from the time the program was formed in 1976 to the 1980s); Dr. Glenn Seaborg's

* Lawrence Livermore National Laboratory (LLNL), *Preparing for the 21st Century, 40 Years of Excellence*, UCRL-AR-108618.

book, *Kennedy, Khrushchev, and the Test Ban**; Dr. Herbert York's book, *Making Weapons, Talking Peace: A Physicist's Journey from Hiroshima to Geneva*†; extracted, unclassified excerpts from Dr. William Ogle's early test ban history‡; and Benjamin Greene's book, *Eisenhower, Science Advice, and the Nuclear Test-Ban Debate, 1945–1963*.§

The LLNL technical report archives provided a key source for Laboratory involvement from the 1950s through the 1970s, and we extend our thanks to former Laboratory archivist Maxine Trost, who organized the archives to make it easier to find documents and helped in locating information. We also thank Laboratory archivist Jeffrey Sahaida, who helped us locate photographs for this book. This history also benefits from the work of Dr. Carol Alonso, who was LLNL's assistant associate director for national security in the 1990s. Alonso wrote a draft white paper, "The Road to Zero Yield," that describes the events that led the U.S. to adopt a zero nuclear yield position for the CTBT negotiations that began in 1995.** She also provided excellent references to public materials, such as congressional testimonies, that were not readily available in the Laboratory's files. Information was also gleaned from a number of Laboratory and interagency reports, and personal communications between Laboratory personnel and other individuals involved in test ban negotiations and deliberations or who supported the representatives at the meetings.

During the time that Paul was working on this history and after his death, a number of colleagues and experts were involved in the completion of the final draft of Paul's work. We are sure he would have wanted to acknowledge the contributions and support of Dr. Jay Zucca, Dr. Bill Dunlop, Dr. Wayne Shotts, Dr. George Miller, Dr. C. Bruce Tarter, Mr. John Nuckolls, Dr. Paul Chrzanowski, Dr. Carol Alonso, and Mr. David Brown. Finally, a special acknowledgment is owed to Ms. Gabriele Rennie, who worked closely with Paul during the final months of his life, and whose expertise in scientific and technical editing was crucial to the completion of this history.

Dr. Craig R. Wuest
LLNL, *December 2018*

* G. Seaborg, *Kennedy, Khrushchev, and the Test Ban*, University of California Press, 1981.

† H. York, *Making Weapons, Talking Peace: A Physicist's Journey from Hiroshima to Geneva*, Harper & Row, 1987.

‡ *Account of the Return to Nuclear Weapons Testing by the United States after the Test Moratorium 1958–1961*, U.S. DOE Nevada Operations Office, October 1985, NVO-291.

§ B.P. Greene, *Eisenhower, Science Advice, and the Nuclear Test-Ban Debate, 1945–1963*, Stanford University Press, 2007, p. 145.

** C. Alonso, "The Road to Zero Yield," June 1996. This unpublished draft report was marked "In Strictest Confidence" because of the political sensitivities at the time regarding what people said or did and in what context it occurred. However, more than twenty years have passed, and we have been careful to avoid any political sensitivities.

Contents

Introduction

Arms control, and in particular, nuclear arms control, has been part of Lawrence Livermore National Laboratory's (LLNL's) mission since it was established in 1952 (in this work, LLNL or the "Laboratory" will be used to identify Lawrence Livermore National Laboratory and its prior names: University of California Radiation Laboratory at Livermore, and Lawrence Livermore Laboratory). LLNL, Los Alamos National Laboratory (LANL), and Sandia National Laboratories (SNL) were chartered by law to provide the nation's nuclear weapon deterrent, and they uniquely possess the nuclear testing expertise to serve U.S. Government (USG) needs. LLNL's role has always been to provide technical expertise without advocacy to the Department of Energy (DOE) and other federal agencies as well as state agencies. The Laboratory also interacts with academic institutions, think tanks, and private industry on a variety of national security matters. Although the distinction between technical and political subject matter is not always completely clear, the Laboratory continually strives to be an honest broker in serving USG sponsor needs. However, over the course of LLNL's history, there have been scientific experts in the broader technical community—some with access to classified information—who have disagreed with our technical assessments, questioned our role as honest broker, or who did not think it was appropriate for the University of California (U.C.) to manage a nuclear weapons laboratory.* Nevertheless, LLNL and our sister laboratories have welcomed

* A number of criticisms came from professors at the various U.C. campuses. These included professors Jose Fulco and Walter Kohn (a Nobel Prize winner in chemistry) of U.C. Santa Barbara, U.C. Berkeley professors Charles Schwartz and John Holdren (Holdren served as assistant to President Obama for Science and Technology), and U.C. Davis professor Paul Craig. The author debated some of these professors on the advantages of U.C. management of LLNL and LANL. Criticism also came from individuals at other U.S. academic institutions and industry, such as scientist Richard Garwin of IBM's Thomas J. Watson Research Center, Frank Von Hippel of Princeton University, seismologist Jack Evernden, and seismologist Paul Richards of Columbia University.

challenges in order to ensure that all sides of critical, national security issues are provided in a fair and technically valid way for USG decision makers and leaders.

The Laboratory has been and continues to be involved in the Comprehensive Test Ban Treaty (CTBT) in a variety of ways, including: determining the type of measurements that would be necessary to monitor for nuclear tests or the absence thereof; developing measurement capabilities; addressing technical issues regarding the need to test; and addressing the need to balance the deterrent capabilities of the U.S. against those of its potential adversaries.

When the Laboratory opened for business in September 1952 as a branch of U.C. physicist and Nobel prize winner* Ernest O. Lawrence's Radiation Laboratory in Berkeley, the Soviet Union, under Stalin's rule, was well under way developing its nuclear capability. The Soviets had tested their first fission device in 1949, and would conduct their first test of a thermonuclear device (commonly known as a hydrogen bomb) in 1953. Lawrence and Laboratory co-founder and physicist Edward Teller had accomplished their mission to establish a second nuclear weapons laboratory to generate competing nuclear weapon designs with LANL to ensure that the U.S. stockpile could adequately stand up to Soviet aggression.

By the mid-1950s, both the U.S. and the Soviet Union were conducting high-yield thermonuclear tests, and there was mounting international pressure for a ban on testing, due to the concerns about the spread of radioactive contamination. There was also a belief that a cessation of nuclear testing would stop the arms race. When the United Kingdom (U.K.) tested its first hydrogen bomb in May 1957, public pressure mounted even more. In the U.S., the issue of a nuclear test ban became part of Democratic candidate Adlai Stevenson's presidential campaign. World-renowned scientists also called for a nuclear test ban, including Otto Hahn, co-discoverer of nuclear fission. Linus Pauling, who would win two, undivided Noble Prizes† collected signatures from more than 9,000 scientists from 43 countries to end testing.

The path of test ban-related discussions and negotiations has involved a series of fits and starts over the years, particularly from the late 1950s into the 1970s. Initially, three countries were involved—the U.S., the U.K., and the Soviet Union. Here we capture the most relevant events in which the parties involved attempted to achieve technical and political agreement in the test ban debate, particularly for those events in which there was prominent participation by Laboratory personnel.

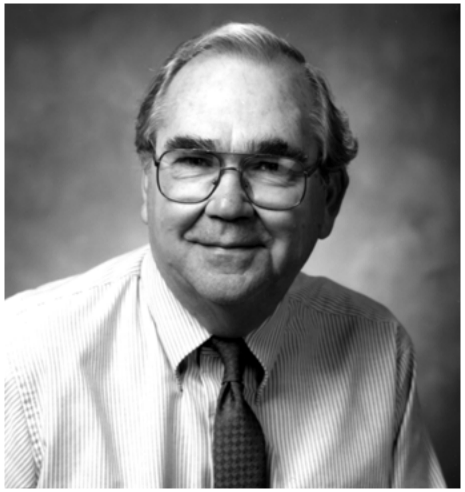
This history focuses on the author's experience and views of nuclear weapons implications and treaty negotiations, although it can be difficult to separate the weapons testing issues from the test monitoring issues, especially when it comes to treaty negotiations and political considerations. Where necessary, this history will touch upon the aspects of nuclear test monitoring.

* E.O. Lawrence was awarded the Nobel Prize in physics in 1939 for inventing the cyclotron.

† Pauling was awarded the Noble Prize for chemistry in 1954, and the Noble Peace Prize in 1962 for his opposition to weapons of mass destruction.

Laboratory Participation in Test Ban Deliberations through the Years

On April 18, 1983, Dr. Milo Nordyke, who was LLNL's Treaty Verification program leader, sent a memo to Laboratory Director Roger Batzel providing a brief summary of LLNL participation in arms control deliberations. The table below shows information that Nordyke included in that memo. Much of what is discussed in this history has been inspired by the information Nordyke provided. Other published and draft material were used to expand on the information in the table below; however, the specific nature of Laboratory participants' contributions in the deliberations was not always clear; in this history, we attempt to clarify these roles. We also discuss the Limited Test Ban Treaty (LTBT; also known as the Atmospheric Test Ban Treaty) that participating countries adopted in 1963, when it became apparent that a CTBT was beyond reach.



Milo Nordyke served as the Laboratory's treaty verification program leader from the time the program was formed in 1976 to 1980. His draft history of the Laboratory's involvement in the nuclear test ban negotiations was a source for this manuscript.

Milo Nordyke's summary of LLNL participation in arms control deliberations as of April 1983.

Date	Activity	LLNL participants
January 1958	Bethe Panel (PSAC)	H. York, H. Brown
June 1958	Western Panel of Experts to Conference of Experts on CTBT	E.O. Lawrence, H. Brown
October 1958 to January 1962	Geneva Conference on CTBT	H. Brown, S. Colgate, R. Herbst, W. Heckrotte
December 1958	Berkner Panel on Seismic Improvement (PSAC)	K. Street, W. Heckrotte
June 1959	Technical Working Group I to the Geneva Conference (W. Panofsky, chairman)	S. Colgate, R. Herbst
November 1959	Technical Working Group II to the Geneva Conference (J. Fisk, chairman)	H. Brown
January 1961	Fisk Panel–a State Dept. panel	H. Brown
June 1961	Panofsky Panel (PSAC)	J. Foster
March 1966 to April 1983	ENDC/CCD/CD–UN Conference in Geneva	R. Herbst, W. Heckrotte, G. Werth, W. Grayson, J. Landauer, J. Taylor, W. Dunlop, J. Miskel, F. Holzer
May 1968	UN special session on the NPT	W. Heckrotte
May–June 1974	TTBT negotiations delegations	W. Heckrotte, M. May
September 1974 to April 1976	PNET negotiations delegation	W. Heckrotte, M. Nordyke
September 1974 to May 1976	SALT II negotiations delegation	M. May as DoD representative
July 1977 to November 1980	CTBT negotiations delegation	W. Heckrotte, M. Nordyke, J. Landauer, J. Hannon, D. Springer
February 1980 to April 1983	CTBT Group of Scientific Experts to the CD	D. Springer
June 1982	UN special session on disarmament	F. Holzer

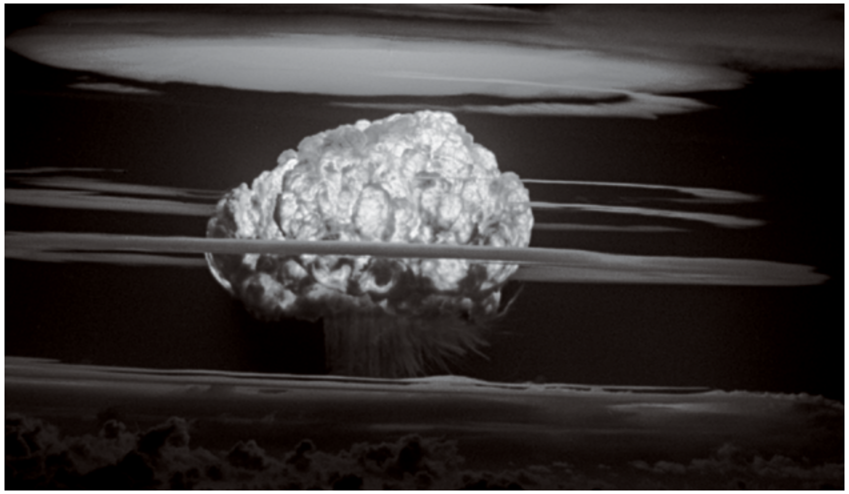
Timeline for events from the 1940s through the 1960s.

Date	Activity
Dec. 1941	Roosevelt pursues the development of an atomic weapon. The U.S. Army Corps of Engineers establishes the Manhattan District for the project.
Nov. 1942	Los Alamos, New Mexico, is chosen as the site to develop an atomic weapon; Oppenheimer leads the effort.
July 1945	U.S. conducts the world's first nuclear weapon test, Trinity, at Alamogordo, New Mexico.
Aug. 1945	U.S. drops an atomic bomb on Hiroshima, Japan.
Aug. 1945	U.S. drops an atomic bomb on Nagasaki, Japan.
Jan. 1946	United Nations General Assembly approves the creation of a United Nations Atomic Energy Commission (UNAEC).
July 1946	U.S. conducts its first underwater test (23 kt) in Operation Crossroads in the Marshall Islands.
Jan. 1947	United States creates its Atomic Energy Commission (USAEC, or simply AEC) as part of the Atomic Energy Act of 1946, and the AEC becomes operational.
Aug. 1949	Soviet Union's first nuclear test is conducted near Semipalatinsk in Kazakhstan.

E.O. Lawrence and Edward Teller enjoy a moment during Operation Greenhouse in 1951 at Enewetak Atoll. Greenhouse diagnostics were used to develop thermonuclear weapons.

Timeline for events from the 1940s through the 1960s (cont.)

1950	AEC establishes the Nevada Test Site (NTS).
Jan. 1950	President Harry Truman announces the U.S. will develop the hydrogen bomb.
June 1952	AEC establishes a second weapons laboratory at Livermore; it operates as a branch to the U.C. Radiation Laboratory in Berkeley. (In this history, we will use LLNL or the Laboratory throughout, regardless of the time-frame being discussed.)
Sept. 1952	U.C. Radiation Laboratory opens its new Livermore branch, with Herbert York serving as its first director.
Oct. 1952	U.K. tests its first nuclear device near the Monte Bello Islands off Australia.
Nov. 1952	U.S. conducts the world's first thermonuclear device test, Mike (10.4 MT), in Operation Ivy at Eniwetok Atoll.
Mar–April 1953	Livermore's first two nuclear tests, Ruth and Ray at NTS fail.
Aug. 1953	Soviet Union conducts a preliminary thermonuclear device test, producing some yield. In November, 1955, they conduct a test achieving their first complete thermonuclear device with a yield of 1.6 MT.
Dec. 1953	Eisenhower proposes the Atoms for Peace program at the United Nations General Assembly.
Mar. 1954	U.S. detonates thermonuclear device, Bravo, in the Bikini Atoll in the Pacific, producing twice the expected yield.



On March 1, 1954, the U.S. detonated the thermonuclear device, Bravo in the Bikini Atoll in the Pacific. The explosion (15 MT) produced twice the expected yield. (photo credit: PBS)

Timeline for events from the 1940s through the 1960s (cont.)

April 1954	India's Prime Minister Nehru is the first world leader to call for a halt to nuclear testing.
Feb–May 1955	Livermore completes its first successful fission device test in Operation Teapot.
June 1955	AEC acquires Site 300—LLNL's explosives test area located near the Altamont Pass east of the Laboratory.
Summer 1955	Livermore receives its first warhead assignment, which is to develop a small warhead (W27) for the Regulus II Navy missile; several months later, Livermore is assigned the W45 for the Army's Little John and Terrier missiles.
May 1957	U.K. conducts its first hydrogen bomb test at Christmas Island.
June 1957	The Navy assigns warhead development for its new Polaris missiles to Livermore. Polaris is the first submarine-launched missile.
June 1957	AEC establishes a program (Plowshare) for non-military uses of nuclear explosions at LLNL's Division of Military Applications.
Sept. 1957	LLNL conducts Rainier, the first fully contained underground nuclear explosion (1.7 kt).
Nov. 1957	Eisenhower creates the position of special assistant for Science and Technology and appoints James Killian, Jr., who will also lead the President's Science Advisory Committee (PSAC).
Mar. 1958	Nikita Khrushchev becomes Soviet premier. On March 31, the country declares that it will halt all nuclear tests as long as Western nations also stop.
April 1958	Teller becomes LLNL's second director.
Summer 1958	Conference of Experts convenes to examine the issues involved in verifying a nuclear test ban.
Aug. 1958	E.O. Lawrence dies, and in November, the U.C. Regents rename the two laboratories as the Ernest Orlando Lawrence Radiation Laboratories (LRL-Berkeley and LRL-Livermore).
Sept–Oct 1958	U.S. conducts Hardtack II at NTS. Results contradict Conference of Experts conclusions on ability to predict yield.
Oct. 1958	U.S., U.K., and the Soviet Union begin negotiations on a comprehensive nuclear test ban at the Geneva Conference on the Discontinuance of Nuclear Weapons Tests. The U.S. and the U.K. begin a one-year testing moratorium, which the Soviet Union joins a few days later.
Dec. 1958	Berkner panel convenes on seismic improvements in test ban monitoring.
June 1959	Technical Working Group I to the Geneva Conference; discussion includes high-altitude tests.
Sept. 1959	VELA program begins.
Feb. 1960	France conducts its first nuclear weapon test in the Sahara Desert.

Timeline for events from the 1940s through the 1960s (cont.)

May 1960	A U.S. U-2 reconnaissance plane is shot down over Sverdlovsk in the Soviet Union, which stops progress for a CTB for the remainder of Eisenhower's administration.
July 1960	Harold Brown becomes LLNL's third director.
Nov. 1960	George Washington (SSBN-598), the first Polaris submarine, is armed with 16 Livermore-designed warheads.
June 1961	John S. (Johnny) Foster, Jr. becomes LLNL's fourth director.
Sept. 1961	The Soviet Union resumes atmospheric nuclear testing on September 1. The U.S. resumes underground testing on September 15.
Sept. 1961	Arms Control and Disarmament Agency (ACDA) is established.
Oct. 1961	Soviet Union detonates 50 MT Tsar Bomba, the largest nuclear explosion in history.
Dec. 1961	Plowshare's first nuclear explosion, Gnome, tests the feasibility of a deeply buried explosion for energy recovery.
Mar. 1962	President John Kennedy meets with Laboratory leaders at Lawrence Radiation Laboratory in Berkeley.
April–Nov. 1962	Operation Dominic, the largest (and last) U.S. atmospheric nuclear test series, is conducted near Christmas Island.
July 1962	Plowshare Sedan test is conducted at NTS to explore peaceful uses of nuclear explosives for mining and excavation.
Nov. 1962	Last U.S. atmospheric nuclear test is conducted at Johnson Atoll as part of Operation Fishbowl. Tightrope was a warhead launched by a Nike Hercules air defense missile and detonated at an altitude of 13 miles.
Oct. 1963	The Limited Test Ban Treaty (also called the Partial Test Ban Treaty) enters into force on October 10, banning nuclear tests in the atmosphere, underwater, and in outer space. The ban includes nuclear explosions for peaceful purposes.
June 1964	Livermore begins the design process for the warhead for Minuteman III.
Oct. 1964	China conducts its first nuclear test at Lop Nor on the Qinghai Plateau.
Mar. 1965	Livermore is assigned to develop the warhead for Poseidon C-3.
Oct. 1965	Michael May becomes the Laboratory's fifth director.
June 1967	China detonates its first thermonuclear device (3 MT).
Dec. 1967	Plowshare Gasbuggy event in New Mexico tests the feasibility of stimulating natural gas production. Results showed that gas production was six to eight times higher than previous rates.
July 1968	The Treaty on the Nonproliferation of Nuclear Weapons (NPT) is signed by the U.S., U.K., and the Soviet Union, and 58 other countries. The treaty enters into force on March 5, 1970.
Sept. 1968	France detonates its first hydrogen bomb.
April 1969	First U.S.–Soviet Plowshare meeting in Vienna.

The 1950s and 1960s

In the early 1950s, there was considerable international and national pressure for a ban on nuclear testing. On April 2, 1954, Indian Prime Minister Jawaharlal Nehru became the first world leader calling for a "standstill agreement" on nuclear tests. Author Benjamin Greene writes that, while President Eisenhower wanted a CTBT, he didn't move solidly in that direction because of resistance in his administration.[1] For example, Atomic Energy Commission (AEC) Chairman Lewis Strauss supported testing, as did Pentagon officials who felt testing was necessary to maintain U.S. superiority over the nuclear capabilities of the Soviet Union. The test ban was an issue in the 1956 presidential campaign between Eisenhower and Democrat candidate Adlai Stevenson. Many famous individuals spoke out against testing, including Albert Schweitzer and Linus Pauling. The United Nations Disarmament Commission, which was established in 1952, took a serious interest in the subject.

Because of his administration's divided opinions about a CTBT, Eisenhower delayed his policy decisions. He sought consensus but was not able to achieve it. He lacked a technical understanding of the issues (e.g., seismic detection of nuclear weapon tests) and relied heavily on scientific counselors, many of whom were against a test ban in the first half of his presidency. Greene writes,[2] "Much of the scholarship on the test ban debate identifies a lack of presidential leadership as a principal reason for the administration's failure to achieve a test-ban agreement." However, as Greene notes, in 1956, Eisenhower began to act without having the consensus he sought, and in his second term, he more aggressively sought movement toward a test ban. On March 31, 1958, the Soviets announced that they would discontinue nuclear tests with the caveat that the other nuclear powers do the same. The Soviets had just completed several megaton-class nuclear tests,[*] so to many at the time, it seemed to be a disingenuous act on their part, with the goal of swaying public, international support for a test ban. Either way, this put more pressure on Eisenhower, who decided to enter a testing moratorium and begin negotiations for a CTB.

* For information on nuclear weapons terminology, see *The Effects of Nuclear Weapons*, third edition, Departments of Defense and Energy, S. Glasstone and P.J. Dolan, eds., 1977.

The Soviet Union announced their willingness to change their long-standing position against having monitoring stations on their territory, as well as a willingness to enter a two-to-three-year moratorium on nuclear tests; however, the U.S., U.K., Canada, and France insisted that such a move must be part of a larger disarmament package, something that the Soviets would not accept. Glenn Seaborg comments in his book, *Kennedy, Khrushchev, and the Test Ban*,[3] that a fundamental difference between the U.S. and the Soviet Union was that the U.S. wanted controls to be in place before disarmament while the Soviets wanted disarmament first. There were a lot of interchanges between Eisenhower and the Soviets, and the Soviets tried to play to public opinion in the West.

Bethe Panel

In November 1957, Eisenhower created the position of special assistant for Science and Technology and named Massachusetts Institute of Technology (MIT) President James R. Killian, to the position. In response to the Soviet launch of Sputnik 1 and 2, Eisenhower also expanded the Science Advisory Committee that was established by former President Truman. The new President's Scientific Advisory Committee (PSAC) was moved to the White House from its former place under the Office of Defense Mobilization. Killian would lead the PSAC.

The PSAC was tasked to provide an assessment[4] of what it would take to monitor underground explosions in a CTBT. In 1958, Killian appointed Hans Bethe, a professor of physics (and future Nobel laureate) at Cornell University and one of the scientists involved in the development of the first atomic bomb, to lead a panel to examine the test ban issue. The panel comprised representatives from the PSAC, the AEC, and the Department of Defense (DoD). Laboratory scientist Harold Brown and former Laboratory director Herbert York were members of the panel. York had taken a leave of absence as the director of Lawrence Radiation Laboratory (LLNL's name prior to 1971) and went to Washington to spend time on the PSAC. In 1958, York was selected as the first chief scientist for the new Advanced Research Projects Agency (ARPA),* and soon after that, he became the first DoD director of Department of Defense Research and Engineering (DDR&E). Nordyke writes in his draft history:

> *"The Panel was charged with examining two general questions: 'What would be the comparative impact [of a test ban] on the U.S. and Soviet Union nuclear arsenals and nuclear weapons laboratories?' and 'How well could the U.S. detect Soviet atmospheric and underground nuclear explosions?' "*

Nordyke continues:

> *"Although the Bethe Panel was heavily weighted with representatives of the nuclear testing establishment within the government, somewhat surprisingly the recommendations of the panel were modestly favorable to a nuclear test ban. Their report, submitted on March 27, 1958, concluded that 'a practical detection system' involving some number of permanent monitoring stations and teams of roving inspectors could be devised that would provide adequate verification of such a ban, although there was no such thing as a perfect verification system. They also concluded that the U.S. could benefit from additional testing but could not estimate whether a test ban would be to the net military advantage of the U.S. It has also been reported that they concluded U.S. nuclear weapons technology was sufficiently mature relative to U.S. requirements and the capabilities of the Soviet Union that a nuclear test ban could be entered into without prejudice to the U.S. national security."*

Greene[5] writes that the members of the Bethe Panel were of mixed opinion as to whether a test ban was a good idea or not, but they did agree on the feasibility of monitoring such a ban. Had Edward Teller been on the Bethe Panel, the conclusions may have been somewhat tempered from Nordyke's description, since Teller at the time was an outspoken critic of any test ban, as well as an outspoken proponent for the peaceful uses of nuclear explosions. Greene either cites or surmises many examples in which scientists like Teller expressed opinions that were counter to those expressed by scientists who were favorable to a CTB, such as those on the PSAC.

* ARPA was formed in 1958. Its name was changed to DARPA (Defense Advanced Research Projects Agency) in March 1972 and then changed back to ARPA in February 1993. In March 1996, the name was changed once more to DARPA.

Conference of Experts

According to Nordyke,[6] in 1958, President Eisenhower decided to pursue the recommendations of the Bethe Panel to bring together a panel of experts to study the possibility of detecting violations of a possible agreement on the suspension of nuclear tests. After an exchange of letters between Eisenhower and Soviet Premier Khrushchev, a panel of scientific experts representing the two sides—a Western panel of experts from the U.S., U.K., France, and Canada, and an Eastern panel from the Soviet Union, Poland, Czechoslovakia, and Romania—met in Geneva in July and August of that year. Killian appointed James Fisk, member of the PSAC and a vice president at Bell Laboratories, to lead the U.S. delegation. Ernest Lawrence and Robert Bacher (one of the leaders of the Manhattan Project and a LANL scientist) were members of the delegation. LLNL scientist Harold Brown and Bethe served as technical advisers. Lawrence's participation was cut short due to illness. He flew home but died soon after, on August 27. The panel's recommendations for seismic verification were based mostly on the results from the Rainier nuclear test data (Rainier was the first underground nuclear test conducted by the U.S.), which would later become an issue.

Nordyke writes:

"The general description of the nature of the detection and identification problems in the Conference of Experts' report has stood the test of time very well, especially when it is considered that at the time of the conference, there had been only one underground nuclear explosion with any significant yield, RAINIER, and no nuclear explosions at high altitude or in outer space. They correctly described the various types of phenomena involved in nuclear explosions in these various environments and what the observable effects would be. However, their quantitative predictions for the magnitude of some of the signals were somewhat in error. Thus, their specification of the required control system, particularly for underground explosions, suffered considerably from the lack of technical data and was to be the subject of continuing controversy over the following years as new data became available and as better technical understandings of nuclear explosion phenomena were developed."

E.O Lawrence, Edward Teller, and Herb York, 1957 (photo credit: Jon Brenneis).

"The report of the Conference of Experts served to define the basic 'technical problems involved in the detection and identification of nuclear explosions' carried out on the surface, at high altitude, in outer space, underwater and underground as well as 'the technical equipment of the control system necessary for the detection and identification of nuclear explosions.'"

According to Glenn Seaborg,[7] who was then the associate director of Lawrence Radiation Laboratory at Berkeley, as well as the chancellor of U.C. Berkeley, the system proposed by the Conference of Experts came to be known as the "Geneva System." Seaborg notes that although the Geneva System was considered an accomplishment at the time, the optimism it inspired for achieving a quick CTB was unwarranted, as it took more than forty years to achieve that goal. Soviet recalcitrance and refusal to go along with what were considered reasonable U.S. and U.K. proposals contributed immeasurably to the lack of success. Seaborg writes[8] that the Geneva System turned out to be inadequate. For one thing, at the time there was a lack of technical information on the nature of nuclear weapon explosions as it relates to monitoring. As this history will discuss, the Laboratory's technical knowledge about test ban monitoring greatly increased over time, eventually making it possible for the U.S. to enter into a CTBT. Much of this was possible because of the USG

A scientist sets up equipment for the Rainier event—the world's first fully contained underground nuclear explosion (1.7 kt) conducted on September 19, 1957 at the Nevada Test Site.

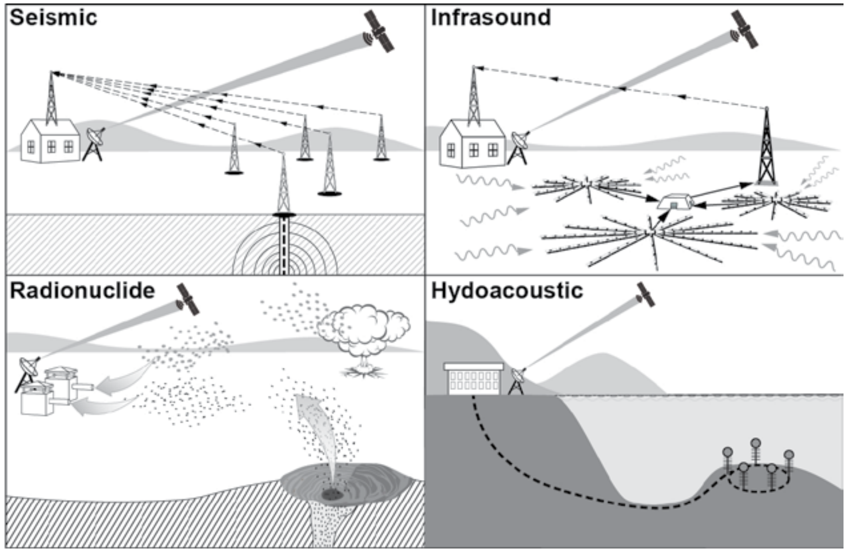
support for the necessary research and development (R&D) that led to viable monitoring systems.

Seaborg recounted[9] that the U.S. political participants were inexperienced, and the support agencies at home were uncoordinated. It was difficult to get guidance from Washington. There was a lot of interagency disagreement, apparently more than would be encountered in the 1980s and later. Seaborg said that President Kennedy was fully aware of the lack of continuity in U.S. arms control leadership when he took office. Although these issues continued to have some bearing over the ensuing years, they seemed heightened during the late 1950s and early 1960s. Seaborg notes that there was acknowledgement in Washington about these inadequacies, and that later, agreement was finally reached to provide better coordination of the country's arms control efforts with the establishment of the Arms Control and Disarmament Agency (ACDA) in September 1961. William Foster served as its first director.

In August 1958, the Conference of Experts submitted its final report to the United Nations Security Council and General Assembly. The report adopted conclusions regarding the use of various methods such as registering acoustic waves, seismic waves, and radio signals, and the collection of radioactive debris (see **Figure**). The Conference also adopted conclusions on the detection of high-altitude tests by measuring gamma radiation and neutrons emanating from nuclear explosions using satellites, and the registering of ionospheric phenomena using radio techniques and light. However, the panel made no definitive recommendations; they only drew conclusions about the technologies that could be used. They also formed conclusions about the equipment that would be necessary at monitoring control stations. Harold Brown contributed in writing this report; a draft is located in the LLNL archives. It is generally concluded[10] that the report contributed to Eisenhower's decision the following day to enter a nuclear test moratorium and negotiate a CTBT.

On August 22, 1958, the White House issued a press release stating the technical feasibility of supervising and enforcing a test ban and expressed the willingness to enter a one-year moratorium with provision for renewal on a year-to-year basis, depending on whether an agreed inspection system was operational and progress was being made on a number of other arms control measures that the U.S. had proposed.

William (Bill) Ogle, who was a former nuclear test division leader at LANL, wrote on the conclusions from the Conference of Experts, noting that the available methods "made it possible to detect and identify nuclear explosions down to somewhere between 1 kiloton (kt) and 5 kt underwater, underground, or in the atmosphere, up to 10 kilometers (km) in altitude, and that detonations at the same yield would probably be detected but not identified up to perhaps 50 km."[11] He continued, "The methods to be used for collection and identification included the collection of samples of radioactive debris; recording of seismic, acoustic, and hydro-acoustic (underwater) waves; recording of electromagnetic waves; and onsite inspections (OSIs) of identified events



The Comprehensive Test Ban Treaty Organization's (CTBTO's) global nuclear explosion alarm system distinguishes nuclear explosions amid natural sources such as earthquakes, volcano or mining activity, and reactor accidents. Four types of monitoring systems are used: 170 seismic stations, 60 infrasound (low-frequency waves inaudible to the human ear), 11 hydroacoustic (sound waves traveling in the ocean), and 80 radionuclide (particles or gas). The stations are set up in arrays to help determine the location of an event. Computers transform the electrical signals from the arrays and send the data via satellite to the CTBTO in Vienna, where the information is analyzed. (Source: ctbto.org)

which could be suspected of being nuclear explosions."

Meanwhile Teller, who became the LLNL director after York left, agreed with AEC Chairman John McCone that a moratorium would be a bad idea. Ogle reports[12] that Teller was convinced that the Russians would cheat in a CTB, especially by utilizing decoupling.* The concept of cavity decoupling derived from a request Teller made to the Laboratory and RAND Corporation to study ways a state could evade the CTBT. Albert Latter of RAND demonstrated[13] (theoretically) that a 300 kt event could be decoupled by firing the device in a very large underground cavity in order to make it look like a 1 kt explosion on a seismograph. Geophysicist and RAND co-founder David Griggs* had first suggested the decoupling idea when he considered the design of a Plowshare power generating facility in which the ground shock at the power plant could be reduced by a factor of 10 to 50 by firing the nuclear explosives in a steam-filled cavity. LLNL and RAND would collaborate on verification efforts for many years to come. Teller also felt a moratorium would hurt Plowshare efforts, discussed later. He wrote to General Alfred Starbird of AEC's Department of Military Applications saying that any test in which the energy production was less than that of the high explosive (HE) should be allowed.† He also suggested that since tests below a kiloton could not be detected and identified, explosions below a limit of 100 tons should be allowed. He would also allow one-point safety tests. One-point safety is a nuclear weapon design consideration that protects the weapon against an accidental or unauthorized nuclear explosion.‡

The Geneva Conference

After Eisenhower announced his willingness to enter a one-year moratorium, the Soviets agreed to an October 31 start date. Leading up to the testing deadline, both the U.S. and the Soviet Union conducted dozens of nuclear tests so that they could get as much data as possible before the moratorium was in effect. The Soviets continued to conduct their final shots several days after the deadline, but nonetheless, negotiations for a CTB began at the Conference on the Discontinuance of Nuclear Weapons Tests, which was more commonly known as the Geneva Conference. U.S. Deputy Ambassador to the U.N. James Wadsworth led the U.S. delegation to the Geneva Conference. Semyon Tsarapkin was the Soviet's chief delegate.

In January 1959, Ambassador Wadsworth met with Tsarapkin regarding the underground tests in the Hardtack series. The findings indicated that the Conference of Experts overestimated the ability of seismic instrumentation to detect underground tests and distin-

* Decoupling is a method in which a nuclear device is detonated underground in an air-filled cavity with a sufficient radius that the material outside the cavity can respond elastically to the pressure from the explosion. By employing this method, the seismic signal from a nuclear explosion is drastically reduced.

* Griggs authored several UCRL publications that are in the LLNL archives.

† Nuclear weapons are triggered by chemical HEs to create the extreme temperature and pressure required to initiate a nuclear explosion.

‡ DOE Order DOE O 452.1E states that "Nuclear explosives must be inherently one-point safe; i.e., the probability of achieving a nuclear yield greater than 4 lb of TNT equivalent in the event of a one-point initiation of the high explosive must not exceed one in a million."

guish them from earthquakes. Their conclusions were based almost entirely on data from Rainier, which was the only underground test at the time. Hardtack provided additional data that indicated that the minimum yield of underground tests that could be detected and distinguished from earthquakes by the Geneva System was 20 kt, not 5 kt. This meant that more than the180 manned control stations contemplated by the Geneva System would be necessary. Since many of the additional systems would have to be on Soviet soil, the Soviets would have none of it; they rejected the new information.

Up through January 1962, LLNL's Harold Brown, Stirling Colgate, Roland Herbst, and Warren Heckrotte served as U.S. technical advisers at the Geneva Conference. Brown played a particularly noteworthy role in the negotiations, contributing much to the requirements of seismic detection, even though he was not a seismologist.

The LLNL archives contain a number of papers Brown wrote on what it would take to detect radioactivity, locate test points, and measure seismic signals. He presented at delegation meetings with the Soviets on subjects such as the number of seismic and other stations that were necessary. He helped publish a paper on a 170-station seismic network while he was a member of the Technical Working Group II that formed in 1959, and another paper on the definition of test thresholds; i.e., the yield below which monitoring systems would not detect a nuclear test. In one example, Brown told the Soviets that their concerns about data tampering at control stations were unfounded, since all of the staff at the stations were Soviet Bloc people. Technical Working Group II also addressed onsite inspections (OSIs). Brown wrote to AEC Chairman McCone on December 26, 1959 regarding the negotiations. George Washington University National Security Archives describes[14] the key role that Brown played in the negotiations and in the events that followed.* Included is the following:

> *"Harold Brown, soon to be director of Livermore Radiation Laboratory [LLNL's name at that time] and a future secretary of defense, served as scientific adviser to the U.S. test ban negotiating team at Geneva during 1958–1959. In this letter, he related his discouragement over the technical talks with Soviet scientists on the problem of underground test detection. While the Soviets had been cooperative in private discussions, even accepting U.S. claims about decoupling, in public sessions 'they denied it.' Moreover, Brown argued that in recent weeks, U.S. scientists in Geneva had concluded that detection 'system capability is considerably less than believed even a few months ago.' Not only did successful on-site inspection have a 'very small' probability of success, but 'large hole decoupling' was 'much easier than had been thought.' Brown's comments on the possibilities of evasion suggested that the demands on U.S. intelligence capabilities were much greater than Allen Dulles had suggested a few months earlier. Just as McCone had suggested a 'threshold' test ban in the meeting with Nixon, Brown was thinking along the same lines, in this instance, a ban on atmospheric tests and on 'underground for yields higher than about 100 or 150 kilotons.' These suggestions presaged future policy developments.*

Thus, in early February 1960, the U.S. proposed a limited test ban treaty banning atmospheric, underwater, and high-altitude tests and underground tests above a 4.75 seismic magnitude reading—the equivalent of 19 or 20 kilotons of explosive yield—the threshold at which underground tests could be adequately monitored. Moreover, the three powers would begin a joint research program on improvements of underground test detection below the threshold."

1958 Panofsky and Berkner Panels

The Geneva Conference highlighted the fact that negotiations would require more technical data than was available at the Conference of Experts. Killian addressed the issue by appointing two panels, one on the feasibility of very high-altitude detonations, and the other on seismology. Stanford professor Wolfgang Panofsky led the panel focusing on very high-altitude detonations. Panofsky would later become the first director of the Stanford Linear Accelerator Center. The group concluded that no nation was likely capable of using high-altitude detonations in the near future.

* The National Security Archives extracts unclassified information from historical USG documents and makes this information generally available to those interested in the subject matter.

In December 1958, James Killian appointed the president of Associated Universities (AU), Lloyd Berkner, as chairman of the panel to examine seismology issues. AU operated Brookhaven National Laboratory and the National Radio Observatory at Greenbank, West Virginia. The panel examined data from the Hardtack II series of nuclear tests that looked at detection thresholds. Scientists by then realized that it was more difficult than originally thought to discriminate between naturally occurring earthquakes and nuclear explosions. The variability of seismic signals is also associated with geology. Laboratory scientists Ken Street and Warren Heckrotte participated in the Berkner Panel to study ways to improve the effectiveness of the seismic stations that were being considered for monitoring a CTBT.

The panel recommended[15] (1) a ten-fold increase in the number of seismometers at a given station, (2) using seismic surface waves as a means of discrimination, and (3) placing "black boxes"* in earthquake-prone areas of a suspect state. The panel also addressed evasive techniques such as the use of cavity decoupling. According to Seaborg,[16] the most important product from the Berkner Panel's deliberations was their recommendation for a vigorous program in explosion seismology that led to the formation of the ARPA Vela Program† for research on nuclear test detection.

Bacher Panel

According to Seaborg,[17] the cavity decoupling situation depicted by the Berkner Panel was made worse by another report released by a panel led by PSAC member and physicist Robert Bacher of the California Institute of Technology (CalTech). Seaborg writes, "The Bacher Panel concluded that onsite inspection of a suspicious event would have an exceedingly small chance of proving that an underground test had actually occurred, especially if the perpetrator was bent on concealment." Seaborg notes that the panel had concluded this as a

* "Black boxes" is a term dubbed by Soviet physicist Lev Artsimovich. At the tenth Pugwash Conference on Science and World Affairs in 1962, U.S. and Soviet scientists discussed a proposal for monitoring seismic activity by using sealed, automatic, seismic recording stations. The scientists believed that the "black boxes" would limit OSIs. Correspondence between Kennedy and Khrushchev subsequently considered the idea of using "black boxes." [M. Evangelista, *Unarmed Forces: The Transnational Movement to End the Cold War*, Cornell University Press, Ithaca, 1999, p. 77.]

† Vela Uniform involved detection of underground explosions, Vela Hotel involved detection of high altitude and space explosions, and Vela Sierra involved detection of high altitude tests by ground stations.

counter-argument "to the aggressive arguments of Harold Brown," who was at the time an associate director at the Laboratory. Seaborg went on to say, "It is noteworthy that Brown, one of the persuasive opponents of a test ban at this time, became one of the most effective spokesmen for the LTBT after it was presented to the Senate in 1963." It is not clear whether Brown, or for that matter other Laboratory personnel, were members of the Bacher Panel, or whether Brown just provided the panel with his technical views. Benjamin Greene also notes that Brown influenced the Bacher Panel. In a footnote, Greene writes,[18] "According to Kistiakowsky (who replaced Killian as the president's science adviser and chairman of PSAC),* the panelists unduly yielded to aggressive arguments of Harold Brown, who was then Teller's deputy at LLNL. Brown provided an especially negative assessment of the effectiveness of onsite inspection."

Ogle writes[19] that in early 1959, Edward Teller was skeptical that a test moratorium could continue for long. He felt that underground or deep space testing would occur because there was no way to achieve a satisfactorily monitored ban on such tests. LLNL had already tested underground, and LANL was reluctant to do so; instead, they wanted to test in the atmosphere. Ogle notes, "Livermore, sparked by Teller and Harold Brown, was doing everything it could to move toward a treaty that would still allow testing." He continued, "It is interesting that at this point, Harold Brown, after returning from Geneva, proposed a treaty apparently based on observation of nuclear testing by the use of satellites and that would not involve either a threshold limit or inspection teams."

Technical Working Group I

In April 1959, Eisenhower proposed a treaty to ban tests in the atmosphere up to 50 km in altitude and in the ocean. Although Khrushchev rejected the idea, he agreed to form a group to discuss the detection of nuclear explosions conducted at high altitude as well as verification methods. In June, Laboratory scientists Stirling Colgate and Roland Herbst participated in Technical Working Group I[20] to the Geneva Conference. The following month, the group published their recom-

* George Kistiakowsky worked on the Manhattan Project overseeing the development of new chemical explosives. He went on to chair the National Academy of Science's Committee on Science, Engineering, and Public Policy.

mendations for a system of five or six large satellites at 18,000 miles orbit to detect space explosions, supplemented by equipment to be located at the 170 ground stations of the Geneva System.

Technical Working Group II

Soviet diplomat Semyon Tsarapkin proposed shortly after the first technical working group concluded that a second working group assemble to review the U.S.'s new seismic data.[21] At the meetings, Bethe and Latter provided a presentation on decoupling, and U.K. representatives presented the results from some small tests of TNT in cavities that supported the decoupling theory. The Soviets argued that there was no proof that decoupling would work in practice. The group also discussed OSIs; however, no consensus could be reached.

Ogle writes[22] that the AEC followed the Berkner Panel's recommendation for an underground program to "determine the parameters of detection and concealment of underground nuclear detonations…" In preparation for the second working group, LLNL and RAND worked with the DoD and SNL to implement the recommendations. Geophysicist Carl Romney of DoD, who later served as director of the Vela Seismological Center at the Air Force Technical Applications Center (AFTAC), and director for research at DARPA, provided guidance, along with the Laboratory's Glen Werth and Harold Brown, and Al Latter of RAND. The scientists were under a lot of pressure to get fast results, especially in the area of decoupling, but Brown pointed out that it would be better to take a year and get correct results than erroneous results too quickly.

Ogle writes[23] that the DDR&E formed a panel chaired by geophysicist Frank Press, who at the time was the director of the seismology laboratory at CalTech. The group was called the "Scientific Panel to Evaluate the Overall Adequacy of Test Detection Systems." Brown was the AEC representative. The panel's deliberations led to a series of HE decoupling shots called Project Cowboy. However, the Cowboy results were inconclusive for nuclear decoupling because of the differences in physical size of nuclear versus conventional explosives. Brown then pushed plans for a number of nuclear shots for seismic purposes. LLNL's test director Jerry Johnson was involved in the planning. Ogle notes[24] that by the end of 1959, just after the Vela Uniform seismic detection program had been formed, "An appreciable part of the fiscal year (FY) 1960 weapons funding had been transferred to that purpose." Ogle details[25] the Vela Uniform planning and activities, particularly the possibility of a joint program with the Soviets. A joint program required considerations on black box monitoring systems, the type of nuclear explosive device to be used, and how to protect secrets about the devices. Brown participated heavily, and it was also during this time that Teller expressed his preference that the U.S. go with its own Vela program rather than engage in a joint program with the Soviets. Teller felt the Soviets would certainly cheat and make any Vela test of theirs into a nuclear weapon test.

By December 18, the Technical Working Group II was not going well. The delegations could not come to any agreement, and no final report was issued. Seaborg writes[26] that President Eisenhower angrily issued the statement, "The prospects for a nuclear test ban have been injured by the recent unwillingness of the politically guided Soviet experts to give serious scientific consideration to the effectiveness of seismic techniques for the detection of underground nuclear explosions." Eisenhower followed this with the announcement that the U.S. would not be bound by its voluntary test moratorium when it expired on December 31, 1959.

Talks in Geneva continued. The Soviets agreed to the convening of a seismic research program advisory group, which would meet during the second week of May in 1960. However, on May 7, U.S. pilot Francis Gary Powers was flying a high-altitude U-2 reconnaissance aircraft over Soviet territory, and he was shot down by a Soviet missile. Although the seismic research group continued with their plans to meet, the atmosphere had turned dark and by May 27, Tsarapkin said that the Soviet Union saw no need to engage in a joint research program.

In 1960, Harold Brown became the Laboratory director and according to Ogle,[27] Brown wrote a letter to the AEC's San Francisco Operations Office expressing that weapons development had been hindered by the nuclear test moratorium in spite of "more elaborate" techniques of calculations, nuclear weapon design, and laboratory experiments that served only as a partial substitute for weapons tests. He added that the exigencies of the seismic improvement program had essentially eliminated the readiness program to resume nuclear tests, and he listed the types of stockpile improvements that

researchers could make if testing resumed.

During the last days of the Eisenhower administration, the Geneva delegation continued but nothing substantial resulted, and when John F. Kennedy took office in 1961, both he and Premier Khrushchev were under continued pressure from opposing sides on the issue of a nuclear test ban. In the U.S., the Pentagon and nuclear weapons laboratories continued to argue for testing, and on the other side, there was general international pressure to end it. With the new administration, there were major changes for those working on arms control. Kennedy created a Disarmament Administration under the State Department. Arthur Dean replaced James Wadsworth as chief representative to the Geneva Conference, and Glenn Seaborg replaced John McCone as AEC chairman.

The Fisk Panel

In January 1961, President Kennedy appointed James Fisk, then the president of Bell Laboratories, to serve as chairman on a State Department panel of 14 experts to assess the technical capabilities and implications of the monitoring system that had been proposed in Geneva. Brown participated as did York, who was then DDR&E.* J. Carson Mark, director of the Theoretical Physics Division at LANL was also a member. Mark would eventually become an ardent supporter of a CTB. The panel judged that while the Geneva System was capable of detecting atmospheric and underwater tests, it fell short in its capability to detect underground tests and in space. Ogle wrote[28] that at one of the meetings, Mark took issue with Brown's views on the advances that could be made by continued testing. Brown predicted much higher yields could be achieved for a nuclear device than Mark did. This was an example of how LLNL was typically more optimistic about potential advances in nuclear weapons than was LANL.

Ogle writes[29] that in a publication by the Foreign Policy Association of the World Affairs Center,[30] Bethe and Teller presented opposing views on continued testing. Bethe argued that little was to be gained from further tests, and that there was little risk that the Soviets would catch up. Teller argued that continued testing would allow an "effective second strike force for the U.S. and small tactical weapons for limited warfare." He pushed the merits of the Plowshare program of peaceful uses of nuclear explosions and said the moratorium had been a failure for furthering arms control, in spite of the views of some, and that the moratorium had increased the intensity of the Cold War. Ogle discusses[31] the Plowshare experiments that were planned for after the moratorium was lifted. He notes that there was a mutual usefulness between nuclear tests that would be conducted for the Vela Uniform seismic improvement program and those for Plowshare purposes.

According to Ogle[32] there were a number of discussions with the AEC in early 1961 about a readiness program to resume testing should the moratorium end abruptly. At a March 17 meeting in Livermore, LANL Director Norris Bradbury expressed that if testing resumed, it would not likely stop again anytime soon. In contrast, Brown felt an urgency and wanted to reduce the six-month readiness time to test to two months. Brown wrote a letter to General Austin Betts, the head of the AEC's Department of Military Applications, proposing a new nuclear test readiness program and outlining what LLNL would test, and the construction that would be necessary at NTS.

Second Panofsky Panel

In June 1961, President Kennedy asked his science adviser, Jerome Weisner to convene a panel to examine nuclear testing issues. Weisner appointed Wolfgang Panofsky to lead the panel. LANL Director Bradbury and John S. (Johnny) Foster, Jr., who had replaced Brown as LLNL director, were members of the panel. According to Glenn Seaborg,[33] the panel's objective was to address "the perennial question of whether or not the Soviets could be conducting clandestine nuclear tests, and what progress they could make by so doing. The panel also addressed what progress the U.S. could make if it resumed testing and, if both sides resumed, whether the Soviets could catch up with the U.S." Foster presented arguments that atmospheric testing was necessary to develop an enhanced radiation weapon (ERW, which came to be known as the "neutron bomb."). He was very supportive of the U.S. resuming testing whether or not the Soviets tested.

Seaborg, as AEC chairman, sat in on several sessions. The panel's conclusion on August 8, 1961 was that there was no evidence the

* In 1961, President Kennedy appointed Harold Brown as DDR&E. In 1965, President Johnson appointed him secretary of the Air Force. He was the secretary of defense from 1977 to 1981 under President Carter.

In 1961, John S. (Johnny) Foster (left) succeeded Harold Brown (right) as Laboratory director.

Soviets had or had not conducted secret tests. They also concluded that the lack of testing had negatively impacted the U.S., but that these impacts could be compensated by other measures to some extent. In the long run, if the Soviets conducted secret tests, the U.S. would have to test or jeopardize its relative military capability. Kennedy asked the panel if we should resume testing even if the Soviets did not resume. Panofsky and Bradbury said no, while Foster said yes, reiterating his view that atmospheric testing was necessary to develop the neutron bomb via atmospheric tests. President Kennedy countered that if we resumed, it would have to be limited to underground testing. The Soviets broke the moratorium on September 1, 1961 with a series of thirty atmospheric, high-yield tests. In response, President Kennedy announced on September 6 that the U.S. would resume testing. One of the Soviet's atmospheric tests, Tsar Bomba, detonated on October 30, 1961 had a yield of 50 MT, and remains the largest nuclear explosion ever detonated.

We note that Seaborg became AEC chairman on March 1, 1961. By his own admission, he was more favorable toward the merits of a test ban than were the rest of the AEC, the DoD, and the Joint Committee on Atomic Energy, and he had philosophical disagreements about testing with many others in Washington. In this regard, Seaborg was well aligned with Kennedy, who had appointed him. That said, Seaborg presented an unbiased accounting of the history of that time period in his book.[34]

Plowshare Considerations

Nordyke relays in his draft history[35] that in 1956, Harold Brown worked in a nuclear device design group at LLNL, and that Brown suggested to the AEC that a symposium be held to discuss non-military uses of nuclear explosions.[36] Brown and other LLNL scientists such as York, Teller, Jerry Johnson, and Arthur Biehl had some ideas for peaceful uses of nuclear energy. In addition to furthering understanding about the physics and engineering requirements for different applications,

Edward Teller poses with a model of the Soviet 100 MT nuclear weapon, Tsar Bomba, at the Chelyabinsk-70 Nuclear Weapons Museum. The Soviets detonated Tsar Bomba on October 30, 1961 using a lower yield configuration of 50 MT to minimize fallout, and blast and radiation threats to the air crew that dropped the bomb. The explosion was the most powerful ever detonated.

they believed engaging in efforts for peaceful uses could also help attract more top talent to the Laboratory.

On February 6–8, 1957, a joint laboratory symposium on non-military uses of nuclear and thermonuclear explosions was held at LLNL. Brown invited scientists from RAND and General Atomics in addition to LANL and SNL nuclear weapons scientists. Twenty-four papers covering a wide range of ideas were presented. The symposium was quite successful, and on June 27, 1957, the AEC formally established a program for non-military uses of nuclear explosions in the Division of Military Applications at LLNL. Teller, who was a particularly outspoken advocate for peaceful nuclear explosions (PNEs), related that when Brown told Columbia University physicist Isidor Isaac Rabi about the program in 1957, Rabi responded to Brown saying, "So you want to beat your old atomic bombs in plowshares."[37] And the Plowshare name stuck.*

Meanwhile, as test ban negotiations continued, whether or not to allow PNE shots in a test ban was an ongoing discussion. The Soviets had an extensive PNE program and were also interested in preserving the right to do such experiments under a test ban. The main dilemma posed by permitting PNEs under a test ban was carrying them out while preventing them from contributing knowledge for advancing nuclear weapons design.

According to Nordyke, the AEC tasked Brown and others at LLNL to develop ideas on how PNE experiments could be done without yielding useful, new nuclear weapons data. Many Laboratory scientists who were heavily involved on test ban verification efforts began working on Plowshare projects during the 1960s. These scientists included Nordyke, Glenn Werth, Jim Hannon, Howard Rodean, Roland Herbst, and Don Springer. Nordyke writes[38] that Brown's group initially proposed four ideas to the AEC:

- "Using whatever device a country desired for the PNE, under observation by representatives of the U.N. and other countries, including the Soviet Union, but without diagnostics to measure the device performance;

- Establishing an international stockpile with each country desiring to conduct PNEs, placing some number of devices in the stockpile on the date a test ban went into effect;

- Using devices only from the reciprocal country; i.e., the U.S. and the U. K. would use only devices provided by the Soviet Union and vice versa; and

- Using devices that were subject to inspection by all the nuclear weapons states party to the test ban, including the U.S.S.R. This would have required the use of obsolete devices or, if they were new devices, of a design that contained no militarily useful design principles."

Nordyke indicates that the AEC was initially receptive to the first idea, but eventually recommended the international stockpile option to the interagency negotiating group. The Soviets at first rejected any PNEs on December 15, 1958, stating that they would only accept a ban on all explosions. However, ten days later, Soviet Foreign Minister Andrei Gromyko said the Soviets would accept PNEs with conditions, including an equal number of shots between East and West, and "if all the devices to be used were subject to complete internal and external examinations." Nordyke suggests that the Soviet proposal may have been in response to Teller's congressional testimony nine months earlier when he stated,[39] "In order to have an effective international inspection [of peaceful nuclear explosions], it is necessary not only to have the explosion inspected, but to open up the explosive, look into it, and see that it is an ordinary type of nuclear explosive. This could be done, but it certainly would give away a lot of information which at present is kept very closely guarded."

The Soviets laid down some hardline conditions, and the U.S. was concerned that some of them might give the Soviets veto power over Western PNE projects. However, eventually the U.S. an-

* Rabi's statement is derived from Isaiah 2:4.

nounced* to the U.N. that "agreement in principle has been reached that nuclear explosions for peaceful purposes will be allowed… under carefully prescribed conditions under international observation." As we now know, the proposals for PNE accommodations in a CTBT per se went nowhere. The Peaceful Nuclear Explosions Treaty (PNET) was signed in 1976, setting rules as to how PNEs would be conducted and monitored. This is discussed later. The Threshold Test Ban Treaty (TTBT) and the PNET were ratified in December 1990 with improved protocols, but because of the test moratorium begun in 1992, which is still in effect, they were never implemented.

CTBT discussions continued through the Eisenhower administration and into the Kennedy administration with little closure on anything. After the Soviets broke the moratorium in September 1961, all progress toward a CTBT stopped.

Seaborg writes about his efforts[40] to save Plowshare. During the test ban discussions, he consulted with Foster and others at the Laboratory to recommend safeguards that would go into a treaty that would allow peaceful explosions to continue. The safeguards would go into a treaty annex and would include: (1) No diagnostics on Plowshare shots†; and (2) A nation sponsoring a PNE would need to make explosion debris available to other permanent members of the international commission.‡

Seaborg noted that the issue of how to include PNEs in a CTBT remained an active subject of debate when he published his book in 1981. The exclusion of PNEs from a CTBT dropped off the table completely when the CTBT was signed by President Clinton in 1996 (but never ratified by the Senate). The trilateral Geneva Conference (Conference on the Discontinuance of Nuclear Testing) formally adjourned in January 1962, and two months later, on March 14, the task of negotiating a nuclear test ban treaty was turned over to a new multilateral disarmament forum under a United Nations mandate, the Eighteen Nation Disarmament Committee (ENDC).§ It comprised

* Nordyke cites a statement by the U.S. representative, Henry Cabot Lodge, to the Fits Committee of the General Assembly on October 1, 1959.

† To prevent gaining any technical information on the physics of the explosion.

‡ As a means of determining that the nuclear detonation was an accepted standard detonation and not a new type of device that could further a country's military applications of nuclear weapons.

§ The ENDC became the Conference on Disarmament in August 1969.

On March 23, 1962, President John Kennedy visited the laboratory directors in Berkeley. From left to right: Norris Bradbury (LANL director), John Foster (Lawrence Radiation Laboratory–Livermore director), Edwin McMillan (Lawrence Radiation Laboratory director), Glenn Seaborg (AEC chair), President Kennedy, Edward Teller, Robert McNamera (secretary of defense), and Harold Brown, (former LRL, Livermore director).

members from Western and Soviet bloc states.. While the East and West were unsuccessful in their attempt to come to an agreement on a CTBT, the negotiations did lead to a limited nuclear test ban that prohibits nuclear weapons tests "or any other nuclear explosion" in the atmosphere, in outer space, and underwater. On September 24, 1963, the U.S. Senate consented to ratification, and Kennedy ratified the LTBT on October 7, 1963.

In early 1969, the Soviets proposed technical exchanges with the U.S. in which both sides would discuss the progress each country had made with PNEs. The U.S. accepted and in April, the first meeting was held.[41] Among the LLNL scientists participating were Roger Batzel (then associate director for Chemistry and Biomedical Research), Glenn Werth, the associate director for Plowshare, and Fred Holzer, deputy K Division leader. LLNL presented the results from their Gasbuggy experiment, which involved using a nuclear explosive to fracture an underground gas reservoir so it would produce gas at a higher rate. The Soviets presented features of a water storage reservoir that was formed by a nuclear crater. LLNL geophysicist Robert Schock, who was K Division leader in the 1970s, says "Plowshare had two parts. There was a civil engineering component—using nuclear explosives to make canals, dams, and such, and an energy component—using nuclear explosives to stimulate natural gas reservoirs, process underground oil shale into oil, and so on."[42]

Timeline for events in the 1970s and 1980s.

Mar 1970	Nonproliferation Treaty (NPT) enters into force, prohibiting nuclear weapon states from transferring nuclear weapons, other nuclear explosives or nuclear weapon technology to non-nuclear weapon states. Non-nuclear weapon states must not acquire nuclear weapons or other nuclear explosive devices in exchange for help with acquiring nuclear energy for peaceful purposes.
June 1971	U.C. Regents divide Lawrence Radiation Laboratory into Lawrence Berkeley Laboratory and Lawrence Livermore Laboratory and end administrative ties between the two laboratories.
Dec. 1971	Roger Batzel becomes the Laboratory's sixth director.
May 1972	U.S. and Soviet Union sign the Strategic Arms Limitation Talks I (SALT I) Treaty, limiting arms and anti-ballistic missiles. In November, they begin SALT II negotiations.
Summer 1972	LLNL's laser inertial confinement fusion (ICF) program begins.
May 1973	Rio Blanco, the last U.S. peaceful nuclear explosion experiment, is conducted to explore gas stimulation.
May 1974	India conducts its first nuclear test (10–15 kt) underground at Pokhran in the Rajasthan Desert.
July 1974	The Threshold Test Ban Treaty (TTBT) is signed, limiting the yield of underground military explosions to 150 kt.
Jan. 1975	AEC splits into the Nuclear Regulatory Commission (NRC) and the Energy Research and Development Administration (ERDA).
May 1976	Peaceful Nuclear Explosions Treaty (PNET) is signed, limiting underground explosions for peaceful purposes to 150 kt, the same as for the TTBT. The treaty enters into force in December 1990.
Oct. 1977	ERDA becomes part of the newly formed Department of Energy.
Fall 1977	The 20-beam Shiva laser is completed at LLNL; it is the world's highest energy laser.
June 1979	Soviet Union and U.S. sign the SALT II treaty. In December, the Soviets invade Afghanistan and the U.S. Senate removes SALT II from consideration.
Dec. 1979	Congress changes the weapon laboratory names to Lawrence Livermore National Laboratory, and Los Alamos National Scientific Laboratory, ("Scientific" is generally omitted).
Feb. 1980	Group of Scientific Experts to the Conference on Disarmament convenes.
Oct. 1980	China conducts the world's last atmospheric test.
Mar. 1983	President Reagan launches the Strategic Defense Initiative (SDI) and seeks to negotiate additional verification protocols to the TTBT and the PNET.

Timeline for events in the 1970s and 1980s (cont.)

Feb. 1985	LLNL's Nova laser, now the world's highest-energy laser, conducts its first experiments.
July 1985	Gorbachev declares a nuclear test moratorium until December.
Jan 1986	Gorbachev extends the Soviet moratorium for three months.
Mar. 1986	Reagan proposes using the hydrodynamic yield measurement method, CORRTEX, for onsite monitoring to strengthen verification for the TTBT and PNET.
May 1986	Following the Chernobyl accident, Gorbachev extends the Soviet testing moratorium through August 6, and later extends it further until the end of 1986.
Feb. 1987	Soviet Union resumes nuclear testing.
Dec. 1987	U.S. and the Soviet Union sign the Intermediate Range Nuclear Forces Treaty, which eliminates all nuclear and conventional missiles (and launchers) with ranges of 500–1,000 km (short range) and 1,000–5,500 km (intermediate range).
April 1988	John Nuckolls becomes the Laboratory's seventh director.
Aug–Sept 1988	U.S. and Soviet Union conduct the Joint Verification Experiment (JVE) to develop confidence in the verification system.

Livermore Director Mike May with then California governor Ronald Reagan in 1967.

The 1970s

In July 1971, the AEC asked LLNL, "What would the Laboratory do in case of a complete test ban?" At the time, non-nuclear programs amounted to 25 percent of the Laboratory's work. Michael (Mike) May, who became the Laboratory director in 1965, responded to the AEC by saying that the focus of the Laboratory's work would shift from development/weaponization to maintenance. Work on materials and seismic research would increase while work in modifying existing nuclear weapon designs would greatly decrease, and Laboratory scientists would need to carefully shift their work through the use of the best calculational and computational methods. Nuclear design work would diminish once researchers examined and understood past experimental data, and it would be difficult to retain people with the necessary expertise. The test program would decrease, although some work could be done on readiness activities and some on laser-induced implosions (see sidebar). Much of the supporting research in physics, computers, chemistry, and engineering would continue. New programs such as atmospheric modeling of hazardous plumes and pollution modeling could help the Laboratory maintain its expertise.[43]

The LLNL archives contain many classified memos that Laboratory physicist Warren Heckrotte wrote to AEC headquarters when he was on assignment as the AEC representative to the Conference on Disarmament (CD) in 1972. Included in these memos, he mentioned the many pressures that various states in the CD raised for a CTBT. When LANL scientist Jim McNalley succeeded Heckrotte as AEC representative, McNalley continued to write memos to the AEC.

On November 13, 1972, Heckrotte wrote a memo in response to questions raised by Donald Cotter, who was special assistant for nuclear policy to Secretary of Defense James Schlesinger.* Cotter sought Laboratory responses on critical issues of a CTBT in order to prepare an official position on it. Included in his response, Heckrotte said that: (1) Strategic and tactical systems would remain as central features of military posture and security, and we need to be wary of those with similar capabilities who hold different values than our own. (2) These military systems are of great technical complexity. A CTBT

* From October 1973 to March 1978, Cotter was the assistant to the Secretary of Defense (Atomic Energy), and he was on the Military Liaison Committee to the AEC.

Livermore Director Roger Batzel and physicist Edward Teller greet former U.S. vice president Nelson A. Rockefeller on the vice president's visit to the Laboratory in March 1977.

would impact the ability to maintain the reliability of these systems and deal with unknown developments. (3) The proponents of a CTBT argue that testing matters little in terms of technical capabilities that are already sufficient to do enough damage, and any reduced technical capability will make the world safer. Heckrotte countered that better technical surety and capability would lessen the prospects for nuclear weapon use. He said that proponents argue that if a serious problem arises with a system, a "crash" program could resolve it; however, it is far better to have an orderly and non-traumatic response to issues that might arise.

On November 30, 1973, a CTBT workshop was held to address test requirements for new systems and stockpile problems.[44] A summary statement of the report from the workshop says, "The importance of testing at various yields is illustrated by a review of U.S. military systems both current and projected." Much of the information in that report was included in a report that former LLNL associate director for Nuclear Design Jack Rosengren[45] wrote addressing stockpile issues and the role of testing for the AEC. Laboratory physicists George Miller, Paul Brown, and Carol Alonso updated Rosengren's information and expanded upon it in both classified and unclassified

Laser Experiments Step Up to Support the End of Nuclear Testing

Shortly after Theodore Maiman at Hughes Research Laboratories invented the ruby laser in 1960, a group of Laboratory scientists including Stirling Colgate, Ray Kidder, and John Nuckolls studied the possibility of using powerful, short-duration laser pulses to compress and ignite a small quantity of deuterium–tritium fusion fuel. They believed that laser-driven fusion microexplosions could simulate physics processes that occur in nuclear weapons. Subsequent computer calculations showed that they could get valuable data on fusion experiments from lasers producing as little as 10 kilojoules of energy, so under Laboratory Director Roger Batzel's leadership, the Laboratory's inertial confinement fusion (ICF) program was established in 1972.

When a laser is fired in a fusion experiment, powerful pulses of light can be used to heat the outer surface of a spherical capsule containing the fusion fuel, in a process called direct-drive ignition. The outer surface of the capsule is rapidly vaporized and escapes outward, driving the inner part of capsule and the fuel in on itself, bringing the fuel's temperature to about 100 million degrees. A different process, called indirect-drive ignition, places the spherical fusion capsule inside a hollow cylindrical metal container, called a hohlraum. Lasers are directed onto the inner surface of the container through end windows and create X rays, which then strike the fusion capsule, leading to rapid vaporization and capsule compression and heating. The combination of fuel compression and temperature increase can result in fusion reactions, that under proper conditions can ignite and burn the fusion fuel, producing significantly more energy gain than used to initiate the reaction. Over the years, LLNL developed increasingly powerful and higher-energy lasers, from Janus in 1974 to Shiva in 1977 to Nova in 1984; each laser provided improved control of higher temperatures and greater compression and density of the deuterium–tritium fuel.

Data from laser experiments have continued to improve computer simulations, which in the days of nuclear testing, were critical in evaluating weapon design options. When the U.S. stopped underground nuclear testing in 1992 and signed the Comprehensive Test Ban Treaty (CTBT) in 1996, reliance on laser experiments and other so-called above-ground test capabilities to maintain U.S. nuclear competence increased. A year later, construction began on LLNL's National Ignition Facility (NIF). NIF was to serve as the flagship experimental capability for the newly created stockpile stewardship program to help ensure that the nation's nuclear weapons stockpile remained safe and effective without a need for full-scale nuclear tests.

In 2009, NIF became operational. NIF's 192 laser beams focus more than 1.8 million joules of laser energy and 500 trillion watts of power in billionth-of-a-second pulses on indirect-drive targets, typically smaller than the size of a pencil eraser. NIF's three main missions include studying fusion ignition for energy production and for understanding nuclear weapon physics processes; high-energy-density science to explore the properties of matter at temperatures and pressures found only into the interiors of planets, stars, and nuclear weapons; and basic science experiments designed to study fundamental properties of nuclei and matter. NIF has

allowed scientists to examine the complex physics processes that occur during the detonation of a nuclear weapon. More than two decades after the U.S.'s self-imposed moratorium on nuclear testing, LLNL's lasers have continued to contribute to U.S. national security by providing confidence in our ability to annually certify that our stockpile remains safe, secure, and reliable.

Secretary of Energy Federico Pena and U.S. Representative Ellen Tauscher assist Laboratory Director Bruce Tarter in groundbreaking for the National Ignition Facility on May 29, 1997.

(Sources: *Preparing for the 21st Century: 40 Years of Excellence*, UCRL-AR-108618, pp. 64–65; *How Do Lasers Work?*, LLNL-BR-611652; "Stockpile Stewardship and Beyond," *Science and Technology Review*, December, 2002, pp. 4–13; "Adapting to a Changing Weapons Program," *Science and Technology Review*, January/February, 2001, pp. 18–20.)

reports that the three authors wrote for the U.S. Congress.[46]

On January 15, 1974, DARPA sponsored a three-day workshop at the Laboratory that was timely to finalize the TTBT in July of that year, but focused on technical issues of a CTB. Discussions involved stockpile maintenance and how evasive testing by the Soviets could lead to destabilizing asymmetry. Participants also discussed how a CTB would decrease U.S. capability to develop new warheads, while Soviet evasion would allow them to make advances in this area. The workshop included discussions on evasion technology, and the group recommended more testing of decoupling schemes. Ernie Martinelli of R&D Associates wrote a report[47] on the workshop, saying that on many of the subjects, the workshop did not provide any new insights or positions. However, there were new insights on the importance of low-yield testing, and the need for a research program to provide for a basis for testing under a threshold test ban. Participants presented arguments on how a threshold test ban would allow for certain maintenance capability and new advances to be made. The AEC weapon laboratories, including LLNL, provided arguments that helped form the basis of the conclusions drawn at the meeting.

Laboratory scientists participated in another CTB workshop that DARPA held in March 1974. A report[48] was issued, and an appendix to that report includes a presentation by Laboratory researchers Peter Moulthrop, Joe Landauer, and Larry Germain on nuclear weapons under a CTBT. Moulthrop played a major leadership role in furthering scientific advances. Another appendix includes a presentation by Rodean, Heckrotte, and Nordyke* on Soviet PNEs and seismology in the context of CTB evasion. The researchers' arguments reflected the viewpoint widely held within the Laboratory well into the 1980s. Related to the Rodean, et al., paper was another paper[49] by Nordyke, Heckrotte, Harry Hicks, Landauer, Moulthrop, Rodean, Larry Schwartz, and Howard Tewes titled, "PNE Verification Procedures and Evasion Possibilities." This paper was written after the TTBT had been signed and before the PNET was negotiated. The report addressed PNE-related evasions that the Soviets could perform and essentially indicated what should be included in the PNET. The CTBT, TTBT, and PNET considerations were consistently

* Also reported in LLNL Technical Report COPK 74-1, January 2, 1975.

intertwined, as evidenced by such activities.

Roy Woodruff, a rising star at the Laboratory during that time, wrote a report[50] in April 1977 titled "Some Thoughts on the Verification of a CTBT." At the time, Woodruff was the leader of L Division and responsible for the prompt diagnostics used to collect data from nuclear tests.* In 1978, he became the leader of A Division, and eventually he led the Laboratory's Weapons Program (Defense Systems). In his report, he mentioned a seminar that Treaty Verification Program Leader Nordyke hosted on March 23, 1977. The seminar focused on LLNL's research on CTBT verification and addressed R&D on conventional verification schemes (i.e., seismic) as well as new ideas such as ionosonde detection. Woodruff felt the Laboratory needed to accelerate both areas of R&D. He commented, "Very little has been done recently to quantify what level of clandestine testing under a CTBT would impose a serious threat to national security."

Woodruff believed that the combination of larger, faster computers, and data from laser fusion facilities could allow advances in nuclear weapon design with many fewer tests, maybe even with just one test, making the problem of effective verification more difficult, and perhaps impossible. A party could test in deep space, and if only one test is necessary, this would be a serious possibility. He suggested that more effort be made into determining what advanced computers can do, and how high-energy lasers such as LLNL's Janus and Argus could be used to provide atomic physics data such as opacities.† He cautioned that if the U.S. could make such accomplishments, so could the Soviets. The issues Woodruff raised became recurring themes throughout the test ban debates of the 1980s.

On November 11, 1977, Laboratory Director Batzel issued the statement, "The Ramifications at LLNL of a Nuclear Test Ban."[51] It is not known to whom the statement was addressed, but it is an unclassified summary of remarks he may have made to Congress, or more likely to the U.C. What is noteworthy is that it is probably the most positive piece Batzel wrote regarding the ability to live with a CTBT that we have been able to locate. The statement addressed impacts on Laboratory employment. Batzel said that under a test ban, the Laboratory expected no decrease in the number of employees, and the institution would remain healthy and viable in order to pursue its national security mission. He added that many nuclear weapon design problems could be addressed without the need to test. Periodic inspections would be necessary to maintain stockpile warheads. Batzel emphasized the Laboratory's programmatic diversity and its ability to accommodate shifts through internal employee transfers; however, he said, it would be necessary to maintain the expertise and ability to resume testing should the situation call for it.

Batzel testified about a CTBT before the Subcommittee on Arms Control of the Senate Armed Services Committee (SASC) on March 26, 1979. Senator Henry Jackson asked Batzel several questions during his testimony, and Batzel responded in a letter[52] to the committee on April 4, 1979. Although we don't have the transcripts from the testimony, Batzel's written answers are illuminating with regard to his views at the time, and they represent a somewhat harder tone than is mentioned in the previous paragraph. Jackson asked Batzel about his meeting with President Carter that took place a few months before and whether Batzel's concerns about the CTBT had been alleviated since the meeting. Batzel responded that he had concerns if the CTBT would be of unlimited duration, but that a limited duration CTBT would not impact staff retention, and any problems could be addressed on resumption of testing. Regarding whether the nuclear testing budget for FY80 was adequate, Batzel replied that it was insufficient to complete weaponization requirements, address safety and security needs, and improve physics understanding. On questions regarding the overall weapon R&D level, Batzel said it was inadequate, and it was difficult to say if it was sufficient to keep up with the Soviets. He said it was important to maintain the U.S. lead in computer technology. In response to "rumblings" that the contractual arrangement with U.C. was deteriorating, Batzel expressed confidence that the arrangement was solid. Regarding questions on non-weapons R&D, Batzel assured the senator that weapons R&D was not taking a "back seat" but rather, weapons R&D remained the Laboratory's main focus, and the goal of doing non-weapons R&D was to complement the weapons work.

* Prompt diagnostics take data during the actual nuclear explosion, for example x-ray and neutron output. Delayed diagnostics are used to take data after the explosion has occurred, typically days to months afterwards to measure radioactive by-products of the explosion.

† Opacity refers to an element's transparency to x-rays as a function of x-ray energy and the element's temperature and density. Understanding opacity is an important part of the physics of nuclear weapons.

On September 26, 1978, Nuclear Design Associate Director Harry Reynolds appointed Joe Landauer as assistant associate director for arms control.* Previous to this assignment, Landauer spent two years at the Pentagon, where he was involved in arms control issues, including an assignment as a DoD adviser to the CTBT negotiations. In September 1979, Landauer wrote a letter to DOE Assistant Secretary for Defense Programs Duane Sewell† addressing Presidential Decision Directive (PDD)/NSC-50, signed by the president on August 24, 1979. The directive provided criteria to ensure that arms control proposals are fully supportive of national security. Landauer concluded that a CTBT does not meet the criteria that NSC-50 called for, and that while a CTBT might have some foreign policy benefits, it would not contribute to U.S. defense and force posture goals, and it would not contribute to stability. He added that it was the delivery systems that needed to be limited, not warheads. Criteria in NSC-50 regarding an arms control proposal included:

- Does it contribute to achieving our defense and force posture goals?

- Are its foreign policy implications constructive in terms of deterring and restraining our adversaries, supporting our allies and alliances, and furthering other foreign policy interests?

- Is its arm control rationale compelling, i.e., does it promise to limit arms competition and reduce the likelihood of conflict?

Essentially, Landauer stated that a CTBT failed to meet criteria 1 and 3, and it only partly satisfied criterion 2.

PNEs continued to be a subject of discussion up through the 1970s, albeit never as intense an item as in the earlier days of test ban discussions. In February 1977, Nordyke wrote a memorandum[53] to Batzel on PNE accommodations to a CTB. Shortly after entering office, President Carter requested a staff paper on a CTB, including a section on PNE verification. Nordyke participated in an interagency group to prepare the PNE section. Prior to that time, it had been presumed that there would be no PNE accommodation in a CTB. The paper addressed Soviet and U.S. PNE programs, possible military benefits of a PNE accommodation under a CTB, international considerations, PNE explosive development, and options for accommodating PNEs. The interagency paper assumed that the U.S. would not have an active program in the foreseeable future, while the Soviet PNE program was active, particularly their Pechora Kama Canal project (see sidebar). The paper addressed possible advantages that the Soviets would gain in new/future weapons development, stockpile reliability, weapons testing, and maintaining the weapons technology base.

The interagency group's paper concluded that a PNE accommodation would give legitimacy to PNEs and might encourage proliferation by then current hold-outs to the NPT, such as India, Israel, and South Africa. The NPT's objective was to ensure that the countries that didn't already have nuclear weapons, wouldn't acquire them. They would be encouraged to not do so in exchange for help with peaceful nuclear programs. Another objective of the NPT was to commit the five nuclear weapon states (U.S., U.K. Russia, China, and France, referred to as the P-5) to eliminate their nuclear weapons. The interagency group's paper also addressed the following:

- The risks of weapon advances inherent in developing new explosives for PNE applications.

- The inadequacy of current PNET provisions to prevent undesirable weapon-related activities.

- The nuclear explosives used, including options such as whether the explosive should be provided by the observing state party to the treaty, use of a limited set of PNE explosives registered at the time of the treaty, using warehoused explosives the design of which had been frozen in time, and implementing a cooperative program with disclosures of design information.

* Others who performed this role included Robert Barker, Joe Taylor, Paul Brown, and Ronald Ott.

† Prior to being appointed as an assistant secretary at DOE, Sewell was the deputy director at LLNL. He served as deputy to all LLNL directors from 1952 to 1993, except for the ten years he was working in the Carter administration and as a consultant.

The Pechora Kama Canal

In the 1970s, the former Soviet Union had a very active program to develop peaceful uses of nuclear explosions. One effort they considered was using nuclear explosives to divert the flow of water from the upper portion of the Pechora River in northern Russia into the basin of the Kama River, a tributary of the Volga River. From the Volga, the water would continue to the Caspian Sea. The undertaking would require a 112-km canal and a series of four dams and reservoirs. They would use nuclear excavation by detonating a series of nuclear devices underground to construct the northern 65 km of the canal. These underground detonations would lead to a series of subsidence craters that would form the canal. The Soviets estimated that they would need to detonate about 250 nuclear explosives to produce an extended subsidence crater with a cross-sectional area of about 3,000 m^2. They believed that the nuclear excavation method for constructing the canal would be three to three and a half times less expensive than it would be with conventional earthmoving methods.

After a series of small experiments, on March 23, 1971, the Soviets detonated three 15-kt underground nuclear explosives near the village of Vasyukovo in Cherdynsky District of Perm Oblast. The test, known as Taiga, produced a crater about 700 m long, 340 m wide, and 10 to 15 m deep. Although the Soviets initially reported that their experiments demonstrated that nuclear excavation in a weak, saturated alluvial medium is feasible, they decided that it was not feasible to construct an entire canal using nuclear excavation. In 1986, the Soviet government abandoned the northern river reversal plan and today, the Taiga crater serves as a recreational fishing area for nearby residents.

(Sources: *Energy & Technology Review*, September 1976, pp. 1–8; https://en.wikipedia.org/wiki/Pechora%E2%80%93Kama_Canal)

Other approaches considered including a ban on all PNE experiments, except the Pechora Kama project, and an agreement to "kick the can down the road" by having a complete ban on testing and accommodating PNEs in future discussions. Nordyke added that some high-level DOE officials such as U.S. Air Force (USAF) General Edward Giller and U.S. Army General Starbird made it clear that if a PNE accommodation were to be made, then the U.S. would have to have an active PNE program too.

Herb York's Accounting of CTBT Negotiations during 1977 to 1980

Herb York presents perhaps the best accounting of Laboratory personnel activities during the CTBT negotiations of 1977 to 1980. After serving as Laboratory director from 1952 to 1958, in 1961, York became the founding chancellor of the U.C. at San Diego, and eighteen years later, President Carter appointed him as ambassador to the CTBT negotiations, and he served from 1979 to 1980. In his book, *Making Weapons, Talking Peace: A Physicist's Journey from Hiroshima to Geneva*,[54] York captured the highlights of his illustrious career in the area of national defense. Chapter Ten summarizes his experiences as the CTBT ambassador and describes some of the Laboratory's involvement in the CTBT negotiations. The LLNL archives contain many classified cables addressing the details and speeches that took place at the negotiations; however, York's book presents a concise overview of what transpired at the negotiations, and it is worth including some excerpts here.

York notes that the CTBT trilateral (U.S., U.K., U.S.S.R.) negotiations during the Eisenhower and Kennedy administrations were in almost continuous session from October 31, 1958 to January 19, 1962. York writes,[55] "Internal disputes among the Americans studying the issues in Washington, combined with some hard-nosed attitudes on the part of the Soviets in Geneva, delayed the negotiation of a treaty." Laboratory people were involved in many of the studies and disputes that York mentions in his book.

During 1977–1980, CTBT negotiations resumed under President Carter. York notes[56] that the review, or "interagency study," led to the group's initial report, Presidential Review Memorandum-16 (PRM-

16),* which strengthened Carter's resolve to pursue a CTB. Carter directed his science adviser, Frank Press to form a White House panel of experts. Batzel and LANL Director Harold Agnew provided regular input to the panel that included Bethe, Richard Garwin, Carson Mark, Panofsky, Jack Ruina, and York. The main argument in favor of a CTBT was to prevent vertical proliferation.† The main argument against a CTBT was stockpile reliability. Laboratory directors Batzel and Agnew argued against a CTBT, saying that it would prevent the development of safer and more secure weapons, limit the tailoring of warheads to delivery systems, make it more difficult to understand weapon effects, and impact the laboratories' ability to maintain expertise.

According to York,[57] the panel of experts studied "stockpile reliability thoroughly, and except for the laboratory directors, decided that the nuclear establishment's worries were exaggerated." York writes that Agnew and Batzel, along with the staff at the laboratories and the various agencies related to the nuclear establishment, disagreed, including DOE, DoD and the Defense Nuclear Agency (DNA), and the Joint Chiefs of Staff, who went along. Secretary of Energy James Schlesinger, who previously held positions as AEC chairman, CIA director, and secretary of defense, felt a CTBT was a bad idea and arranged for Batzel and Agnew to brief President Carter. York writes that "…the direct intervention by the laboratory directors at the highest level eventually caused quite a stir in the U.C. system, a stir that persisted for many years."‡ This is something with which York had a lot of experience. As was evident in discussions Laboratory physicist Paul Brown had with York in the 1980s,[58] many professors favored a test ban and even objected to U.C. management of the nuclear laboratories. York says he personally disagreed with the laboratory directors,

* PRM-16 called for a "Special Coordination Committee to undertake a special review of the major issues involved in the termination of testing."

† Vertical proliferation refers to a country's ability to improve its nuclear weapons capabilities through a variety of means, including nuclear and non-nuclear testing and computational modeling and simulation. Horizontal proliferation refers to the transfer of nuclear weapon information from one actor (state or non-state) to another actor.

‡ Paul S. Brown participated in a number of debates with the U. C. academic community on the issue of U.C. management. His views were expressed in several publications, including, P.S. Brown, "The Relationship of the University of California and the Weapons Labs and Its Importance to National Security and Arms Control," UCRL-100549 Preprint, February 14, 1989, American Physical Society Meeting, January 14–19, San Francisco, CA; and P. S. Brown, "The Importance of UC/Weapons Labs Relationship," Physics and Society, Vol. 18, Number 2, April 1989.

but that President Carter had every right to consult with them, and that the directors had every right to express their views as they saw them. York says he had "no doubt they told the president the truth as they saw it. I cannot fault them for having done so."

According to York,[59] Agnew thought he and Batzel had persuaded Carter. However, York said that he knows for a fact that Carter wanted the Strategic Arms Limitations Talks II (SALT II) to take precedence.* Apparently, Batzel and Agnew did not persuade Carter but rather, he came to realize how strong the resistance to a CTB was. Nevertheless, trilateral negotiations on a CTB began in October 1977, and Paul Warnke was the first ambassador to the talks. Former LLNL director Harold Brown was the secretary of defense at the time and, according to York,[60] Brown supported Carter's quest for a CTB, as did Brown's appointees. In late 1978, Warnke resigned his posts as director of the ACDA and chief U.S. negotiator in several arms control forums, including the CTB talks. Retired Army general George Seignious replaced Warnke as ACDA director and in early 1979, Seignious asked York to become the chief U.S. negotiator at the CTB talks.

York describes[61] the makeup of his negotiating team as holdovers from Warnke's team, which included Jerry Johnson, who had been Warnke's deputy and was Brown's personal representative. Johnson and Brown were colleagues at LLNL dating back to the Laboratory's earliest days. Johnson had been a test director at LLNL and then became test director for the AEC in Nevada. Warren Heckrotte was also a member. Heckrotte was a student of York's at U.C. Berkeley, and he joined LLNL when York was director. Heckrotte became involved in nuclear test limitation issues and was an adviser to DOE and ACDA.

York relays that in 1986, when the U.S. team attended the Nuclear Test Experts Meetings (NTEMs) in Geneva to discuss improving the TTBT† protocols, the U.S. team's office was at the Botanique, the botanical gardens in Geneva. Below the office was a lamp shop that never seemed to have customers. There was a standing joke[62]

* The SALT process had begun in 1969. The U.S. and Soviet Union had agreed to constrain the development of anti-ballistic missiles (ABMs). The treaty also limited each country to two strategic defensive ballistic missile sites (this was eventually reduced to one site for each country). The ABM Treaty was signed in 1972. The SALT II limited the number of deployed strategic nuclear weapons. The U.S. signed it in 1979, but because of Soviet aggression in Afghanistan, President Carter recommended against ratification, and it was never entered into force.

† The TTBT limited explosive yield to 150 kt.

that the Soviets owned the lamp shop and used it to spy on the U.S. negotiators through the ceiling.

In discussions with the Soviets about a Separate Verification Agreement (SVA) that would help each party feel confident that the other two countries were abiding by the CTBT, York indicates[63] that the discussions went well, and by end of 1978, he optimistically thought they could finish a treaty in six months. There was general agreement to have national seismic stations (NSSs), a provision for OSIs, a finite treaty length at the end of which a conference would be held to discuss extending the treaty, and a ban on PNEs, at least for the first duration of the treaty. When York arrived, they just needed to work out the "details." However, as they say, the devil is in the details. The two sides couldn't resolve all the issues with the NSSs, the data transmission from them, or the locations in the countries party to the treaty.

Laboratory experts attending the negotiations and those backstopping them at home provided input into the discussions. However, the U.S. and Soviet teams were unable to resolve OSI issues (in addition to the NSS issues discussed above); namely, what equipment to use, how to approve an OSI, and how many OSIs per year would be allowed. York notes[64] that there was a lot of controversy over Soviet insistence on ridiculous NSS locations in the U.K., such as Pitcairn Island, the Falkland Islands, Belize, and Hong Kong. The Soviets wanted[65] an equal number of NSSs in the U.S., U.K., and U.S.S.R. This was, of course, hardly a winning proposal for the U.K., and the historical files show some grumbling on the U.K.'s part about this.

York recalls[66] a Soviet test performed at Semipalatinsk that seemed to violate the TTBT and sour the CTB negotiations. Unfortunately, the test happened just before York made a visit to Moscow, so it did not make for a great visit. After Ronald Reagan's defeat of Carter in the presidential election, it amounted to the end of CTBT negotiations, since Reagan did not want a CTBT. However, York believed the negotiations would have failed regardless of the presidential election because: SALT II was a higher priority, there was opposition to a CTBT in Washington, there was failure to resolve the issues surrounding OSIs and NSSs, there were concerns about Soviet data encryption, the Soviets had introduced their new Tupolev TU-22M (NATO designation: Backfire) supersonic bomber, there were new Soviet troops in Cuba, the crisis at the Iran embassy occurred, the Soviets invaded Afghanistan, and U.S. restrictions on technology exports to the Soviet Union were not favorably received.[67]

York was convinced[68] that he could have pulled off a treaty were it not for external factors such as those above (in today's world, such factors would be readily identified as "deal-breakers"), but he thinks Senate ratification would have been impossible anyway. He laments the whole process of congressional approval, as evidenced over the years by events such as the Chemical Weapons Convention* (which was going on at the time York wrote his book), and approval of the League of Nations after World War I. He believed that as long as the Joint Chiefs object, the road ahead can be difficult. He did, however, feel the Soviets and their Politburo were serious about getting a CTBT[69]; it just wasn't in the cards. In this author's opinion, it seems York felt the tables were reversed from earlier CTBT negotiations in terms of the views of the respective negotiating parties. Earlier, the U.S. seemed to be more receptive to a CTBT, although there was resistance in the nuclear hierarchy. Later, it was the Soviets who were more receptive.

On October 20, 1980, Landauer attended a CTBT review meeting in Las Vegas, Nevada and described the status of permitted experiments based on the articles in the draft CTBT and U.S. statements at the NPT Review Conference. Landauer emphasized the impracticality of low-yield (less than100 lb) experiments for monitoring stockpile weapons. Instead, he proposed a definition of a nuclear test explosion that was not directly related to a threshold. This led to a lively discussion amongst the meeting participants. There was general agreement that the issue of permitted experiments had to be resolved for treaty ratification.

Toward the end of the CTB negotiations, Nordyke wrote a memorandum[70] describing the CTBT negotiations from October 23 to November 11, 1980. In it, he mentioned a discussion that he had in Geneva with Senator Charles Percy on November 11, 1980. Percy, a Republican senator from Illinois who was well known over the years as a moderate supporter of arms control, wanted to renegotiate the TTBT to a lower threshold. However, according to Nordyke, the U.S. delegation discouraged that idea and surprised Percy by urging ratification of the TTBT as is.

* The Chemical Weapons Convention was ratified by the U.S. in 1997.

The following section describes some details on key Laboratory contributions on CTBT issues.

Warren Heckrotte

From 1958 through the 1980s, LLNL physicist Warren Heckrotte actively participated in many in arms control deliberations, in particular, on test ban matters. He was a technical adviser for many negotiations, including: the CTBT from 1958 to 1962; the Berkner Panel of Seismic Improvement in 1958, the ENDC from 1966 to 1983; the United Nations session on the NPT in 1958; the TTBT and the PNET negotiations from 1974 to 1976; and CTBT negotiations again from 1977 to 1980.

In Kennedy, Khrushchev, and the Test Ban,[71] Seaborg includes details that Heckrotte shared with him about the CTB negotiations. For example, during the November 1959 discussions regarding OSIs, seismic data, and decoupling issues at Technical Working Group II, the Soviets disagreed with the U.S. data about the large number of earthquakes expected in the USSR, and the large number of OSIs required to sort out earthquakes from possible explosions. Heckrotte told Seaborg that the findings of the DoD Project Vela in 1962 showed that the Soviets may have been more correct on this issue than the U.S. scientists.[72] Heckrotte once asked a U.K. representative how many OSIs per year the U.K. would like to see.[73] The U.K. representative replied three to fifteen; the U.S. wanted twenty. Heckrotte surmised that the U.K.'s number of three may have explained the Soviet's eventual suggestion of two or three OSIs.

On June 12, 1980, while Heckrotte was the AEC representative to the CTB negotiations, he sent a communication to Seaborg providing highlights on some of his interactions. On Senator Hubert Humphrey, he said:[74]

> *"The Senator visited the U.S. delegation during the summer of 1961……He spoke strongly in favor of a CTB and was strongly critical of its principal opponents, whom he identified as the AEC, the Defense Department, certain scientists, generals, etc. He evidently felt that I, as the AEC representative on the delegation, deserved all the criticism—it was heaped on me at length, with an occasional request to explain this or justify that. It was a harrowing experience for me! Afterwards, Charlie Stelle (Ambassador Dean's deputy) suggested that the senator and I chat privately in Charlie's office. We did, and the senator was another person—quiet, thoughtful, and not at all dogmatic."*

Laboratory physicist Warren Heckrotte served as a technical adviser in arms control deliberations from 1958 through the 1980s. Committees on which he served included negotiations for the Comprehensive Test Ban Treaty, the Eighteen Nation Disarmament Committee, the Nonproliferation Treaty, the Threshold Test Ban Treaty, and the Peaceful Nuclear Explosions Treaty.

Even when the negotiations weren't formally in session, Heckrotte indicated that they could continue during informal settings, such as at a luncheon in Geneva about which he relayed to Seaborg:

> *"[I] was seated between Sir Michael Wright (the head of the British delegation) and Senator Hickenlooper. Sir Michael spent most of the luncheon pleading with the senator that the U.S. should not resume testing. The British were very concerned that we meant to do so."*

On August 28, 1961, Ambassador Arthur Dean presented a U.S. proposal to the Soviets in which the U.S. would make concessions and suggest convening a panel six months before the end of the three-year moratorium to recommend improvements to the control system and to consider a reduced threshold or the elimination of tests altogether. The Soviets balked and said a test ban could only be considered in context of complete disarmament. Heckrotte notes in his June 1980 communication to Seaborg[75]:

"We on the U.S. delegation assumed (correctly!) that Tsarapkin had returned with a message. Our speculations on what it might be ran the gamut of positive and negative moves. None of us guessed right."

Seaborg notes that Ambassador Dean could often be "vague" in his statements, particularly about the OSIs. Heckrotte wrote:

"Most of us on the Geneva delegation felt that, irrespective about what [Ambassador] Dean thought he said, [Deputy Foreign Minister] Kutnetzsov's report was a correct appraisal of what he thought he had been told."

In a 1989 communication to Seaborg, Heckrotte said[76]:

"In July, the U.K. pressed for an August recess. The Soviets indicated a readiness to recess if we proposed it—their typical approach. I recall Charlie Stelle saying he felt instinctively that a recess could be a mistake. Since he couldn't identify the reasons for his misgivings; however, we sent a message to Washington asking authorization to propose the August recess. And the message came back: stay in session. Charlie's instincts were right, as were also Washington's. If we had recessed, the course the Soviets had chosen would have been a little less awkward for them."

In his book, Seaborg relays this insight from Heckrotte regarding the Soviets breaking the testing moratorium in 1961[77]:

"From his vantage point as a member of the U.S. test ban negotiating team in Geneva, Warren Heckrotte offers another possible explanation. Referring to President Eisenhower's announcement, following the end of Technical Working Group II, that the United States would no longer be bound by its voluntary test moratorium when it expired on December 31, 1958, Heckrotte states that this was interpreted by the Soviets as seeming to indicate that the U.S. intended to resume testing. Heckrotte said, 'I've wondered if this event did not give impetus to the Soviet decision to begin preparations for their extensive test series.'"

In May 1961, Heckrotte and another AEC representative to the negotiations, Wilmot Hess, wrote a letter[78] to Dr. D.G. English, who was the special assistant to the general manager of the AEC, addressing Ambassador Dean's concern about the AEC's state of readiness to resume nuclear tests, including a full development test, seismic research, and stockpile confidence tests. Heckrotte and Hess questioned why it would take as long as a year to do a "significant" full development test. These issues were of vital concern in view of the fact that the Soviets broke the test moratorium less than four months later.

During the 1977–1980 CTBT negotiations, there was concern that the Soviets would not comply with the TTBT, and Heckrotte discussed with the Soviets how the U.S. could become confident in Soviet yields. The Soviets responded that if the U.S. would ratify the TTBT, the U.S. would have access to the data exchanges that would clarify any alleged Soviet violations of the 150 kt threshold. Heckrotte became instrumental in Laboratory studies of seismic data showing that it could not be proven if the Soviets were cheating on the TTBT, and that they were observing a yield limit consistent with TTBT compliance.

In May 1983, Heckrotte discussed the difficulties in negotiating the CTBT with the Soviets.[79] He said, "The perspectives and concerns with which Soviet and U.S. negotiators approach nuclear testing negotiations may contrast sharply but are not necessarily irreconcilable." He said that during the 1977–1980 CTBT negotiations, PNEs dominated the early stages of the talks. The Soviets wanted to accommodate PNEs in any CTBT. The U.S. took a different view. The Soviets finally acceded to a moratorium on PNEs for the duration of any CTBT. The

Soviets also favored "voluntary" inspections, while the U.S. wanted mandatory inspections. Eventually, the U.S. conceded to voluntary OSIs, with the hope that they could serve as a deterrent to cheating.

In *Making Weapons, Talking Peace: a Physicist's Odyssey from Hiroshima to Geneva*, York said of Heckrotte,[80] "All told, Warren has had more experience on negotiating teams than anyone else I know. He favored nuclear arms control in general but had some reservations about the practicality of a comprehensive ban on testing."

John S. (Johnny) Foster, Jr.

John S. (Johnny) Foster, Jr., served as Laboratory's fourth director from 1961 to 1965. Years earlier, he was the first leader of LLNL's B Division (which conducted research on the nuclear weapon's primary stage or trigger that drives the thermonuclear secondary stage). Foster joined the U.C. Radiation Laboratory (now Lawrence Berkeley National Laboratory) as a graduate student under Ernest O. Lawrence. In 1952, he was among the first group of scientists to go to Livermore to start the Laboratory. Others in the group included Herb York, Michael May, and Edward Teller.

While serving as Laboratory director in 1963, Foster testified before the Senate Foreign Relations Committee (SFRC) during hearings on the LTBT. Senator J. William Fulbright chaired the session. Foster argued against the treaty and expressed doubt that underground tests could be successfully contained without considerable costs; he also doubted that nuclear weapon effects, important for assessing military utility of nuclear weapons, could be adequately studied. He was concerned about maintaining the readiness to resume atmospheric tests should the need arise. He argued that the development of ABMs would be better done with atmospheric tests, and that atmospheric testing would better allow the development of hardened warheads capable of penetrating through ABM defenses.

In the question and answer session, Foster expressed concerns about the Soviet's high-yield tests when they broke the moratorium in 1961, and how the secrecy in the U.S.S.R. prevented us from knowing what they were ultimately up to and whether or not asymmetries existed between them and the U.S. In response to a question from Senator Strom Thurmond about the state of U.S. weapons development, Foster indicated that the U.S. had not expended the all-out effort that the Soviets had, and it would take "a couple of years of maximum effort by this country to be able to reach the rate of operations demonstrated by the Soviets in their last test series." Senator Robert Byrd raised concerns about the dangers of fallout, and Foster downplayed them. Senator Fulbright inquired about the tests that both countries conducted, and Foster expressed concern about the great number of high-yield tests the Soviets had done vis-à-vis the lower-yield tests that the U.S. had conducted.

In response to Senator Byrd on the transferability of data between underground and atmospheric tests, Foster said that it would be difficult to extrapolate from underground tests (likely based on the limited experience with underground testing up to this point) what could be learned from atmospheric tests, and that there was no guarantee that either theory or future underground tests could enable weapon scientists to give the Senate the assurance that they could do so in the future. Foster agreed with Senator Thurmond that without atmospheric testing, the Soviet advantage in high-yield weapons and ABM capabilities would be frozen. He also agreed that it would be wise through further underground testing "to maintain a superiority over the communists."

Senator Thurmond pressed Foster on the radioactive fallout issue, and Foster replied that fallout did not pose a hazard to people's health, and that it was of "little significance compared to the major issue with which the development of warheads is attempting to deal." Foster said that he shared Thurmond's concern that the Russians might conduct clandestine tests or prepare for a tremendous series of future tests that would abrogate the LTBT.

Senator Jackson questioned Foster about safeguards. These safeguards, requested by the Joint Chiefs of Staff, would provide for: an aggressive underground test program, health maintenance for laboratory and facility workers, a readiness program to resume testing, and monitoring for Soviet clandestine activity. Foster described Laboratory activities that took place during the 1958–1961 moratorium to stay ahead of the Soviets, and agreed with Jackson that testing was necessary to prove past theoretical assumptions and findings. Foster emphasized that the weapon laboratories needed to be able to conduct the planned experiments, and the severe, non-technical limitations imposed on them should be lifted. The Senate could accommodate

the Joint Chiefs' safeguards, and the laboratories submitted estimates of what they ought to and could do but had yet to receive requests that had been generated based on recommendations from the SASC and the Preparedness Committee. These requests still needed to go through the executive branch of the government.

Senator Byrd questioned Foster further about the Joint Chiefs' safeguards, and Foster replied that the safeguards would not change his answer as to what could be done for assessing nuclear weapon effects without atmospheric tests. Foster agreed that the U.S. was taking a risk that could not be calculated with the LTBT, even with the advocated safeguards.

After his long tenure at LLNL, Foster served as DoD's DDR&E for eight years under presidents Lyndon Johnson and Richard Nixon. In 1973, he became vice president for science and technology at TRW, Inc. He continued to serve on several defense-related advisory committees and task forces for the next three decades. As of the date of this writing, Foster is still active in national security matters and visits the Laboratory frequently.

Michael May

Michael "Mike" May was the Laboratory director from 1965 to 1971, associate director at large from 1972 to 1988, and was appointed director emeritus in 1988. While he was completing his Ph.D. at U.C. Berkeley in 1952, Herb York, who was one of May's Ph.D. committee members, suggested that he come to LLNL as a nuclear weapon designer. May served as an adviser on many arms control delegations and boards, including as a technical adviser to the TTBT and SALT negotiating teams. He served on the general advisory committee to the AEC, the Secretary of Energy advisory board, and the Committee on International Security and Arms Control of the National Academy of Sciences.

Among the awards May has received are the Distinguished Public Service and Distinguished Civilian Service medals from the DoD. In 1970, he received the E.O. Lawrence Award for his work in weapons-related efforts. The award reads, "For his early and original contributions to the applications of computer techniques and theoretical calculations important to the design of nuclear weapons and for his continuing technical leadership in both the Weapons and Plowshare programs of the Atomic Energy Commission."

On May 21, 1971, May wrote a letter[81] to AEC Chairman Seaborg regarding the consequences of a CTB saying, "In summary, a ban on nuclear tests would, over any period of more than a few years, destroy our capability to know where we are and where we can go in the field of nuclear explosives. Such a ban would cause inherent conflicts between the effectiveness (in several cases, the feasibility) of future weapon systems and their reliability. It would prevent us from getting data essential to the evaluation of system survivability and would thereby particularly handicap second-strike systems." Further, he said, "There is no assurance that the handicaps I described will work in symmetric fashion against the U.S. and the Soviet Union."

The following month, on June 10, May wrote a letter to Congressman Chet Holifield in response to Holifield's comments in the April 11, 1971 Washington Post news article, "Tiniest 'A' Blast Identifiable Now." May said he agreed with Holifield's comments on identification, but there is more involved than just verification. Copies of May's classified letter to Seaborg on the consequences of a CTB, which addressed verification and other issues, had been sent to a number of people, including Senator John Pastore of the Joint Committee on Atomic Energy. May subsequently wrote an unclassified summary to distribute to a wider audience.

In his summary, May raised a number of arguments as to why a test ban posed serious limitations, arguments that subsequent Laboratory directors would raise. He argued that: (1) a CTB would handicap the design of second strike forces more than first strike forces because of the lack of information on weapon effects; (2) Nuclear weapon systems will continue to change, because of new needs, new vulnerabilities, and new technologies, thereby creating strong pressures to change existing warheads. Conflicts would arise between warhead reliability and military effectiveness that would only get worse the longer a test ban lasted; and (3) The laboratories' abilities to understand nuclear explosives would degenerate, and there would be no assurance that the impacts would be symmetrical between the U.S. and the Soviet Union, owing to a variety of factors, including different strategies, different manpower policies, different weapons systems, and different public information policies. May pointed out that the U.S. placed more emphasis on weapon sophistication and reduced payloads, while the Soviets took a high payload approach.

While he was associate director at large for the Laboratory, May

wrote an op-ed that appeared in the June 28, 1976 issue of the *Wall Street Journal*. In his article, "Do We Need a Test Ban?," May continued the theme that Batzel made in the 1970s and that Laboratory directors in the 1980s and 1990s would make. May indicated that in spite of any arguments about the verifiability of a complete test ban (by this point, the TTBT and PNET had been signed), a complete ban on testing was inadvisable for technical reasons. He argued for modifying weapons to: (1) fit into new delivery systems; (2) make weapons lighter, safer, more difficult to tamper with, and more economical; (3) study vulnerabilities to weapon effects; (4) make them more reliable; and (5) understand the science of how weapons work. He argued that testing was necessary to make even seemingly small changes in weapons.

May also argued against the idea that testing damages the environment, since by then all testing was conducted underground. Further, an end to testing would not save money because without it, the U.S. might be forced to pursue more expensive options in building and maintaining weapon systems. May believed that the arms race competition between the U.S. and the U.S.S.R. was inevitable, and that it was better to pursue limits on the numbers and destructive power of weapon systems as was being attempted in SALT. Regarding the Soviet proposal to ban weapon tests but allow PNEs, May argued that it would be impossible to verify such an agreement. He added that U.S. weapons were more sophisticated and therefore required more maintenance than Soviet systems.

May disputed the arguments that a CTBT would help prevent proliferation, indicating that potential proliferators could use the technology that was already out there. In response to calls for the U.S. to help non-proliferation efforts by ending testing, May argued that the true cause of proliferation was insecurity, and that U.S. weapons threatened no one; weapons in the hands of enemies do. He felt that the U.S. must play a leadership role in the matter of nuclear weapons control, and that the solutions would involve "new treaties, new security arrangements, new arrangements for dealing with nuclear technology." May stated, "In summary, it is difficult to see why U.S. adherence to a nuclear test ban should inhibit nuclear weapons proliferation. Whether it will reduce the threat of the U.S.–Soviet nuclear arms competition is even more questionable. Its effect will be rather to introduce uncertainties in the performance and invulnerability of nuclear forces, forces which neither side can abandon at this time of history."

On March 23, 1977, May wrote a letter to Senator Henry Jackson saying that as long as the U.S. relied on nuclear weapons, some level of testing should continue. He included the above-mentioned article he wrote for the *Wall Street Journal*. He addressed President Carter's pursuit of a CTBT by presenting several arguments: (1) The Soviet threat must be assessed, particularly in light of what might be achieved in SALT, and appropriate U.S. responses must be formulated, some of which would require nuclear testing. (2) While the U.S. and Soviet Union might set an example of restraint to dissuade other countries from acquiring nuclear weapons, the countries of gravest concern had serious security concerns, and they would unlikely be swayed by a CTBT. Better steps to control proliferation would include reinforcing alliances, non-nuclear arms shipments, security guarantees, and diplomatic good offices. Further, China was opposed to a CTB, and China poses a direct threat to several of the major potential proliferators. (3) For the past few years, the nuclear test program had been cut back, and the nuclear tests that were conducted addressed providing warheads for new systems. What was missing were the necessary tests to improve the physics understanding of warheads in general, and "Two or three years are needed to carry out certain tests which would enable them to understand better the effects of inevitable variations and deterioration in nuclear weapon systems now deployed or to be deployed." May closed his letter by stating that he believed that a CTBT was not a good course of action, but that if it were to be pursued, the arguments he had made "constitute important reasons for proceeding in a cautious and deliberate manner."

Michael May went on to join the faculty at Stanford University in 2000. He is now Professor Emeritus (Research) in the School of Engineering and a faculty member at Stanford's Center on International Security and Cooperation. May continues to actively participate in nuclear nonproliferation and disarmament issues.

Edward Teller

In 1943, theoretical physicist Edward Teller began working at LANL's Theoretical Physics Division (T Division) to research approaches

for fission weapons. In 1952, he left LANL to join the Laboratory at Livermore, which was established that year in part because he vigorously campaigned for a second nuclear weapons laboratory to compete with LANL. Teller argued that healthy competition would be good for LANL and would result in speeding up the development of thermonuclear weapons.

From 1958 to 1960, Teller served as LLNL's second director. When he stepped down, a greater portion of his time was spent vigorously opposing a CTB. Various authors, including Seaborg[82] and Greene[83] have written about Teller's views, and the LLNL archives contain many documents reporting Teller's interactions with federal agencies as well as with scientists and engineers from the nuclear weapons complex involved in CTB negotiations and deliberations. Teller was not alone in his views. In a November 4, 1956 U.C. Office of Public Information press release, E.O. Lawrence and Teller stated that:

> *"1. We have no sure methods of detecting nuclear weapon tests;*
> *2. We cannot maintain a fast-moving scientific and technical nuclear weapons program without tests;*
> *3. The radioactivity produced by the testing program is insignificant; and*
> *4. We are convinced that no matter who is elected president, tests will continue to be carried on with scrupulous regard to public health."*

Many AEC scientists and DoD staff opposed a test ban, and Teller urged Eisenhower to allow continued testing, or at least to allow testing underground. Greene writes that Eisenhower gradually marginalized the views of Teller and other CTBT opponents such as AEC Chairman Lewis Strauss. He more readily accepted the arguments of members of his PSAC; however, he maintained lingering concerns that Teller's and Strauss's arguments may have been valid.

According to Greene,[84] Teller was unsuccessful in convincing James Wadsworth, the U.S. ambassador to the 1958 Geneva Conference on the Discontinuance of Nuclear Weapon Tests, that a test ban would "injure the United States." Teller pointed to the loopholes in the Geneva system, particularly the difficulties of detecting underground, for example, by employing decoupling methods, and high-altitude tests. He also stressed the importance of testing to develop peaceful applications of nuclear explosions. Greene writes[85] that Teller was "the most visible of scientists" who believed the U.S. should develop the most powerful weapons possible with lower fallout. On August 11, 1972, Teller wrote a letter to Senator Charles Percy expressing his views that "policing such a test ban would be practically impossible." He said it would be easy for the Soviets to hide nuclear explosions in an earthquake, and he described the intense earthquake activity in the Soviet Union, particularly in the Kamchatka peninsula and the adjacent Kurile islands.

Over the years, Teller remained steadfast in his objection to nuclear test limitations. When the attempt for a CTBT failed in the early 1960s, and the U.S. pursued an LTBT, Teller opposed its ratification, arguing that atmospheric tests were necessary. According to Seaborg,[86] the basis for Teller's arguments was that "The treaty was based on prediction in a field that had repeatedly proved itself unpredictable. It would prevent the U.S. from acquiring knowledge of weapons effects needed for developing a ballistic missile defense, knowledge which Teller believed the Soviets had acquired in their 1962 tests." Seaborg describes Teller's belief that: (1) the U.S. would need to add lots of warheads to make up for quality, leading to an arms race, (2) an LTBT would not deter proliferation because underground testing would continue, (3) it would sow dissent with NATO allies because they would lack control over nuclear weapons in time of need, and (4) most weapons would release measurable radioactivity, which would severely wound Plowshare.

LLNL Director Foster agreed with Teller, while LANL Director Bradbury heartily endorsed the treaty. Harold Brown respected Teller, but he has said that he and Teller disagreed on these issues. As Seaborg states[87]: "This disagreement between the directors of Los Alamos and Livermore laboratories carried forward a long-standing difference in emphasis between the two laboratories." While LLNL adopted a harder stance than did LANL on CTB issues, we see examples over the years in which the opposite has been true, demonstrating that views change over time as technological capabilities evolve and strategic needs change.

Greene wrote[88] that Teller and Strauss provided technical advice to Congress and other high-level officials from the former Eisenhower

Edward Teller meets in the Oval Office with President Lyndon Johnson.

administration and the Kennedy administration about the inadvisability of a CTBT. Their efforts to persuade Eisenhower continued after he left office. However, Eisenhower ended up supporting Kennedy's test ban efforts, including his decision to resume testing after the moratorium. Teller also gave "alarming testimony[89] on the necessity of atmospheric testing for the development of an ABM system" to the SFRC. Greene notes that Bethe wrote to Senator Fulbright, the chairman of the SFRC, contending that while Teller was an expert on nuclear weapons, he knew little about missile defense technology and that underground testing would suffice to develop ABM warheads.

According to Greene,[90] Teller even took his case against a test ban to the popular media. He participated in a public debate with Linus Pauling, and wrote op-ed pieces for the *New York Times* on the importance of atmospheric testing for national security. He even wrote a series of essays for the *Saturday Evening Post* and *Reader's Digest*, in which he called the moratorium "idiotic," and even suggested that radioactive fallout might be slightly beneficial for humans.

Greene notes[91] that Teller and Strauss tried unsuccessfully to persuade Eisenhower that the laboratories would be unable to retain their top scientists under a test ban, and that the Soviets could test clandestinely in space. However, when Eisenhower sent his endorsement of the LTBT negotiated by the Kennedy administration to Senator Fulbright, he did acknowledge some of the concerns that Teller and Strauss had raised, saying that there were "great differences of opinion" amongst the experts on some matters. Teller and Strauss were outnumbered by many eminent scientists, some of whom were members or consultants of the PSAC, or who provided counter arguments[92] to what Teller and Strauss were saying.

Edward Teller served as director emeritus, dividing his time between LLNL and Stanford University until his death in 2003. Teller continued to advocate for technically ambitious national security programs, most notably, the DoD's Strategic Defense Initiative (SDI), known popularly as Star Wars, which Teller pressed former president Reagan to support in the 1980s. It has been argued[93] that the SDI program contributed to the fall of the Soviet Union when leaders in that country concluded that they could not compete with the U.S. in an attempt to maintain or gain military superiority in light of this program.

The 1980s

During the 1980s, public pressure for a CTBT intensified due to the emerging nuclear freeze movement, which called for an end to testing, producing, and deploying nuclear weapons. What began as a grass roots movement burgeoned into a national campaign that reached its peak during the Reagan administration. By the fall of 1982, freeze movement referenda were debated in three-quarters of the nation's congressional districts. Laboratory personnel were drawn into debates in local communities. While these debates concentrated mostly on proposals to reduce or eliminate the strategic and tactical nuclear forces of the U.S. and the Soviet Union, the issue of nuclear testing inevitably arose in the context of modernizing those forces. Laboratory scientists made the case that testing was necessary to maintain the safety and reliability of the nuclear stockpile and to meet evolving deterrence requirements. Laboratory directors testified under intense pressure before Congress, and Laboratory officials briefed U.S. government personnel and congressional staff. During most of the 1980s—from 1981 to 1987—Democrats, who were generally less supportive of nuclear weapons, controlled the House while Republicans controlled the Senate.

By 1984, the freeze movement became part of the Democratic Party's presidential campaign platform. However, Reagan, who at the time was very opposed to a freeze, won the November reelection, and so the idea of a bilateral freeze with the Soviet Union eventually fell away. That April, Batzel wrote to Senator John Warner regarding a six-month moratorium on nuclear testing that was proposed in the context of a CTBT, or as part of a general freeze on the development of new nuclear weapon systems. Batzel emphasized the need for testing to modernize the U.S. nuclear arsenal for improvements in safety, security, survivability, and effectiveness, and to maintain nuclear expertise. The need for continued testing was especially important because the Soviets had spent the previous 15 years engaged in an extensive modernization program for their nuclear arsenal. A moratorium, he argued, would create a negotiating atmosphere that would surrender the incentives needed to deal effectively with the Soviets. Batzel believed a CTBT should be considered in the total context of all U.S. arms control objectives.

Former president Ronald Reagan introduced Edward Teller to then Soviet General Secretary Mikhail Gorbachev at a Washington, DC reception.

While Reagan was opposed to a testing freeze, he also pushed for a defense against nuclear weapon attack. On March 23, 1983, President Reagan launched the SDI. As the Laboratory's associate director of nuclear design, Roy Woodruff oversaw the development of a nuclear explosion-pumped x-ray laser to be used as a defensive system for the SDI. In October, 1985, Woodruff resigned as associate director and George Miller, who at the time was the deputy associate director for Nuclear Design, assumed the associate director position. Another LLNL technology that was to be used in the SDI was Brilliant Pebbles—small, lightweight spacecraft that could stop advanced ballistic missiles by intercepting and destroying them at high speeds. Ultimately, the demise of the Soviet Union changed the geopolitical landscape, along with the impetus for an SDI.

House Joint Resolution 3 and Impacts of a CTBT

In January 1985, Congressmen Jim Leach and Edward Markey introduced House Joint Resolution 3 (JR 3) stating that the Senate and the House were resolved that the president, at the earliest possible date, seek ratification of the TTBT and the PNET, with plans to negotiate supplemental verification procedures. The resolution would also ask the president to propose to the Soviet Union that the two countries immediately resume negotiations toward a verifiable CTBT. The hearing for JR 3 took place the following year on February 26. We have been unable to determine if Laboratory personnel briefed Congress or testified at the hearing; however, Laboratory researchers were involved in JR 3-related activities, and they interacted with DOE on briefings regarding the progress of JR 3 in Congress.

The issue of JR 3 came up in a hearing on January 7, 1985, when Woodruff was called to testify before the House Armed Services Committee's (HASC's) Special Panel on Arms Control and Disarmament. Woodruff read his prepared statement, outlining the impact of the 1958–1961 test moratorium. He elaborated on the surprises and weapon design problems that the Laboratory encountered during the moratorium, the testing capabilities and difficulties in resuming tests, and the effect on the Laboratory's staffing and ability to get work done. Further, he stated that the Soviets gained considerable ground on the U.S. when they resumed testing with an extensive, well planned program that caught the U.S. by surprise. After reading his prepared statement, Woodruff answered questions about verification, including the relative ease of verifying a CTBT versus a TTBT, and he conjectured that a CTBT would be a lot harder to verify (particularly at low yields). He also addressed the possibility of evading a CTBT by testing in deep space. LANL Deputy Director Robert Thorn also testified on LANL's experiences under the moratorium.

Woodruff answered questions related to the impact that a CTBT would have on new weapons systems, responding that LLNL should have completed testing for the MX warhead* before a test ban would go into effect. He agreed with his LANL counterpart, C. Paul Robinson, that a CTBT would preclude weapon effects testing. Also, a change in the basing options of the Midgetman missile* to, for example, a road mobile system might necessitate a different warhead, and a test ban would prevent such an option.

Woodruff was asked about the effect that the lack of warhead reliability might have on the president's decision to use a particular weapon. Woodruff said that the lack of reliability could spur the production of additional weapons. He did not think a CTBT would reduce the possibility of war, and he paraphrased Winston Churchill in that it is a mistake to have disarmament prior to having peace. He added that a test ban is just one element of the problem, and that given the asymmetries between Soviet and American societies, limitations on technologies are particularly disadvantageous to the U.S. as compared to the Soviet Union. Woodruff said that his personal opinion was that it was better to pursue treaties that limited arms quantitatively rather than treaties that limited technologies and research.

On May 30, 1985, Congressman and member of the House Foreign Affairs Committee, Henry Hyde wrote to the Laboratory directors regarding JR 3. The committee had received a letter from a distinguished group of scientists† asserting that nuclear testing was unnecessary to maintain weapon reliability, and that disassembly, inspection, and non-nuclear tests were quite up to the task. The scientists further claimed that "in no case…was the discovery of a reliability problem dependent on a nuclear test, and in no case would it have been necessary to conduct a nuclear test to remedy the problem." Congressman Hyde asked the laboratory directors whether these claims were true, and whether the U.S. would have high confidence in its stockpile without nuclear testing, and to list specific consequences of maintaining an "unreliable stockpile."

In a joint response letter dated June 7, 1985, LLNL Director Batzel and LANL Director Donald Kerr wrote to Congressman Hyde that continued testing was "absolutely essential" to ensure stockpile reliability. They emphasized the complexity of weapon systems, and the need

* The MX warhead was to be fielded on the new MX or Peacekeeper missile delivery system under development by the U.S. Air Force at that time. Fifty Peacekeepers were deployed in modified Minuteman silos across southeastern Wyoming, in an area directly north of Cheyenne. Peacekeepers were operational from 1987 through 2005.

* The Midgetman missile, also known as the Small ICBM, was an Air Force program to deploy a road-mobile ICBM system that would be more survivable to attack than fixed, silo-based ICBMs. Midgetman was canceled in 1992 after the end of the Cold War.

† Hans Bethe, Norris Bradbury, Richard Garwin, Spurgeon Keeny, Wolfgang Panofsky, George Rathjens, Herbert Scoville, and Paul Warnke.

for testing to maintain skilled people who can verify their ideas experimentally. They said we must modernize weapon systems in order to counter advances that the Soviets had made over the years. Regarding maintaining reliability via disassembly and non-nuclear testing of components, Batzel and Kerr said that while such approaches were useful, "the most serious stockpile problems are only revealed and solved by nuclear tests." They addressed the difficulties of ensuring the reliability and effectiveness of remanufactured weapons without nuclear tests to certify that changes in materials and workmanship quality had not had adverse impacts. It was their belief that the U.S. could not maintain high confidence in its stockpile without nuclear testing.

As for the consequences of maintaining an "unreliable stockpile," Batzel and Kerr noted the asymmetries in openness between the U.S. and Soviet societies, which "would be a prescription for political instability, and possibly, disaster." They said that verification of a CTBT was not sufficient to prevent the Soviets from cheating on the treaty, leading to further instabilities. They summed up by saying that a CTBT is an incomplete form of arms control, and that it would limit only one part of the equation, while missing out on controlling Soviet progress in increased missile accuracy, expanding anti-submarine capability, improving air defenses, and expanding ABM capabilities.

A month later, on July 30, 1985, the Soviets announced a nuclear test moratorium. On September 18, Batzel testified before the Subcommittee on Arms Control and Disarmament of the HASC. He addressed the difficulties of identifying seismic events as nuclear explosions, the need for an in-country seismic network, evasion methods such as detonating explosions in cavities or during an earthquake, false alarms from chemical explosions, and evasion by testing in deep space. Batzel discussed the promise of high-frequency, seismic signal detection in reducing the uncertainties from certain evasion scenarios, and the role of an OSI. He talked about the Laboratory's readiness efforts to mitigate the effects of a CTBT—efforts aimed at improved understanding of the physics of current nuclear designs, improved computational modeling, and improved experimental capabilities, such as hydrodynamic and laser facilities. Batzel closed his testimony by warning of the disadvantages of a moratorium based on past U.S. experiences with the 1958–1962 moratorium, and he downplayed the purported benefits of a CTBT for nuclear nonproliferation.

House Resolution 12— The Mutual Warhead Testing Moratorium Act

On January 6, 1987, Congresswoman Pat Schroeder introduced House Resolution 12 (H.R. 12)—the Mutual Warhead Testing Moratorium Act. This act called for the president to stop testing warheads and negotiate a CTBT with the Soviets, starting with a mutual, one-year verifiable moratorium on testing. The act provided that there be reciprocal in-country monitoring arrangements. Simultaneously in the U.S. Senate, Senators Mark Hatfield and Edward Kennedy introduced the Underground Nuclear Explosions Control Act.* Batzel testified on nuclear test limitations before the SFRC on January 15, 1987. Batzel emphasized the complexity of nuclear weapons, and he detailed the need to test for maintaining reliability, modernizing weapons, studying nuclear effects, and enhancing the safety, security, and effectiveness of nuclear weapons.

Batzel addressed the TTBT saying that we could meet current military requirements and do necessary weapon physics research within the 150 kt upper limit allowed by the TTBT, and he mentioned the advantages the Soviets would have in being able to test at higher yields if the 150 kt limit were to be lifted. He went on to say, "Based on our own assessment of the relationship between yields and seismic magnitudes for the Soviet test sites and the patterns of Soviet testing, we have concluded that the Soviets appear to be observing some yield limit. Livermore's best estimate of this yield limit, based on a probabilistic assessment, is that it is consistent with TTBT compliance." He then addressed the advantage of improved TTBT verification measures that were then being pursued with the Soviets. Batzel concluded by saying that "a nuclear test ban, or more restrictive test limitations, should only be considered in the context of an integrated and comprehensive approach to arms control." Independent of all the congressional action at the time, in 1986, the Reagan administration and the Soviet Union began negotiations and joint verification experimental activities for the TTBT and PNET. The TTBT and PNET were later ratified in December 1990.

* This act would have prevented the obligation of funds, during a two-year period beginning 180 days after enactment of this Act, for the conducting of an underground nuclear explosion: (1) with a yield greater than 1 kt, except for two test explosions, each with a yield not exceeding 15 kt; (2) at a location that is not part of a single designated test area; and (3) unless a public announcement has been made at least 30 days before the date of the explosion.

Ray Kidder's Proposal for a High-Energy-Density Experimental Facility

On February 3, 1987, LLNL scientist Ray Kidder sent a letter to Congressman Markey proposing building a high-energy-density experimental facility (HEDEF).* Kidder had early experience in nuclear weapon design computations, and he was the first leader of the laser fusion (ICF) program at the Laboratory. In a testimony[94] to the DOE Defense Nuclear Facilities Panel of the HASC, he spoke again on building an HEDEF. The facility would allow experimental explosions up to yields of 1 kt in a reusable, underground, instrumented chamber. Kidder argued[95] that such a facility would "engage the interest, challenge the talents, and maintain the skills of nuclear weapon designers and nuclear weapon test personnel." In his writings, Kidder referred to Soviet facilities that appeared to be designed for similar, low-yield experiments. A news article[96] in *Scientific American* mentioned an HEDEF and cites Kidder as saying that such a facility could accommodate up to 40 blasts a year, each with a yield of 300 tons. He also presented his views in an independent proposal when he testified[97] before a subcommittee of the Supreme Soviet, and he published[98] his views in *Arms Control Today*.

On February 20, 1987, LLNL's Associate Director for Defense Systems George Miller wrote to Congressman Markey saying there was no need for an HEDEF, pointing out that the decision not to fund the facility was "based on the fact that there are already-established, cheaper, and more efficient ways and means of accomplishing the same thing." The means that Miller referred to would make use of vertical holes and horizontal tunnels at the NTS. Miller also mentioned plans to pursue a future ICF facility at LLNL that would allow many valuable physics experiments for the weapons program. That facility became the National Ignition Facility (NIF), which became operational in 2009.[99]

On March 17, 1987, Kidder wrote to Congressman Markey defending his HEDEF proposal, saying that the HEDEF would provide higher quality data at higher acquisition rates than the tunnels referred to in Miller's plan, and that an HEDEF would be of more relevant and immediate utility to weapons research than an ICF facility, which wouldn't be available until far off into the future. Kidder also took issue with several other points Miller raised regarding the need to test to ensure the adequacy even of identically rebuilt warheads. The exchange between Kidder and Miller was typical of that encountered in other exchanges of the times as Laboratory scientists grappled with how best to address various test ban proposal limits. In the end, the nuclear testing moratorium that began in 1992 rendered the issue of an HEDEF versus tunnel experiments moot, and the NIF eventually became a reality, as discussed later.

* Kidder referred to his proposed facility as CONVEX; however, the facility was more commonly referred to as HEDEF.

State of California Testimonies

On February 11, 1987, California State Senator Dianne Watson, chair of the California State Senate Committee on Health and Human Services, called for a hearing on nuclear issues. Her justification for a hearing was that the U.C. managed LLNL and LANL. The hearing was co-sponsored by Assemblymen John Vasconcellos and Tom Bates. Senator Watson credited the Southern California Federation of Scientists for arranging for a number of scientists to be at the hearing. The American Federation of Scientists and most of the scientists that they had arranged to be present at the hearing were opposed to the Laboratory's stance on the CTBT, so the tone of the hearing was fairly political. In fact, the Southern California Federation of Scientists hosted a separate press conference attended by nine scientists who had consistently opposed the Laboratory's positions.

In her opening remarks, Senator Watson alluded to the long-standing debate as to whether the U.C. should be managing the nuclear weapon laboratories at Livermore and Los Alamos. Her questions included: (1) Do the laboratories support a CTBT, and if not, why not? (2) To what extent are the laboratories' arguments on CTBT verifiability based on scientific fact vis-à-vis political considerations? (3) To what extent do the laboratories attempt to influence federal policy on weapon development and testing? (4) Are the laboratories testing for reliability or are they developing new Star Wars laser technology? (5) Should the U.C. manage the weapon laboratories, and should it exercise greater oversight? (6) Should the state's environmental impact laws address the consequences of nuclear weapon development?

LANL physicist Paul White and LLNL physicist Paul Brown testified before the committee, addressing the role of testing in nuclear weapon R&D. White focused on the national policy aspects under which LLNL and LANL operated while Brown explained the importance of testing for stockpile modernization in order to maintain the global, strategic balance to enhance the safety of stockpile weapons. Brown also addressed the need for testing for weapon effects/survivability and the maintenance of scientific judgments. Brown referred to the ongoing NTEMs, (discussed later) that he had been attending in Geneva with the Soviets since July 1986.

Brown also submitted testimony prepared by LLNL scientist Jim Hannon, who addressed verification capabilities for a CTBT. Hannon's testimony cited an article[100] he wrote that was published in *Science* in 1985. Although U.S. capabilities were classified, Hannon was able to mention the monitoring capabilities estimate reported by the Group of Scientific Experts of the Conference on Disarmament. Hannon addressed the issues of discriminating explosions from earthquakes, underground evasion scenarios, the need for in-country monitoring, and the promise of high-frequency seismic signal detection. He also addressed the role of OSIs and evasion in other environments such as space and the ocean. He spoke about the possibility and technological challenges of having a low-yield TTBT and quotas of tests.

Kidder and LLNL physicist Hugh DeWitt also testified at the Sacramento hearing. DeWitt was a theoretical physicist who worked on the statistical mechanics of strongly coupled plasmas. The views of both scientists were frequently sought out by members of Congress and by anti-nuclear members of the academic community. While the Laboratory's personnel in the weapons program continued to defend the need for nuclear testing in order to accomplish its mission, Kidder and DeWitt, who both worked in LLNL's Physics Department rather than in its nuclear weapons program, disagreed and often voiced their views publicly. At the hearing, both were critical of U.C. oversight of the weapon laboratories. DeWitt was particularly critical of what he perceived was the Laboratory's role in advancing an anti-CTBT agenda. Kidder acknowledged that while U.C. management did make it possible for critics like himself to give testimony such as the one he was giving that day, it was his belief that improved U.C. oversight would control what he viewed were excesses by the laboratories in not doing what was needed to make a CTBT possible.

Over the years, DeWitt has written articles against nuclear testing. For example, in the August 1983 issue of *Physics Today*, DeWitt and Robert Barker, then assistant associate director for arms control in LLNL's weapons program,* published separate articles on the CTBT. Barker presented arguments on the need for testing, while DeWitt argued that a CTBT was vital to world security, and that the two superpowers were competing unnecessarily to achieve "an illusory nuclear superiority." He wrote that the nuclear weapon laboratories' arguments against a CTBT were largely self-serving in order to stay in business. He questioned the laboratories' claims that testing was needed to address weapon aging issues because original materials were unavailable to remanufacture weapons to their original specifications, and that the laboratories were driven by an interest in developing new, third generation weapons, such as directed energy weapons in general, and the x-ray laser in particular.

DeWitt cited the views of seismologists outside of the government (e.g., Sykes and Everden, *Scientific American*, October, 1982, p. 47), who claimed that a CTBT would indeed be verifiable based on the monitoring success for the TTBT. The authors stated that "seismological monitoring techniques have become so good in recent years that compliance with a CTBT could be effectively verified." Even with decoupling, the authors felt the largest blast that the Soviets could mask would only be two or three kilotons. The views of these external experts were in fact consistent with Laboratory seismologists who had also performed studies, and their seismic data indicated that the Soviets were complying with the TTBT. Laboratory management† backed up the seismologists with official statements and testimony, such as Batzel's testimony on January 15, 1987 discussed above.

DeWitt stated, "Technology for seismic verification of a CTBT appears to be sufficient already, and I am not convinced by the labs' arguments about the need for indefinite nuclear testing." He

* Barker went on to serve as the assistant to the secretary of defense for Nuclear, Chemical, and Biological Defense Programs [ATSD(NCB)] from 1986 to 1992.

† A separate section of this history focuses on the TTBT. Carol Alonso relayed an incident in which the energy secretary telephoned Roy Woodruff at home at 5:30 a.m. asking him how he dared to oppose administration policy on the TTBT. In an interview with the *Washington Post*, Woodruff had backed up the LLNL seismologists' conclusions that the Soviets had been observing a yield limit that was consistent with TTBT compliance. Woodruff answered that he worked for the U.C., not the DOE, and that he had every right to speak his mind on the issues. The Secretary apologized.

closed his article by recommending that Congress or some part of the government appoint a scientific committee to address how to facilitate the remanufacture of warheads in order to enter into a CTBT, that Congress examine realistically the ideas for and necessity of third generation nuclear weapons, and that it be acknowledged that verifiability of a CTBT was indeed sufficient.

DeWitt also had exchanges over the years with members of Congress or their staff. In a particularly strident letter to Congressman Markey on June 26, 1987, DeWitt responded to Markey's request asking about statements Batzel made that one-third of all modern weapon designs that were thoroughly tested before entering the stockpile had required post-deployment nuclear tests to resolve or identify problems. DeWitt claimed that he and Kidder had examined the classified data on which the statement was based and alleged that Batzel's statement was "misleading to the point of being false."

On February 26, 1987, Batzel testified before the SASC. Although the emphasis of this hearing was on the TTBT, the CTBT was also mentioned. Batzel began by saying that "there are two laboratories which have the responsibility for nuclear research and development in this country, i.e., LANL and LLNL. These laboratories have the responsibility for certifying U.S. stockpiled warheads, and the two laboratories take that responsibility seriously." Batzel elaborated on why testing was necessary, pointing out that the U.S. was already operating under the TTBT test limits and getting the job done. He addressed the uncertainties of monitoring that treaty and concluded that the Soviets were observing a yield limit that is consistent with TTBT compliance. His written testimony also included statements as to the difficulty of monitoring a CTBT.

LANL Director Siegfried Hecker spoke next, addressing the limitations that the TTBT posed on the ability to design higher-yield weapons optimized for weight, size, and use of special nuclear material. He stated that the Soviets had aggressive programs to harden and bury their prime targets, for which higher-yield weapons would have applications, and that such weapons were difficult to design under the TTBT, and would be even more difficult to design under more severe test limitations. In contrast to Batzel, Hecker was more pessimistic that the Soviets were complying with the TTBT, saying that they could gain substantial advantages by cheating on the TTBT limit. Nordyke also testified on TTBT issues at the hearing.

A de facto Debate: Reports to Congress on the Need for Testing

On March 30, 1987, Congressmen Markey, Norman Dicks, John Spratt, Les Aspin, and Dante Fascell, and Senator Kennedy wrote to LLNL Director Batzel requesting that Ray Kidder be made available to address previously published reports[101] and testimony[102] citing stockpile problems that justified nuclear testing for their resolution. In particular, the letter requested that Kidder "prepare for us a comprehensive report (in both classified and unclassified form) that addresses the issue of whether past warhead reliability problems demonstrate that nuclear explosive testing is necessary to identify or 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." Batzel responded on April 17 that he would make Kidder available to do such a study; however, he said, that while Kidder was a respected physicist with considerable experience in Laboratory programs, "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." Therefore, Batzel had asked Associate Director for Defense Systems, George Miller, to provide a separate analysis of the issues.

The two reports—Kidder's "Maintaining the U.S. Stockpile of Nuclear Weapons during a Low-Threshold or Comprehensive Test Ban,"[103] and Miller's "Report to Congress on Stockpile Reliability, Weapon Remanufacture, and the Role of Nuclear Testing"[104]—were submitted to Congress, in both unclassified and classified form. Miller's report is hereafter referred to as the MBA report, after its three authors.* The two reports did not agree on whether nuclear testing was necessary to maintain the reliability of the nuclear stockpile, or on many other aspects of the need for nuclear testing. The reports did agree on the need for a readiness program to prepare for the eventual cessation of testing, though the elements of the readiness program differed in the two reports.

* G.H. Miller, P.S. Brown, and C.T. Alonso. Much of the information about problems with specific stockpile weapons systems was derived from J.W. Rosengren's "Little-Publicized Difficulties with a Nuclear Freeze," RDA-TR-122116-001 R&D Associates, Oct 1983. Much of what Rosengren wrote was described previously in a report based on a CTBT Workshop held at Livermore on 11/30/73. This workshop is discussed earlier in this history.

A successful readiness program eventually did come together and now constitutes the stockpile stewardship program (SSP), discussed in more detail later.* The MBA report went to great length[105] to address the difficulties of remanufacturing weapon parts, which would be required in order to maintain the long-term health of the stockpile, to be identical to the originals because of "outmoded technologies, health hazards, unprofitable operations, out-of-business vendors, irreproducible materials, lack of documentation, and myriad other reasons." For years after the MBA and Kidder reports were sent to Congress, Kidder and Paul Brown participated in local debates, voicing the different points of view expressed in published reports. To this day, the MBA report continues to serve as a point of reference on stockpile reliability issues.

Lobbying Allegations

While the various congressional legislations to limit nuclear testing were under consideration from March to May, 1987, LLNL and LANL scientists accompanied officials from DOE and other agencies to briefings with congressmen and congressional staff on the technical aspects of nuclear testing. Included in the consideration in Congress was an amendment to substantially lower ceilings on explosive yields on U.S. nuclear tests from 150 kt to 1 kt. DOE's Arms Control Working Group coordinated the briefings. A number of staff from the national laboratories traveled to Washington on assignments to assist in the preparation and to participate in these deliberations. Allegations were raised of illegal lobbying on the part of national laboratory personnel. A subsequent General Accounting Office (GAO, now called the Government Accountability Office) audit[106] concluded that the DOE briefings did not violate applicable law, but recommended that DOE implement regulations and additional guidance to make such use of national laboratory personnel more consistent with existing White House Office of Management and Budget (OMB) guidelines.

* In 1993, Clinton issued PDD/NSC-15, directing implementation of U.S. policy on the stewardship of the U.S. weapons stockpile under an extended moratorium and a CTB. A year later, Public Law 103–106 formally established the SSP. In August, 1995, Clinton announced his decision for a zero yield CTBT, with the condition that safeguards for a strong SSP be in place. Since it has been in place, the SSP has successfully utilized NIF's high-energy-density physics experiments, ASC's advanced computational modeling, and weapons-related research from other Laboratory facilities to enable the laboratory directors each year to certify to the president that the weapons are safe, secure, and effective without the need to resume testing.

Various Publications

In the October 23, 1987 issue of *Science*, two separate articles discussed the CTBT. LLNL's George Miller, Paul Brown, and Milo Nordyke wrote one article[107] while Harold Feiveson, Frank von Hippel, and Christopher Paine (who was a consultant to Princeton University and to Senator Kennedy), wrote the other.[108] Feiveson, et al., argued that:

- A 1 kt threshold treaty that included a small number of tests in the 5–15 kt range would suffice to address reliability and safety issues;
- Such a treaty would be verifiable, even if a party used large cavities to decouple and thereby muffle the seismic signals from explosions, because high-frequency seismic waves could be detected using in-country seismic stations and would prove to be a boon to the ability to monitor low-amplitude signals from nuclear explosions;
- Hydrodynamic yield measurements using the CORRTEX* technique could be used to monitor the yields of the 15 kt explosions; and
- Most safety improvements could be implemented without nuclear tests.

The authors downplayed the national laboratories' claims that testing was necessary to maintain skill levels, and they criticized efforts to develop third-generation nuclear weapons,† arguing against the need for modernization in general to increase the credibility of the U.S. deterrent. A 1 kt threshold would greatly impede new weapon developments, while the limited number of 5–15 kt tests

* CORRTEX (Continuous Reflectometry for Radius versus Time Experiments) is a refined version of the SLIFER (Shorted Location Indicator by Frequency of Electrical Resonance) method of determining yields by measuring the rate of expansion of the shock wave from an underground explosion. The rate is measured by sensing the uncrushed length of a cable that is emplaced in a hole adjacent to the hole in which the explosive is buried. LLNL developed SLIFER, and LANL improved it by developing CORRTEX, using more refined electronics to measure the length of the cable.

† A third-generation nuclear weapon utilizes a design that directs most of the weapon's energy in a particular direction or form.

would allow the capability to address reliability concerns.

Science published a response[109] from Miller, et al., on the Feiveson article. The LLNL authors argued that detecting signals and identifying the signals as explosions are two different things, and the number of unidentifiable events, for example, from naturally occurring earthquakes and underground mining operations, would pose a serious problem, undermining confidence. The complexities of monitoring a multi-threshold treaty would negatively impact the level of mutual confidence that each country must have for a viable treaty. The two groups also viewed deterrence differently. Feiveson, et al., took the view that "stable deterrence" is "the inescapable, mutual vulnerability of the United States and Soviet Union to attack." In contrast, Miller, et al., saw deterrence as a dynamic condition that must respond to technological developments in order to keep the vulnerability of both sides mutual. They argued that weapon modernization allows options to reduce war to the lowest possible level, and modernization requires nuclear testing. Miller, et al., also argued that the treaty that Feiveson, et al., proposed would undermine maintenance of skill levels and scientific judgment, and that the immediate route to increased stability was through major reductions in the most destabilizing weapon systems.

In their *Science* article, "Facing Nuclear Reality," the LLNL scientists said that testing was necessary to ensure proper functioning of a warhead; enhance safety, security, and effectiveness; measure weapon effects; and avoid technological surprise. They argued that the treaty that Feiveson, et al., suggested would be very restrictive. A 1-kt yield was far too low to test the primary stage fission triggers of nuclear weapons. Such a treaty would also undermine weapon enhancements such as modernization, improved safety, security, and survivability. Weapon effects testing is key to ensuring weapon survivability to attack, and the proposed treaty would prevent the necessary testing for this purpose. One 15 kt test per year is not sufficient to do the necessary weapon effect testing, let alone satisfy the other weapon research requirements.

Miller, et al., also addressed whether current computational capabilities were up to the task of maintaining the deterrent, saying, "It is simply not possible with today's computers and computing techniques to include the full range of processes and level of detail in a simulation." The authors expressed that it was difficult to determine what the effect of the proposed treaty would be on the Soviets; however, what they did know was that the Soviet systems had more throw weight capability* than the U.S. systems, which would allow the Soviets to have warheads that were less sophisticated technologically, and thus they would potentially be easier to maintain under restrictive test limits. The authors elaborated on the verification challenges that they spelled out in their response to the Feiveson, et al., article, including challenging the yet-to-be proven adequacy of high-frequency, seismic signal detection in a treaty regime such as the one proposed.

The September 1986 issue of *Energy and Technology Review* (LLNL's unclassified research publication that in later years became *Science and Technology Review*) included an article[110] that captured the arguments Laboratory directors presented in their testimonies over the years, and that other Laboratory officials gave in their briefings. On March 3, 1988, Batzel testified[111] before the HASC, presenting a similar message as in previous testimonies. This would be the last time that he testified as Laboratory director. He expressed statements such as, "Computer calculations or alternative facilities can never replace full-scale testing," and "Deterioration of the nuclear stockpile and loss of deterrence is inevitable without testing. The disagreement is on how rapidly deterioration might take place." Two weeks later, on March 18, Batzel's successor as LLNL director, John Nuckolls, testified before the SASC. He emphasized "the importance of testing to retain and train scientists and engineers. The task of maintaining trained and experienced nuclear weapons expertise is always challenging, but—if testing constraint becomes too severe—it becomes impossible. Reliance upon nuclear systems developed under such constraints could prove disastrous." During the same period, Deputy A Division Leader Carol Alonso gave a briefing[112] to the commander in chief of the U.S. Pacific Fleet (CINCPAC) at Pearl Harbor on how a test ban would cause reductions in experienced weapon designers. She showed his staff group photos of the small number of the Lab's remaining test-experienced nuclear weapon designers and pointed out that most of them would soon be retired. The CINCPAC

* Throw weight is the capacity of missiles to carry a payload to its target. In this case, ICBMs are characterized by their ability to deliver one or more (for multiple independently targeted reentry vehicles—MIRVs) to targets at intercontinental range.

was so struck with the personnel considerations Alonso presented that he arranged for her to give the same briefing to the Joint Chiefs of Staff at the Pentagon.

Nuclear Test Experts Meetings

The ongoing test limitation discussions launched a series of interactions between scientists at the Soviet and U.S. weapons laboratories that were not directly CTBT-related but did address R&D for improved CTBT monitoring. The origin of the interactions was a desire from some DoD elements in the mid-1980s to develop higher-yield weapons capable of attacking deeply buried Soviet targets. However, such developments would likely have involved testing at yields higher than were allowed by the TTBT's 150 kt limit. Some Pentagon officials believed that if it could be proven that the Soviets were cheating on the TTBT limit, then the case could be made to get out of the treaty. Richard Perle, who was assistant secretary of defense for Nuclear Forces and Arms Control Policy in the Reagan administration, was a leading proponent of the arguments to get out of the TTBT.

Countering the argument to get out of the TTBT were two areas of Laboratory research: (1) seismic studies that scientists such as Warren Heckrotte* and Peter Moulthrop conducted showing that the Soviets were adhering to the 150 kt limit, and (2) studies by analysts such as George Smith that showed that earth penetrating weapons that would be very effective at taking out deeply buried targets could be developed under the 150 kt TTBT. Nevertheless, the Pentagon continued to push for an end to the restrictions imposed by the TTBT.

Another area of evolving Laboratory research might have influenced arguments regarding the TTBT status. Laboratory physicist Carol Alonso chaired LLNL's new Physics Experiments Advisory Panel, with the purpose of envisioning the types of experiments to be carried out in a high-energy-density Laboratory facility that would benefit nuclear weapons research and understanding. Many of these experiments have now been carried out at the NIF and at other DOE/National Nuclear Security Administration (NNSA) facilities.

* It is this author's opinion that the Reagan administration failed to make use of the talents that a long-experienced arms control expert such as Heckrotte could have brought to the table. The same can be said about other long-experienced arms control experts such as Peter Moulthrop and Milo Nordyke. These three scientists had the reputation of being honest brokers in the arms control activities with which they were involved.

In August and September, 1988, the U.S. and the Soviet Union conducted the Joint Verification Experiment to develop confidence in the verification system to monitor nuclear explosions. During the exercises, the U.S. and Soviet flags flew side-by-side at the Nevada Test Site.

In 1987, the U.S. proposed to the Soviets that the two countries discuss ways to improve the verification of the TTBT limits and surprisingly, the Soviets agreed to meet.* A series of NTEMs were held in Geneva to discuss the U.S. proposals. Former Laboratory scientist Robert Barker led the U.S. team. LLNL's Paul Brown and seismologist Jim Hannon participated. After three NTEM sessions, both sides agreed to conduct TTBT joint verification experiments (JVEs) at each other's test sites, and to negotiate improved protocols to the TTBT to allow for onsite verification measures using hydrodynamic yield measurements† in addition to seismic measures. Bill Dunlop, George Staehle, and Bill Scanlin were the key Laboratory representatives who were involved on a rotating basis in Geneva in negotiating the improved verification protocol for the TTBT. This negotiation involved the agreement to do the JVEs. The two countries agreed that the yield for the explosions at each other's site would be in the range

* The fact that the U.S. was surprised is one assessment of what happened. Paul Brown recalls a conversation that he and Laboratory seismologist Jim Hannon had with OSD representative Ed Nawrocki on a Sunday walk between NTEM sessions in Geneva. Nawrocki looked more pensive than usual. When asked what was wrong, Nawrocki replied, "The Soviets are asking too damn many questions." The Pentagon representatives had fully expected the Soviets to say "nyet" to the U.S. proposals, and seemed disappointed when they showed interest.

† Hydrodynamic yield was determined by placing sensors in the ground near the nuclear explosion to measure the shock wave emanating from the explosion, which can then be used to determine the explosive yield. The sensor used was COntinuous Reflectometry for Radius versus Time Experiments (CORRTEX).

On September 14, 1988, LLNL scientists and other U.S. personnel (white hats) witnessed the Shagan test at the Semipalatinsk test site in the Soviet Union as part of the Joint Verification Experiment.

of 100 to 150 kt. On August 17, 1988, the first-ever joint U.S.–Soviet nuclear test, called the Kearsarge Event, detonated 2,050 feet below ground at the NTS. On September 14, the Shagan test was detonated at the Semipalatinsk test site in the Soviet Union.

Improved TTBT protocols were soon negotiated between the two countries, but they were never implemented because shortly after the negotiations, the U.S. and the Soviet Union entered into a nuclear test moratorium that has remained in place ever since. However, the positive relations that the interactions engendered through the NTEM talks laid the groundwork for scientific collaborations that were to follow in the next decade or so.

William Walter, who was a graduate student at the time of the JVEs, recorded the tests seismically at the NTS and in the Soviet Union. He said that "these tests convinced everyone that the material and tectonic settling of the explosions affected the seismic signals in significant ways. For example, the U.S. test had a U.S. Geological Survey (USGS) measured seismic magnitude of 5.5 while the Soviet had a USGS measured magnitude of 6.1. This slightly more than half a unit of magnitude difference implies about a factor of 3 difference in the size of the seismic waves at long distances. Such differences matter a lot if you are trying to make inferences about the yield of an explosion from their seismic waves."[113]

Timeline for events in the 1990s.

Date	Activity
July 1991	START I treaty signed; it enters into force on December 5, 1994.
Oct. 1991	The Soviet Union declares a moratorium on nuclear testing.
Dec. 1991	Gorbachev resigns and Boris Yeltsin assumed leadership; the Soviet Union dissolves and forms into the Commonwealth of Independent States.
Feb. 1992	Lab-to-lab collaborative projects begin with Russian scientists.
April 1992	France announces nuclear test moratorium.
Sept. 1992	Senator Hatfield sponsors an amendment to the 1993 Energy and Water Appropriations Bill to have a nine-month nuclear test moratorium. The U.S. conducts its last nuclear test on September 23.
Oct. 1992	George H.W. Bush signs the Hatfield–Exon–Mitchell amendment into law, and a U.S. moratorium on nuclear testing begins.
1993	LLNL's Larry Ferderber joins Senator Reid's staff to provide technical support, including advice on the future of the NTS.
Jan. 1993	Bill Clinton succeeds Bush as U.S. president.
July 1993	Clinton extends the nuclear testing moratorium.
July 1993	Clinton issues PDD/NSC-11, directing implementation of U.S. policy on nuclear testing and a CTB. It also directs DOE to formulate a safeguard program to compensate for the effects of a CTB and protect the capability to resume testing.
July 1993	Energy Secretary Hazel O' Leary visits LLNL and addresses the staff regarding proposed changes to the Lab.
Nov. 1993	Clinton issues PDD-15, which directs implementation of U.S. policy on the stewardship of the U.S. nuclear stockpile under the conditions of a CTB.
May 1994	C. Bruce Tarter becomes LLNL's eighth director.
Feb. 1995	Galvin task force releases a report after ten months of study on redundancies at the weapon laboratories.
Aug. 1995	Clinton announces that the U.S. will pursue a zero yield CTBT.
Sept. 1995	Clinton states that a condition of acceptance of a CTBT would be safeguards for U.S. SSP and maintenance of nuclear facilities.
1995	Life extension program (LEP) begins for the Peacekeeper warhead.
1995	Stockpile Stewardship Program begins.
May 1995	China conducts a nuclear test (95 kt) at Lop Nur. It will conduct its last test (3 kt) on July 29, 1996.
Sept. 1995	France conducts a series of nuclear tests in the South Pacific. It will conduct its last test on January 27, 1996.
Sept. 1996	Clinton is the first to sign the CTBT. The other four nuclear weapons states also sign.

Timeline for events in the 1990s (cont.)

Sept. 1996	Preparatory Commission for the Comprehensive Test Ban Treaty Organization (CTBTO) is established. The CTBTO's mission is to promote the treaty and build up the verification regime's international monitoring system and the international data center.
Oct. 1996	Reis–Ryabev collaborations begin, comprising three workgroups: S&T related to nuclear weapons; safety and security of weapons; and verification and monitoring under a CTBT.
May 1997	Groundbreaking for LLNL's National Ignition Facility (NIF).
Sept. 1997	Clinton passes the CTBT to the U.S. Senate for Advice and Consent to ratify the CTBT.
May 1998	India conducts two underground nuclear tests in Pokhran on May 11 and 13.
May 1998	Pakistan conducts underground nuclear tests in Chagai on May 28 and 30.
Oct. 1999	U.S. Senate fails to ratify the CTBT in a 51 to 48 vote against the treaty.
Oct. 1999	Congress establishes the National Nuclear Security Administration, which begins operation in March 2000.

Laboratory Director John Nuckolls greets President George H.W. Bush on a visit on February 7, 1990.

The 1990s

U.S.–Soviet Laboratory-to-Laboratory Collaborations

In the aftermath of the JVEs, there was an increasing interest to form collaborations between U.S. and Soviet scientists. At a DOE Laboratory directors meeting, DOE Secretary Admiral James Watkins, and DOE's Director of the Office of Arms Control and Nonproliferation Victor Alessi, met with Nuckolls and Hecker. Former LLNL director Bruce Tarter says in his book, *The American Lab, An Insider's History of the Lawrence Livermore National Laboratory*, [114] that at one point in the session, "Apparently, Hecker said, 'Why don't we ask their [the

In February 1992, U.S. and Russian scientists visited each other's country to participate in collaborations.

Soviet's] Lab directors what they think should be done?' and the idea quickly gained favor."

In his book, *Doomed to Cooperate*,[115] Hecker paints a picture of a dynamic and challenging time when the laboratories were moving ahead with plans for cooperative programs,

> *"And concurrently, we at the nuclear weapons laboratories began joint scientific collaboration with the Russian nuclear weapons labs, which helped to build personal relationships and trust that served all U.S. government programs well over the years. The JVE in 1988 opened the doors to each other's nuclear labs and led to the lab directors exchange visits in February 1992. We at Los Alamos quickly forged ahead after Admiral Watkins' official approval for scientific collaboration following the exchange visits. By May 1992, with only general principles agreed to by DOE and the State Department,* we proceeded to get financial support, travel permissions, and definition of types and extent for the initial activities of the collaboration we called lab-to-lab."*

Bill Dunlop, who then led LLNL's Treaty Verification Program, was responsible for Laboratory planning. He wrote a report[116] that outlined ideas on how scientific collaborations between Soviet and American scientists could reduce the dangers of proliferation of knowledge and materials in the event of a breakup of the Soviet Union.† Alessi read the report and with the backing of Secretary Watkins, Dunlop was asked to arrange for an exchange of visits by the leaders of the former Soviet nuclear centers and the U.S. weapons laboratories. Although the State Department and the U.S. ambassador to Russia were skeptical about such a visit, the exchanges were approved.

In early February 1992, the first of the proposed laboratory-to-laboratory collaborations took place at LLNL and then at LANL. In late February, the U.S. team travelled to Russia. LLNL Director John Nuckolls, George Miller, associate director for nuclear weapons, and Chuck McDonald, associate director at large and former B Division leader were among the delegation. LANL Director Hecker was accompanied by John Immele, who led LANL's weapons program, and John Shaner, a physics expert who knew some of the Russian scientists.

During the exchanges, Dunlop noted[117] that the financial conditions in the closed cities of Shnezinsk (home of the All-Russian Scientific Research Institute of Technical Physics, abbreviated in Russian as VNIITF, also known by its postal code Chelyabinsk-70 or C-70) and Sarov (home of the All-Russian Scientific Research Institute of Experimental Physics, abbreviated in Russian as VNIIEF, also known as Arzamas-16, or A-16), were worse than the U.S. had imagined. Dunlop felt that both Russian nuclear weapon laboratories could gain substantial benefits from collaborations with their American counterparts. A protocol was written detailing the types of collaborations that would take place.

At the end of May, a U.S. delegation comprising Dunlop, John Holzricher, and Andre Kusabov from LLNL; Steve Younger, John Shaner, and Jim Shipley from LANL; and Tom Hunter and Paul Stokes from SNL met in Moscow with a group of experts from VNIIEF and VNIITF to develop a plan for joint U.S.–Russian projects. The U.S. and Russian scientists agreed to collaborate in a host of technical areas, including: environmental sciences, computations, nuclear power safety, energy, innovative materials development, manufacturing technologies, lasers, medical technologies, nonproliferation research, accelerator transmutation of waste, pulsed power, and basic science. A few months later, LLNL, LANL, and SNL funded the development of some projects. Dunlop, Alessi, Shaner, and others continued to plan the collaborative efforts that were funded through several U.S. agencies and carried out during the new era in U.S.–Russian relationships.

* This is footnoted in Hecker's book as follows: "The DOE's Victor Alessi and State Department's Robert Gallucci developed an informal memorandum on April 19, 1992 to provide the general guidelines to allow the scientific cooperation between Russian and U.S. nuclear weapons laboratories to begin." In a subsequent informal note, Alessi described the lab-to-lab effort in the following manner: "It had the verbal approval of the NSC staff (BGEN John Gordon and later Dan Poneman). The NSC decision was made not to make it a full interagency effort. Rather it was intended to be a low-profile endeavor with some degree — although minimum — of government oversight. To this end, an agreement on how to conduct these exchanges was reached between DOE (Alessi) and State (Gallucci). In keeping with the low-profile nature of lab-to-lab, this written agreement was not formally signed. The DOE–State agreement continues to guide lab-to-lab exchanges." These informal notes and a copy of the Alessi-Gallucci note are available at https://lab2lab.stanford.edu/sites/g/files/sbiybj8331/f/alessi_5.pdf.

† On October 5, 1991, Soviet Secretary General Gorbachev announced a nuclear testing moratorium. At the time, the Soviet Union was undergoing a process of democratization that destabilized Communist control. The U.S.–Soviet collaborations were timely for addressing the potential proliferation concerns under a Soviet breakup. On December 25, Gorbachev resigned as president, and Boris Yeltsin assumed leadership of Russia, and what was the rest of the Soviet Union became 14 other separate countries. The need for scientific collaborations became quite significant in light of these political changes.

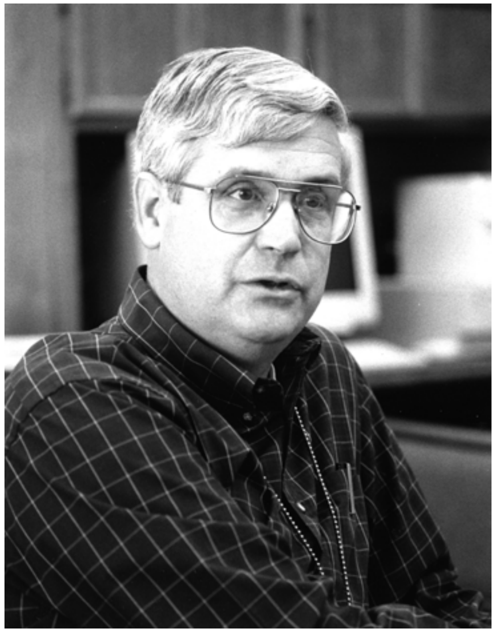
The U.S.–Russian collaborations continued through the 1990s and into the early 2000s. The collaborations provided economic relief to Russian laboratories and furthered U.S. understanding of the Russian nuclear weapons infrastructure and capabilities. The joint efforts started to become more difficult to execute once Vladimir Putin became president in 2000, and they ended in 2010.

Congressional Legislation

Congressional interest in halting nuclear testing continued into the 1990s after the fall of the Soviet Union. Testifying before Congress, Nuckolls defended the need for testing,[118] emphasizing that it was necessary to: maintain nuclear competence and ensure weapon reliability; ensure reliable, safe, secure, and survivable nuclear forces; enable the development of new warheads that might be needed, and to develop the capability to reliably disable terrorist nuclear weapons.

In March 1992, Congressman John Spratt of the HASC convened the DOE Defense Nuclear Facilities Panel to address the requirements for nuclear testing. The hearings addressed the need to test for reliability and enhance weapon safety and survivability. The panel also discussed the implications for nuclear proliferation. Miller, then LLNL's associate director for Defense Systems and Nuclear Design testified before the panel, emphasizing the need to test to upgrade weapon safety, maintain reliability, understand weapon performance, make U.S. weapons immune to terrorist threats, and to maintain nuclear weapon expertise. LLNL scientist Ray Kidder presented his view that testing was not necessary for reliability purposes, and that a modest number of tests would suffice to enhance safety to modern standards. Following the formal testimonies, a number of questions were sent to the Laboratory, and LLNL staff provided written answers.

On September 13, 1992, Senator Hatfield sponsored an amendment to the 1993 Energy and Water Appropriations Bill that called for a nine-month moratorium on nuclear weapons testing. The amendment, which was co-sponsored by Senators James Exon and George Mitchell, passed both houses of Congress by substantial margins. The amendment further restricted the number of tests to twelve between 1993 and 1996, and restricted the purposes of these tests to improve the safety and reliability of U.S. nuclear weapons. According to the legislation, on September 30, 1996, there would be a U.S. moratorium



Physicist George Miller joined the Laboratory in 1972. During the 1990s, he served as the associate director for Defense and Nuclear Technologies. He would later become LLNL director in 2006.

unless another nation conducted a nuclear test after that date. The Laboratory interacted with DOE in responding to this legislation and in helping to abide by its purposes. Most important, the amendment directed the president to pursue negotiations on a CTBT. President George H.W. Bush reluctantly signed the Hatfield–Exon–Mitchell amendment into law in October 1992, and a de facto U.S. moratorium began that matched the existing Russian moratorium. As it turned out, the moratorium continued beyond nine months and has remained in effect to this day. The last U.S. nuclear test was conducted on September 23, 1992. Russia extended their existing moratorium a month later, on October 19, and it has continued to the present.

The Clinton Administration and Birth of the Stockpile Stewardship Program

President Clinton succeeded President Bush in January 1993. That same month the Senate confirmed his choice for Secretary of Energy, Hazel O'Leary. In response to the Hatfield-Exon-Mitchell amendment, which was now law, a number of senior-level meetings were held, including an extensive classified meeting hosted by Secretary O'Leary. George Miller, then the Laboratory's associate director for

the nuclear weapons program was the lead technical briefer. Even prior to this time, the Laboratory had begun preparatory steps in 1991 to develop a strategy for the nuclear weapons program in an anticipated era of greatly reduced budgets and limited or zero nuclear testing. Deputy associate director for nuclear testing, Wayne Shotts and Miller were heavily involved in this process along with Laboratory Director Nuckoll's advisory committee, which included Condoleeza Rice, John Deutch, and Johnny Foster.

In the spring of 1993, when the Clinton administration's direction on nuclear testing became clearer, a small group including Miller, Shotts, former associate director for Military Applications, Larry Woodruff, and associate director for Computation, Bill Lokke held several meetings to lay out a tractable nuclear weapons program for the future. This group developed a letter to President Clinton that encapsulated their thoughts on this, which included acceptance of a no-testing paradigm, expectations of decreased resources, the need to capture the archival history and wisdom of nuclear weapon scientists and engineers, and the importance of laboratory-scale experiments combined with high-performance computing (HPC).

The change in administration set a new tone in pursuit of nuclear test limitations. On July 4, 1993 Clinton signed PDD/NSC-11,[119] which directed the implementation of U.S. policy on nuclear testing and a CTB. It also directed DOE to formulate a safeguard program to compensate for the effects of a CTB and protect the capability to resume nuclear testing. DoD and DOE co-chaired a task force to implement the directive. They submitted their report, "Plan for Stockpile Stewardship under a Test Ban," to the Interagency Working Group on Defense Policy and Arms Control on August 19, 1993, and it was approved by the relevant agencies two months later on October 7. According to Alonso,[120] whose informative paper sheds light on the pursuit to a zero yield CTBT, Clinton requested studies to examine what experiments should be permitted, what is required for verification, and what is required for stockpile stewardship. It is not clear if Clinton's request was part of the PDD.

In 1993, Victor (Vic) Reis became assistant secretary for Defense Programs in DOE after serving in prior roles on the National Security Council staff, as director of DARPA, and as the Director of Defense Research and Engineering. Reis provided the imagination and political acumen to guide the transition to what became known as science-based stockpile stewardship, described in greater detail below. Reis' genius lay in positing the general solution to the challenge of stockpile stewardship and then working backward with different groups to acquire their input, gain support, and develop the details of the program. His major premise was that the core of any long-term stewardship program was a set of world-class scientific and technical laboratories with expertise and activities that would ensure their continued competence in all aspects of nuclear weapons.

On November 3, 1993, Clinton issued PDD/NSC-15, which "establishes and directs the implementation of U.S. policy on the stewardship of the U.S. weapons stockpile under the conditions of an extended moratorium on U.S. nuclear testing and a comprehensive test ban." Elements of the SSP that were outlined in PDD/NSC-15 included: stockpile surveillance and evaluation; hydrodynamic testing and hydronuclear experiments (explained in more detail below); weapons physics experiments; military systems, radiation hardness and weapon effects simulation; review and analysis of historical data; numerical simulation; engineering design and development; improved characterization of nuclear and non-nuclear material properties; production capability; safeguards to ensure the nation's ability to have the technical means and knowledge to support the nuclear deterrent; and capability to resume testing via maintaining a viable infrastructure at the NTS.[121]

There is no mention in the references on PDD-11 or PDD-15 on verification requirements; PDD-11 simply directs the appropriate USG agency to formulate a monitoring package to support effective verification of a CTBT, something that the various agencies, including DOE and its laboratories, had been pursuing all along. The PDD also mentions the need to negotiate an effective verification network.

According to Alonso,[122] in 1993, Nuckolls argued for preparatory measures to be put into place in the event of a CTB. He provided input to the HASC stating: "The 1996 cessation of nuclear testing will create unprecedented challenges in trying to maintain the viability of the U.S. stockpile. An integrated safeguards package which includes significant enhancements to our computer simulation capability, to our non-nuclear hydrodynamic testing capability, and to our fusion capability—the ICF National Ignition Facility—together with experi-

ments in which some nuclear yield is generated, will provide the best mitigation measures possible."

Laboratory Studies on Permitted Experiments

DOE and its laboratories examined a variety of technical issues, ranging from the type of experiments that would be allowed under a CTBT to the requirements for monitoring such a treaty. LLNL led the way in March 1993 by writing a classified white paper on permitted experiments.[123] The report included an appendix with tables that showed what could be accomplished in terms of significant nuclear design at yields ranging from a few pounds up to several kilotons. Over the years, various condensed versions of the tables were sent to members of Congress in response to their questions that related to what could be accomplished at different yield levels. When LLNL developed the tables, LANL reviewed them and only had minor adjustments to reflect their views on what was physically possible. The paper also addressed other experiments such as ICF, weapon effects requirements, and hydronuclear experiments. It discussed various criteria for conducting experiments, e.g., yield thresholds, restriction to certain locations or facilities, use of non-fissile material, restriction to specific purposes such as safety, terrorist disablement, and industrial purposes, etc. These were a key element of the discussions leading up to Clinton's decision to pursue a "zero yield" CTBT. This was in contrast to DoD's position, which favored a low-yield treaty with a 500 ton testing limit. This is discussed in greater detail in a subsequent section on USSTRATCOM's Nuclear Weapons Symposium that took place in the summer of 1995.

While the nuclear weapons laboratories were preparing for the changes that a test ban would bring, LLNL engineer Larry Ferderber was selected in 1993 to be a technical advisor to Nevada Senator Harry Reid. Ferderber, then deputy associate director of Nuclear Test and Experimental Science, had the expertise to advise the senator on the future of the NTS (in light of the pending CTBT). Ferderber's responsibilities during this period included drafting floor statements for Senator Reid, attending staff meetings with DOE officials, and drafting letters to the president. He describes his role in these endeavors as explaining the technical issues, pros and cons, as they related to the senator's policy agenda, and then supporting the senator in executing that agenda. CTBT, stockpile stewardship, and nuclear waste issues were among the areas that Ferderber addressed.

Ferderber reported[124] that Senator Reid was concerned about the CTBT when the Clinton administration adopted it as a goal. Reid believed it made technical sense that if the U.S. had nuclear weapons, then it was necessary to test them. He supported high-quality jobs at the NTS, treaty-compliant experiments, an SSP, and a test readiness program. Reid, along with Republican Senators Jon Kyl, Thad Cochran, and Strom Thurmond, strongly supported low-yield testing. He was a leader in the fight against Senator Exon's (Hatfield–Exon–Mitchell amendment) effort to adopt a zero-yield threshold. Ferderber said that the issue of the TTBT came up before his assignment with Senator Reid, but he didn't think the senator had an issue with the TTBT or with lower thresholds; in other words, Reid felt there could be a credible deterrent at lower threshold yields in the treaty. Ferderber formally left the senator's staff in December 1995, but he continued to provide ad-hoc support to Senator Reid until his replacement, LLNL physicist and former D Division (Military Applications and Effects) Leader Robert Perret[125] arrived in Reid's office later in 1996.

Shaping DOE Secretary Hazel O'Leary's Views and Her Visit to Livermore

Early in O'Leary's term as DOE secretary, she began conducting meetings involving the Laboratory directors and Vic Reis (before he was confirmed as assistant secretary for Defense Programs). O'Leary also would invite some of the most outspoken critics of the laboratories, who were pushing for a CTB.[126] Critics such as Frank Von Hippel of Princeton University were granted a "clearance for a day" so that they could participate in classified discussions.

Von Hippel writes,[127]

> *"I had just written a paper arguing that no more tests were necessary. The indefatigable Dan Ellsberg, now a Washington, D.C.-based nuclear disarmament activist, was aware of the internal administration debate and distributed my paper to a number of high-level officials. As a result, my paper was the first argument against the tests that reached these levels in the administration, and Secretary O'Leary's staff decided*

to invite me in for two sessions during which the Secretary would be presented the arguments for and against the 15 tests. I was issued an interim "Q" clearance so that I could participate in these classified discussions.

"The arguments made for the tests turned out to be extremely weak. There were simply no "problems to be fixed." But the arguments were political as well as technical. Most ironic, perhaps, was the observation that, after all the claims that had been made by the weapons labs about the need for safety and reliability tests, the Senate might not ratify a CTB if no tests of this type were carried out. "Ultimately, Secretary O'Leary made a decision none of her predecessors had been willing to make: stop the testing despite the opposition of the weapons labs and their politically powerful supporters in Congress and the Pentagon. No decision comes without its price, however, and this same meeting produced the seeds of the very costly 'Science-based Stockpile Stewardship Program' intended to maintain the competence—and the funding levels of the labs—without nuclear testing."

George Miller would participate in these meetings as a technical briefer. In his judgement, he viewed Vic Reis as being particularly influential in shaping O'Leary's views over time, in spite of contrary views. In Reis's paper on "Stockpile Stewardship and U.S. Nuclear Weapons Policy,"[128] he provides an excerpt from a note he sent to O'Leary at her request after a two-day workshop held in June 1993:

"In the far term the role of nuclear weapons in national security has yet, to my knowledge, to be defined, but it is prudent to assume that some stockpile of safe, secure nuclear weapons will be part of any future military arsenal. Again, it is even harder to imagine that a small number of "Hatfield compliant" tests, per se could be critical in shaping the future structure of that arsenal. For this longer picture, what is of concern is the health and vitality of the weapons laboratories. After all, shaping the future is what we have them for.

In April 1997, Senator Harry Reid (front center) visited LLNL for an update on programs. From left to right: Greg Daines (staffer), Livermore Director Bruce Tarter, Ron Cochran, Larry Ferderber, George Miller, and Bruce Goodwin.

The most important measure of the state of any laboratory is the quality and quantity of technical talent of its staff. Attracting and retaining top lab talent requires challenging technical problems, stability of funding and flexibility of operations. It is clear that the original mission of the labs—designing new nuclear weapons—will be influenced by the lack of nuclear testing, but given the scale of the problem, it is hard to argue that the testing program as envisioned could seriously impact the overall talent pool at the labs. Indeed, one could make the opposing argument: the prospect of helping to define the nuclear future, and designing contingencies for that future—without nuclear tests—is a technical challenge worthy of our best minds."

Views such as this led to the formation of the "navigators" group, in which the laboratories helped create the technical substance of the

SSP. George Miller and Assistant Director for Physics and Space Sciences, Richard (Dick) Fortner, represented LLNL on this group. John Immele and John Browne represented LANL, Roger Hagengruber and Gerry Yonas represented SNL, and Steve Guidice represented DOE's Albuquerque Operations Office (ALOO). "Super navigators" included the laboratory directors. Later, Reis formed a science council for which scientists would spend six months on assignment in DC. Mike Anastasio, Bill Bookless, and Craig Wuest were part of this group.

On July 27, 1993, DOE Secretary of Energy Hazel O'Leary spoke to LLNL employees[129] and emphasized "getting ready for the future today." She was not supportive of performing additional tests prior to entering into a CTBT, saying, "surely three or six tests will not make that much difference…….. Two more years of testing wasn't going to get it for you or the nation. Getting on to the new mission does." Needless to say, the additional tests called for by the Hatfield–Mitchell–Exon amendment never took place. LLNL physicist Wayne Shotts, who earlier had led LLNL's Nuclear Chemistry Division, Prompt Diagnostics (L Division), and was the principal deputy associate director for Defense and Nuclear Technologies at the time, recalls O'Leary telling the employees in her speech that most people have six or seven job changes in their careers, implying that they should get on with it. Shotts said "You could have heard a pin drop in the auditorium."*

In 1994, DOE held a stockpile stewardship conference in Albuquerque. According to Alonso,[130] "The DP [DOE Defense Programs] laboratories' nuclear weapons experts at this meeting maintained a consistent assessment: that nuclear testing is the only real guarantee of a reliable stockpile; that science-based stockpile stewardship is plausible but not without risk; and that it is not possible to quantify the risks beyond 'gut feeling' from experienced personnel. The DP labs were in solid agreement that if the U.S. were to allow its stockpile to sit passively, it would soon become useless. Because the 'information cycle' of the very important human designer element is around ten years, and because the 'change cycle' of a stockpiled weapon is also often around ten years, they felt that science-based stockpile stewardship (i.e., without nuclear testing) is plausible. But, they pointed out, this also means that it will take 10–15 years

* Private communication with Wayne Shotts. September 13, 2018.

Laboratory Director Bruce Tarter, Secretary of Energy Hazel O'Leary, and Laser Programs Associate Director Mike Campbell tour the Nova laser facility.

to know if science-based stockpile stewardship is in fact working." Now, more than two decades after the 1994 conference, the SSP has indeed proved itself and has so far been working successfully. On May 3, 1994, LLNL's Acting Director Tarter testified[131] before the SASC, outlining the requirements for a successful SSP. He said:

> *"A science-based stockpile stewardship program requires world-class computing and experimental facilities so that nuclear weapons scientists can validate technical judgments in the absence of nuclear testing. These three elements—a highly qualified scientific and technical staff, advanced computing facilities, and world-class experimental facilities—are all essential and reinforce each other."*

Hydronuclear Experiments

During the summer of 1994, there was a debate in DOE, DoD, and Congress about the definition of a nuclear test. According to Alonso,[132] hydronuclear tests became a focal point for what might be included in permitted experiments. During the 1958–1961 moratorium, the U.S. had conducted hydronuclear experiments in which nuclear devices were tested in a weapons configuration but in a sub-critical state by reducing the amount of fissile material in the device. The degree of criticality of devices was gradually increased up toward criticality, but the devices were not allowed to produce any significant nuclear yield. The maximum yield in any of the U.S. experiments was 0.4 lb of TNT equivalent.

LLNL and LANL scientists disagreed on the utility of hydronuclears for the modern U.S. nuclear stockpile. LANL believed that hydronuclears were much more useful than did LLNL. LLNL based its assessment on the nature of modern U.S. designs, which were a lot more sophisticated than those that existed during the 1958–1961 moratorium. However, LLNL scientists acknowledged that there might be some utility of hydronuclears for exploring the physics of simpler designs. Even though Clinton's PDD/NSC-15 called for hydronuclear experiments, arguments against them, largely pushed by the Natural Resources Defense Council,* eventually prevailed. DOE Secretary O'Leary decided to oppose hydronuclears, and the JASON group† supported this decision.

In a letter[133] to the president on September 8, 1994, O'Leary wrote,

> *"I want to take this opportunity to strongly urge you to decide that the U.S. should not conduct, nor prepare to conduct, hydronuclear experiments during the existing moratorium ... It is not technically essential to conduct hydronuclear experiments at this time. The Department of Energy has determined that the existing nuclear stockpile of the United States is safe and reliable and that technical means other than hydronuclear testing can maintain the stockpile in this robust condition for the near term ... Additionally, the JASON group ... weighed the limited technical value of hydronuclear experiments against the costs, the impact of continuing an underground testing program at the NTS, and U.S. nonproliferation goals, and determined that on balance they opposed these experiments."*

The Dellums Report on the National Ignition Facility and Nonproliferation

In June 1994, Congressman Ron Dellums, then chairman of the HASC, expressed concerns about the NIF, which was then in the advanced planning stages. He requested that Secretary O'Leary resolve the question of whether NIF will "aid or hinder U.S. nonproliferation efforts before proceeding with substantial budgetary commitments to construct NIF." The previous October, O'Leary announced Key Decision 1 to build the NIF at LLNL. It is important to note the interrelationship among the SSP, NIF (which is a key component of that program), the CTBT, and U.S. nonproliferation goals.

Congressman Dellums requested that public participation be an essential part of the process and that appropriate interagency coordination be pursued as well. DOE initially held three public meetings to address the outline of the study. While the study was originally conceived as a technical analysis of the impact of the NIF on horizontal and vertical proliferation, it had an impact in addressing U.S. arms control as a key part of the process, and nonproliferation policy goals such as on CTBT negotiations and on the NPT. Laboratory nuclear chemist Carl Poppe wrote a report addressing the key issues. Laboratory scientists Paul Brown and Bill Hogan, in conjunction with Lisa Evanson of the DOE Office of Arms Control, developed and published an unclassified version for public discussion.[134] A committee of scientists reviewed the classified and unclassified versions to ensure that the two reports were consistent. The original draft of the report was released to the public in August 1995, and public meetings were held in Washington and Livermore a month later. A compendium of the public commentary was included as part of the final report published on December 19, 1995. The so-

* The Natural Resources Defense Council, a non-governmental organization, was an opponent of nuclear weapons development and testing in the U.S. and provided technical information and arguments in favor of their position.

† The JASON group is an independent, scientific advisory group that provides consulting services to the U.S. government on matters of defense science and technology.

called Dellums Report became a seminal document that has often been cited when ICF issues related to the CTBT are addressed. The report's conclusions stated:

"(1) The technical proliferation concerns at the National Ignition facility (NIF) are manageable and therefore can be made acceptable; and (2) The NIF can contribute positively to U.S. arms control and nonproliferation goals. Therefore, it is the conclusion of this study that the NIF supports the nuclear nonproliferation objectives of the United States."

The Galvin Task Force

Nuclear testing and critical peer review between LLNL and LANL have been two of the main pillars that the U.S. relied upon for decades to ensure the safety and reliability of its nuclear stockpile.* Computations and non-nuclear experiments were other mainstays, but they were not considered sufficient by themselves. Today, computations and nonnuclear experiments are more prominent than was the case 25–30 years ago. In the opinion of the author, internal peer review has also been very strong at LLNL.

From 1994 to 1995, O'Leary continued to take a strong stand against nuclear testing and even began taking steps toward cutting back the nuclear weapons work at LLNL to a token level. In the eyes of the LLNL staff and other knowledgeable experts, this would have been especially serious in light of an enduring nuclear test moratorium. Even with nuclear testing, a number of LLNL senior weapon designers were quick to point out that peer review was often necessary to explain surprising or unexpected nuclear test results by the other Laboratory. In short, the Laboratory felt strongly that cutting back on its weapons program would be a wrong move and detrimental to both laboratories and the country.

However, O'Leary was motivated to take the steps to cut back LLNL's weapons work. President Clinton had recently asked for a major Federal Laboratory Review (FLR)[135] in order to cut back on redundancies in the federal laboratories. Accordingly, O'Leary appointed Robert Galvin, former head of Motorola, to lead a 23-member task force to study redundancies at the DOE laboratories.

The Laboratory began engaging with the Galvin task force. Laboratory Director Tarter provided the overall direction and Wayne Shotts, who was then the principal deputy associate director for Defense and Nuclear Technologies, coordinated the Laboratory's effort and attended the visits that the Galvin committee made to other laboratories. Shotts notes[136] that the visiting Galvin members had diverse opinions regarding the Laboratory and its nuclear weapons work. Only two committee members had any direct experience working with nuclear weapons: Bill Spencer, who formerly worked at SNL, and Herb York. Shotts recalls one positive interaction when he visited Galvin task force member General James McCarthy, USAF (Ret.) in Colorado Springs. General McCarthy was receptive to additional information that the Laboratory provided. The meeting with General McCarthy included a presentation of a financial analysis that showed that the potential savings for consolidating the weapons program by moving LLNL's programs to LANL were not large when balanced against the loss of independent peer review and the likely loss of expertise in the process of trying to move functions and staff that would still be needed to support the stockpile.[137]

LLNL weapons engineer Joe Keller and Paul Brown were among the Laboratory personnel who provided significant input to Shotts, cataloging LLNL and LANL contributions to the nuclear stockpile over the years. They presented their views on the differences between the two laboratories in culture and in the approach they took to design problems, organizational structure, code development, and hydrodynamic experiments. The Galvin task force considered these differences as they worked to evaluate the strengths of the laboratories and their contributions in the peer review process.

In Shotts' presentation to the Galvin task force, he emphasized LLNL's seminal contributions over the years, including nuclear weapon concepts that formed the basis of much of the modern stockpile, major advances in hardware and weapon design codes, and innovations such as compact, light-weight warheads for submarine-launched ballistic missiles. He emphasized the complementary approaches to physics research that LLNL and LANL took, such as the use of gas guns for high-pressure equation of state measure-

* Carol Alonso notes that to enhance peer review, she and Peter Newcomb, both LLNL weapon designers, instituted a bi-annual nuclear explosives design physics conference between the two weapon laboratories. These were so successful, that a bi-annual nuclear explosives design code developers conference was instituted in the alternate years. Paul Brown recalls attending an early code developer's conference in approximately 1980.

ments* and the use of diamond anvil cells.

DOE's major input to the review process resulted in the Galvin task force's report.[138] Regarding the future of LLNL's weapons program, the report[139] made the following major recommendation:

> *"The task force believes Lawrence Livermore National Laboratory should retain enough nuclear weapons design competence and technology base to continue its activities in non-proliferation, counter-proliferation, verification, and intelligence support to provide independent review for several years while alternative approaches to peer review are developed, and to participate in weapons-relevant experiments on the National Ignition Facility (NIF).*† [140] *Lawrence Livermore National Laboratory would transfer as cost-efficiency allows over the next five years its activities in nuclear materials development and production to the other design laboratory. Lawrence Livermore National Laboratory would transfer direct stockpile support to the other weapons laboratories as the requirements of science-based stockpile stewardship, support of the DoD nuclear posture, and the status of the test bans allows."*

It is this author's opinion that it was easy to criticize the Galvin task force's recommendation, which LLNL scientists considered to be unsupportable. First, in order to provide competent peer review over another group's program, one needs itself to have a program that is much more viable than what the Galvin committee recommended for the Laboratory. Second, it was not clear what "alternative approaches" to peer review would entail. Approaches such as having the peer review teams be at the same laboratory would in the eyes of either laboratory be akin to having the fox watch the henhouse. Third, the strength in LLNL's nonproliferation and intelligence efforts stemmed strongly from its weapon design capabilities. Fourth, it made little sense for the NIF and its weapons-related research to be separated geographically from the weapon design activities. And finally, the gradual transfer of activities over five years from LLNL to LANL would be very difficult to pull off—what scientists with the capabilities to move onto more stable employment would wait around knowing that their jobs were soon to end?

The Galvin task force report fed into the FLR review, which gave the recommendations regarding the DOE nuclear design laboratories. **Appendix A** shows the part of the FLR review that summarizes the recommendations for modernizing the laboratories. Paraphrasing the Galvin report:

> *"The Galvin task force concluded that the labs possess excess capacity in the areas associated with nuclear weapons design and development; that many of these activities would be transferred, as cost-efficiency allows, from Lawrence Livermore to Los Alamos; and that alternative approaches should be explored for peer review of safety and reliability issues within an aging stockpile. Lawrence Livermore would retain its current responsibilities for nonproliferation, arms control, and related work."*

The FLR noted that other experts held different opinions about moving the weapons work from LLNL, and it cited a February 16, 1995 letter from Stanford University professor Sidney Drell, who was the chairman of the National Security Panel of the U.C. President's Council on the National Laboratories. Drell's letter recommended that LLNL retain its weapons design capability for approximately ten years, allowing time for the SSP to become mature enough to ensure the safety and reliability of the stockpile. The FLR also raised the issue of the eventual construction of the NIF and its role in stockpile stewardship and in attracting talented, new, scientific minds to the field.

Ultimately, Drell's many years of experience in following and advising on technical nuclear weapon issues had more clout than Robert Galvin and his task force. The FLR recommended further studies on the subject. DOE was directed to develop detailed recommendations for possible changes in the configurations of the three nuclear weapon laboratories, and these recommendations would be considered by an interagency working group to produce further recommendations

* Equation of state measurements provide scientists with an understanding of the behavior of materials at high temperatures and pressures, similar to those found in nuclear weapons.

† Wayne Shotts points out a key consideration about NIF's role in stockpile stewardship. It made little sense for LLNL to be responsible for NIF without having a major stockpile stewardship role. After all, NIF was being built at LLNL.

In June 1994, Bob Galvin (center) led the Galvin task force to examine redundancies at national laboratories. On the left is Galvin member Benjamin Rosen. LLNL Director Bruce Tarter and many Laboratory staff assisted in the task force activities.

regarding the best functions to be pursued at LLNL in order to ensure the safety and reliability of the stockpile, and alternate missions at the Laboratory, including the role of the NIF.

Initially, O'Leary had a favorable view of the Galvin task force's recommendations. In congressional testimony,[141] she said,

> *"The Department will closely evaluate the task force's recommendations regarding a reduction of some of the nuclear weapons functions at Lawrence Livermore and their transfer to Los Alamos. We have an initial favorable disposition for a careful phase-down of some of Livermore's nuclear weapons work, combined with a re-emphasis on nonproliferation, counter-proliferation, and verification activities."*

O'Leary's testimony clearly contradicted the testimony that Assistant Secretary of Energy for Defense Programs Vic Reis gave two days earlier. Reis argued that the SSP must maintain the nuclear weapons knowledge and skill bases at the three nuclear weapons laboratories. Adding to the debate was the above-mentioned letter that Drell sent to the U.C. president. The letter stated,

> *"Livermore's excellence is of great importance, in particular for peer review purposes…We believe there is a need for strong support to maintain LLNL's excellent design and diagnostic capabilities at this time. …. Gradual consolidation of the two laboratories' weapons activities is entirely appropriate with reduced stockpile needs, but we urge caution in assessing more fully their impact before taking specific actions lest we lose important peer review capabilities while they are still needed."*

While Drell's letter further suggested waiting ten years before final consolidation, it should be noted that ten years is a long time—landscapes change, and decision-makers are apt to forget what the original intent was. As it turned out, it took much less than ten years for attitudes to change. The interagency study that the FLR recommended took place over the summer of 1995, but its results were soon overtaken by events.

On May 3, 1995, O'Leary stated during a press conference that DOE will not eliminate any laboratories but will work to eliminate redundancies. She said that LLNL would not be closed, and that she preferred Drell's U.C. advisory panel's recommendation to maintain a nuclear weapon program at LLNL for at least ten years, over Galvin's recommendation of focusing all weapons work at LANL over five years. Two weeks later, on May 16, all three DP laboratory directors testified before the House Science Committee.*[142] There were differences in the directors' messages, and some of what was said was self-serving. Tarter argued for "the use of independent evaluations to provide the required confidence in the stockpile." He further stated,

> *"I strongly believe that such confidence in the performance and safety of the U.S. nuclear stockpile can only result from independent judgments and evaluations provided by the expertise and capabilities of all of the laboratories in the absence of nuclear testing. We are heading into uncharted territory and must take full advantage of the knowledge and commitment of trained people at each of the laboratories."*

* It is not clear which committee or subcommittee this was. The testimony has not been found.

Hecker testified that LANL had put into the stockpile five of the seven systems that would remain in the stockpile after 2000. He strongly supported the Galvin task force report insofar as it addressed his laboratory's mission, and stated that LANL had "the most complete set of facilities to help support the stockpile of tomorrow." He further stated,

> *"The [Galvin] task force was also asked specifically to address the size of the laboratories. It does not recommend closure of any laboratories. However, it rejects some of the current arguments for the need for two competing nuclear design laboratories, calling for consolidation of key nuclear weapons functions at Los Alamos over the next five years. This recommendation will have to be reconciled with the Department's Defense Program's vision and roadmap of the future weapons complex."*

Hecker's message did not support LLNL nearly as much as Drell's letter did. SNL Director Al Narath clearly differentiated the role of his laboratory from those of the two nuclear weapon design laboratories, and said that SNL's strategic vision was in harmony with the Galvin report. In the end, the LLNL weapons program (and the Laboratory itself) survived the recommendations of the Galvin task force. Shotts[143] pointed out that there were others involved in the process. For example, the DoD was clearly concerned about any steps that would have undercut the long-term viability of the U.S. stockpile. In May 1995, DOE's Office of Defense Programs published the *Stockpile Stewardship and Management Plan*,[144] which stated that DOE was carefully reviewing the Galvin task force's recommended phasing out of LLNL's role in nuclear weapon design and engineering. DOE stated that, "the timing and details of such a phase-down must depend wholly on how we can best meet our continuing national security responsibilities, as discussed in this report." DOE (especially DP) obviously had decided that LLNL was needed to fulfill these responsibilities and ultimately ignored the Galvin task force's recommendation. DOE also made a strong point in the plan about the need for peer review. Despite the lack of overt support from LANL and SNL, LLNL lived to fight another day.

The Summer of 1995 — A Turning Point Toward a CTBT

The JASON Report

Carol Alonso[145] describes events that occurred during the summer of 1995 that led to President Clinton's decision to pursue a CTBT. Some would say these events helped provide the rationale for the decision that the administration already wanted to make regarding the treaty. The first event was an independent JASON study on nuclear testing chaired by Drell, who was also a JASON member. **Appendix B** provides the summary and conclusions of the report. The JASON committee members included several experienced nuclear weapon designers from the design laboratories, including LLNL's Seymour Sack, who has generally been acknowledged as the foremost nuclear weapon primary stage designer that LLNL, or for that matter, the nation, has ever had. Sack was the project manager for the B83 and W84 nuclear warheads.* Other experts included John Kammerdiener, who worked primarily at LANL but also at LLNL, Douglas Eardley, who worked in his early career at LLNL before moving on to U.C. at Santa Barbara, and John Richter, a long-time LANL designer who was one of Seymour Sack's contemporaries. It is safe to say that Sack had a lot to contribute to the JASON's conclusions.

The JASON group's first conclusion was that, based on 50 years of experience and analysis of more than 1,000 U.S. nuclear tests, including 150 tests of modern weapons in the previous 20 years, the U.S. could have high confidence in its stockpile. Their second conclusion was that maintaining that high confidence would require implementation of a comprehensive SSP, with the management of the three nuclear weapon laboratories providing the proper motivation, support, and reward to the efforts of their people. Their third conclusion was to enhance performance margins of the weapons in the stockpile by identified means that were straightforward and that could be accomplished during scheduled maintenance or remanufacturing activities.

* The B83 warhead was designed for the B83 air-delivered nuclear bomb, carried by the B52, which remains in the active stockpile today. The W84 warhead was deployed and fielded on the Ground-Launched Cruise Missile (GLCM), which was to be based in Europe as a response to Warsaw Pact threats to NATO. The GLCM was removed from Europe in 1988 as a result of President Reagan's ratification and signing of the Intermediate-Range Nuclear Forces (INF) Treaty in 1987.

Regarding sub-kiloton testing, The JASON group concluded that,

> *".....the utility to the U.S. of testing at yields of up to approximately 500 tons depends on such tests being performed on a continuing basis and yielding reproducible results. If they are permitted only for a few years, such tests could add to the theoretical understanding of the boosting process and the reliability of the computer codes that attempt to describe it, but would not contribute directly to the reliability of the weapons in the enduring stockpile in view of the possible manufacturing changes made at a later date. To gain evidence as to whether long-term changes in age-affected weapons components have any impact on boost performance, the tests would have to be made with the remanufactured weapons themselves...."*

The committee went on to say,

> *"....testing of nuclear weapons under a 500 ton yield limit would have to be done on a continuing basis, which is tantamount to remaking a CTBT into a threshold test ban treaty. While such ongoing testing can add to long term stockpile confidence, it does not have the same priority as the essential stockpile stewardship program endorsed in Conclusion 2, nor does it merit the same priority as the measures to enhance performance margins in Conclusion 3. In the last analysis, the technical contribution of such a testing program must be weighed against its costs and its political impact on the nonproliferation goals of the United States."*

The JASONs also questioned the utility of hydronuclear tests, except perhaps for one-point safety determinations, but they asserted that other tools were available for such determinations based on two- and three-dimensional computational methods normalized to the large, existing, nuclear test database.

Drell and Senator Reid engaged in heated debates over the perceived policy positions taken by the JASON report (which in the senator's mind was supposed to be a technical report). Reid was also at odds with O'Leary, and he ultimately called for her resignation (and dismantlement of the DOE), because he believed that she had misled him about the DOE position on test site readiness, permitted experiments, and what constituted "zero yield." The CTBT had not been "zero yield" until O'Leary became energy secretary, and Reid saw no technical or political need for zero.*

Nuclear Weapons Symposium

The second key event of the summer of 1995 was a June 2 meeting at United States Strategic Command (USSTRATCOM) chaired by USSTRATCOM Commander Admiral Henry Chiles and attended by about 85 individuals active in nuclear weapons matters from DOE and its organizations, and DoD and its organizations. The meeting, "Nuclear Weapons Symposium," was called by some attendees such as Hecker a "confidence conference"[146] that was to address topics such as testing and stockpile confidence, surveillance, primary design issues, secondary design issues, the production complex, stockpile maintenance requirements, military requirements, and reliable replacement warheads (RRWs). However, the obvious, major purpose was to assess the pros, cons, and risks of maintaining the stockpile under strictly limited testing.

Among the attendees were USSTRATCOM's Rear Admiral David Goebel and USAF Colonel George Sakaldasis, who was assigned to LLNL at the time. Secretary O'Leary, DOE Deputy Secretary Charles Curtis, Steve Guidice from ALOO and DOE Assistant Secretary for Defense Programs Vic Reis represented DOE. LLNL's Associate Director for Defense and Nuclear Technologies, George Miller, and B Division Leader (and future LLNL and LANL director) Michael Anastasio attended for LLNL. Associate Director John Immele, and Don McCoy represented LANL. Roger Hagengruber attended for SNL, and Harold Smith, who was the ATSD (NCB), attended for the Office of the Secretary of Defense. The three Laboratory directors—Tarter, Hecker, and Narath—arrived later in the day. This turned out to be a pivotal meeting that helped frame the internal debate on the changing U.S. position on activities that would not be prohibited by a CTBT.

* This is the "zero means zero" issue that occupied policy makers over the years. Some researchers suggested that below about 4 lb TNT equivalent, no useful nuclear design information could be gleaned, but for maintaining certain skills required for SSP, this would be a useful capability to maintain. Others argued that only zero yield should be accepted in the spirit of the CTB.

Standing between Bruce Tarter and Michael Anastasio is former DOE Assistant Secretary for Defense Programs Victor Reis, the architect of the stockpile stewardship program.

According to Dorothy Donnelly,* who was the senior DOE adviser on the U.S. delegation to the Conference on Disarmament during the CTBT negotiations of 1994–1995, DOE organized the meeting for the "relevant elements of DoD and their advisers."

Anastasio and McCoy addressed how low-yield experiments at 500 tons could help maintain confidence while new stockpile stewardship capabilities were being established. The laboratories asserted that 500 tons† was an important threshold, below which confidence significantly dropped, and that while the SSP was vital to maintaining stockpile reliability, the laboratories could not prove they could do it without a 500 ton threshold. Anastasio presented a "stoplight" chart

* In 2014, Donnelly married LANL physicist Dr. John Shaner and became Dorothy Donnelly-Shaner.

† There has been some variation as to what the various participants have said in interviews regarding the desired minimum threshold. The charts that Anastasio showed had entries as to what could be accomplished with science-based stockpile stewardship and 500 ton yield. Tarter and Hecker mentioned 1 kt as a threshold that was discussed at the meeting, In a separate discussion that Paul Brown had on November 3, 2017 with Anastasio, Anastasio said that 500 tons was an important threshold for testing an important piece of physics for all the weapons in the stockpile. There was one weapon for which 1 kt would have been a better yield for testing that piece of physics.

summarizing the three laboratories' opinion of what would be at risk under very restrictive test limits, with and without a science-based SSP. The color-coded chart showed green for what could be certified with full confidence, red for what could be certified with low confidence, yellow for when the certification is task-dependent, and light blue for when the task has minimum certifiability.

Miller also spoke and said that the SSP was not risk-free, and that a prudent manager would try to mitigate the risks. He indicated that a modest program of 500 ton tests would mitigate the risks. DoD officials pressed the laboratory scientists to quantify the risks, but they could not do so. O'Leary was silent during the technical briefings, although the attendees knew what her biases were. Hecker recalls O'Leary talking at the meeting about her grandmother test, the theme of which was something like: "What would I tell my grandmother that the U.S. could gain by further tests when you look at all the tests we have done over the years?"

According to anecdotal information from several participants who were present,* O'Leary asked the Laboratory directors at the executive session, "Do we need to test?" SNL Director Narath replied, "No," even though SNL was not a nuclear weapon design laboratory involved in testing. Tarter and Hecker did not contradict him. Tarter said[147] that everybody had a chance to say something, and Narath was the first to speak. He felt Narath was outspoken, and when Narath said we did not need to test, Narath was thinking of the SNL (non-nuclear) parts of the nuclear explosive package. Tarter could not remember exactly what he himself said, but he gave the author the impression that it was not up to SNL to comment on what was at the time LLNL's and LANL's purview. Tarter said that he tried to give the impression that nothing was a sure thing. The situation was politically driven, and Tarter felt that DOE Deputy Secretary Curtis understood the thrust of the technical issues, and that he kept things together.

Similar to what Tarter expressed, Hecker also said that, while Curtis lacked deep technical knowledge, he could read people well.

* According to a footnote in Donnelly's history, "The account of Secretary O'Leary's question (and the reply) is anecdotal and came from several meeting participants who were in the room at the time. These same participants 'observed skepticism on the part of Admiral Chiles toward Secretary O'Leary's line of questioning, which they attributed to DoD's concerns about DOE's priorities in supporting the stockpile.' The author obtained O'Leary's quote via a personal communication from a LLNL official."

He felt that Curtis was "swimming upstream vis-à-vis O'Leary and President Clinton. He recalls that when Narath replied, "No" to the question on testing, that he was emphatic. Hecker's approach in answering questions at the meeting was to be careful with what you lose and what you gain at various yield levels. Hecker said that LANL went into the meeting wanting some level of testing, hopefully 1 kt. They realized that the chance for approval of a 1 kt testing level was zero, but wanted for completeness to show what could be done at various levels, as Anastasio's charts had shown. Hecker said that LANL's minimum position was for hydronuclears, anything with a few tons of yield.* In fact, one of the entries on the stoplight chart that Anastasio showed was for stockpile replacement with hydronuclears available. Anastasio noted[148] that that particular entry had two colors—light blue for LANL, who believed that the job could be done with minimum certifiability, and yellow for LLNL, who believed that the job was task-dependent.

There was considerable tension in the room between the DoD and DOE participants. Sakaldasis told Paul Brown[149] that the USSTRATCOM people at the meeting were extremely upset with the meeting outcome. He said that at the post-meeting reception, USSTRATCOM Deputy Commander Lieutenant General Dirk Jameson said that USSTRATCOM felt that they were "blind-sided" at the meeting and asked Sakaldasis why it all happened. After the USSTRATCOM meeting, the DoD began to support a 500 ton limit. However, on June 23, 1995, after an interagency debate below the Cabinet level, President Clinton stated that he would not support a return to testing, and the DoD dropped its support of a 500 ton limit.

The Washington Road Show to the JCS Chairman and the National Security Advisor

The third key event of the summer of 1995 was a meeting in July between Joint Chiefs of Staff (JCS) Chairman General John Shalikashvili, the three laboratory directors, Deputy DOE Secretary Curtis, and Assistant Secretary for Defense Programs Reis. Later that day, the group went to the White House for a similar meeting with National Security Advisor Anthony Lake and National Security Council (NSC) member Steve Andreasen, who was Robert Bell's principal CTBT assistant while Bell was the NSC senior director for Defense Policy and Arms Control. The purpose of both meetings was to discuss the SSP and the need for nuclear testing. Mike Anastasio gave the same briefing using the stoplight chart that he gave at USSTRATCOM. According to one participant,[150] Shalikashvili fully understood the issues. He asked the laboratory directors point blank whether stockpile stewardship would work without testing, and they answered that science works, or something equivalent. Tarter remembers[151] these Washington meetings as the most important actions of that summer. Hecker recalls[152] that:

> *"Vic Reis and Charlie Curtis took us back to see General Shali [Shalikashvili] in the Pentagon. General Shali was in the process of trying to formulate his recommendation to President Clinton on the comprehensive test ban. So he had us there—the three laboratory directors, and it was really our show, with Shali asking whatever questions he needed to convince himself of what position to take. Curtis and Reis were there just to kind of back us up. They were the DOE officials.*
>
> *So we went through some discussions with General Shali. The most interesting part to me—this is where it really came down to remembering the Sidney Drell sort of philosophy. How important it is to give the honest answer, and the answer that is within the bounds of what we have to do at the laboratory? General Shali asked something to the effect of the following: 'In order to assure the safety and reliability of the stockpile, as it is constituted now, do you absolutely have to test? In order to keep the stockpile safe and reliable, do you have to test?'*
>
> *That is the way he phrased the question. My answer was 'General Shalikashvili, in all honesty, I cannot say yes to that. I cannot say that I know that we will have to test. In other words, if we do not test, that the weapons are going to be not*

* It is not clear that LANL really would have expected a few tons since hydronuclear experiments have been touted as producing only a few pounds of yield. It also should be noted that Livermore scientists disagreed strongly with LANL on the value of hydronuclears for U.S. designs. Hecker was aware of LLNL's views but said that that was LANL's strong opinion.

safe and not reliable. I cannot tell you that. But I have to add right away, also, that I cannot tell you that they will remain safe and reliable if we do not test.'

The key thing that he was looking for was–I believe, that if my colleagues and I had told him that we cannot keep these safe and reliable unless we test, I believe that he would have recommended that we test. That is my belief."

The Phone Call to the Laboratory Directors

The fourth event of the summer of 1995 was a phone call from DOE headquarters to the laboratory directors. On August 9, Curtis instructed the laboratory directors to return to their offices for a secure call. Hecker remembers[153] that Reis was also on the call, and he thinks the decision had already been made on requiring an annual certification process. Curtis asked each director independently whether he could endorse the president's desire to seek a CTBT. They all replied that they could endorse such a decision as long as safeguards and a very robust science-based SSP were put into place. In a televised talk subsequently given to Laboratory employees on October 3, 1995, Tarter said:

"Early in August, late one night I was called back to the Laboratory to basically answer the question from the administration as to whether I, and they had also called the other lab directors [if they] could endorse the president's desire to seek a comprehensive test ban treaty. After long conversations, I and the other lab directors independently said they could endorse such a decision as long as safeguards and a very robust stockpile stewardship program were put into place……Two days after those decisions, the president then made his decision on August 11 to seek a comprehensive test ban treaty with the safeguards which we had requested to be built into that announcement."

U.S. Decision to Negotiate a CTBT with Proper Safeguards

On August 11, 1995, President Clinton announced that the U.S. would pursue a CTBT. A month later, on September 25, he said that a condition of U.S. acceptance of a CTBT would be safeguards for "the conduct of a science-based SSP to ensure a high level of confidence in the safety and reliability of nuclear weapons," and on "the maintenance of modern nuclear laboratory facilities and programs in theoretical and exploratory nuclear technology…." Thus, an important future role for the Laboratory was officially cast, guaranteeing that the nation could effectively live with a CTBT. The CTBT would be zero yield.

Dorothy Donnelly's history[154] mentions the interagency discussions that led up to the U.S. position for a zero yield CTBT, including the considerations for a 1 kt or 500 ton threshold, and on what "permitted experiments" and "permitted activities" might be allowed in a CTBT regime. Such activities were generally used to denote a category of (mostly) stockpile and weapons testing activities that would not be prohibited by a CTBT. Donnelly notes that there was vigorous debate among DoD, DOE, JCS, and the three nuclear weapon laboratories about whether to submit for congressional approval a plan for the 15 nuclear tests that were allowed in the 1992 Hatfield–Exon–Mitchell amendment.* There was also a lot of discussion as to whether the U.S. should pursue hydronuclear experiments as an allowed activity under a CTBT regime. Hydronuclear experiments were an initial part of the P-5 CTBT discussions before the Clinton administration decided to forgo such experiments as part of a zero yield CTBT. Such experiments were conducted during the 1958–1961 nuclear test moratorium, and they were considered useful to study weapon issues such as safety, reliability, certification, and ability to render safe mock terrorist devices. The NSC set up a task force led by DOE and ACDA to study the issues. Laboratory scientists participated in the task force activities and provided input to the project.

By this time, the idea of a science-based SSP had been percolating for a number years, but the president's announcements could be viewed as a watershed event toward formalizing U.S. efforts toward the pursuit of a CTBT. The SSP that Reis led while he served as assistant secretary for Defense Programs in the DOE from 1993 to 1999 was formally established by the 1994 National Defense Authorization

* For example, see J. Medalia, CRS Report for Congress, *Comprehensive Nuclear-Test-Ban Treaty: Background and Current Developments*, updated May 28, 2008, Order Code RL33548.

Act (Public Law 103-160),[155] which stated: "The Secretary of Energy shall establish a stewardship program to ensure the preservation of the core intellectual and technical competencies of the United States in nuclear weapons, including weapons design, system integration, manufacturing, security, use control, reliability assessment, and certification." Prior to that, President Clinton had issued PDD/NSC-15, which established U.S. policy on the stewardship of the U.S. nuclear weapons stockpile under a moratorium on testing and a CTB. Needless to say, the SSP is the heart and soul of today's nuclear weapons program at the laboratories. It has also become a crucial part of the nation's ability to sustain a viable nuclear deterrent under a CTBT.

Bob Perret advised Senator Reid on the possible effects that a CTBT would have on the safety of and operational confidence in the then-current stockpile. Perret also advised Reid on the inevitable deterioration of the workforce and loss of expertise that could result from a lack of testing—expertise evolving out of the actual design, test, and analysis of real data from nuclear tests. Perret was concerned about the fallibility of computer codes, and felt that simulation without testing would not provide a comfortable level of confidence in retrofits and re-design of deteriorating weapons components.

Another topic of particular concern to Senator Reid was the possible deterioration of the readiness to resume nuclear testing should the CTBT fail. There were concerns about DOE/NNSA's estimates of the time to resume operations at the NTS, as well as bureaucratic obstacles to fast turn-around testing and the possibility of long periods between decision and action. On a more general and long-term level, the issue of the nuclear weapons program essentially being terminated and the loss of the dedicated workforce concerned Reid, along with other legislative leaders. However, as Perret has noted, the notion that "we did this once and we can do it again" prevailed.

The Reis–Ryabev Collaborations

Similar to the 1991–1992 U.S.–Soviet collaborations, a second set of lab-to-lab discussions took place several years later between the U.S. and Russian ambassadors for possible cooperation in areas more directly related to nuclear weapon research. Bill Dunlop wrote a report about these discussions and some of the subsequent developments from them.[156] Presidents Clinton and Yeltsin bought into the proposals, and the collaborations—named after Victor Reis and his Russian counterpart, Minatom's First Deputy Minister, Lev Ryabev*—were born. The Reis–Ryabev collaborations were formally established/endorsed by the U.S. Government in NSC-47,† on March 21, 1996. NSC-47 states, "This Presidential Decision Directive establishes and directs the implementation of U.S. policy on nuclear scientific and technical cooperation with Russia related to stockpile safety and security and Comprehensive Test Ban Treaty monitoring and verification." A high-level plenary meeting was conducted in Moscow in June 1996, followed by a working meeting in Vienna in October, 1996.

The Reis–Ryabev collaborations comprised three working groups: Group 1 addressed unclassified science and technology related to nuclear weapons; Group 2 addressed the safety and security of weapons; and Group 3 addressed the science and technology of CTBT verification and monitoring. Several LLNL scientists from the weapons program participated in Working Group 1 activities, which included R&D in areas such as shock physics, hydrodynamic instabilities, equation of state, energetic materials, material science, computational methods, and some aspects related to LLNL's ICF efforts. Although the Russians did not have the powerful computers that the U.S. had, their scientists were excellent mathematicians and were able to use their skills at building algorithms to maximize the information they got from their computations.

At the time, Russian scientists also had excellent experimental skills that we found tremendously valuable. Despite pressures from the Russians to collaborate more on ICF, the U.S. did not see much return value in such collaborations, nor in collaborating on laser technology, but there was some perceived value in ICF material science areas such as specialty glass for lasers and for designing and fabricating the targets used in laser experimental facilities. LLNL scientists who participated in the collaborations included Paul Brown, Dale Nielsen Jr., Bruce Goodwin, Oleg Schilling, Elaine Chandler, Mike Dunning, Neil Holmes, Bill Nellis, Harry Vantine, Tom Peyser, and Howard Lowdermilk.

* According to Hecker, who interviewed Ryabev in 2014 and 2015 for a book he wrote, *Doomed to Cooperate*, "L.D. Ryabev is deputy director at VNIIEF and advisor to S.V. Kirienko, director of the State Atomic Energy Corporation (Rosatom). He began his nuclear career as a scientist at VNIIEF in 1956, and during the past 59 years has been largely responsible for most of Russia's nuclear weapon enterprise, including as director of VNIIEF, minister of Medium Machine Building and first deputy minister of Minatom."

† NSC-47 was initially issued as a secret document and has since been declassified.

Dunlop was an active member of Group 3. He notes in a history that he wrote[157] that Group 3 met several times at the U.S. nuclear weapon laboratories and at Russian weapon institutes. Topics included OSI technologies including "tabletop" joint exercises in 1998 and 2000, seismic calibrations, transparency measures at test sites, and studies of electromagnetic pulse signals from explosions. Much of the funding for Russian participation came from the International Science and Technology Center* in Moscow. Dunlop wrote that after the initial meetings in 1995, there were plenary meetings each succeeding year, during which time the U.S. leader changed from Vic Reis to Reis's successors at the DOE, General John Gordon, followed by Ambassador Linton Brooks. Larry Turnbull of the U.S., and academician Evgeny Avrorin of Russia were appointed co-chairs of Working Group 3. Dunlop and Vladimir Nogin were the executive secretaries who executed the planning for the meetings.

Laboratory Involvement with CTB Negotiations

After President Clinton's August 1995 speech, the U.S. became more seriously involved at the United Nations Conference on Disarmament (CD), where Laboratory scientists continued to serve as technical advisers. Bill Dunlop served as the lead science adviser to Ambassador Stephen Ledogar, who was the U.S. lead negotiator. Dunlop gave his expertise on nuclear weapons issues related to the scope of what activities the treaty would ban and allow and technical issues related to verification. LLNL seismologist and geophysicist Jay Zucca addressed verification and monitoring issues. While many of their interactions took place within the main body of the CD, some discussions were held in side meetings with members of the other P-5 nuclear weapon states, all of whom had vested interests in their own versions of an SSP. During the discussions on the verification of the treaty, key scientists from LLNL, LANL, SNL, and DoD were invited to participate.

Donnelly's classified history[158] of the P-5 discussions includes examples of Laboratory participation on issues of the scope of the

* The International Science and Technology Center (ISTC) is an international organization established by an international agreement in November 1992 as a program to prevent nuclear proliferation and the proliferation of other weapons of mass destruction (WMD) by giving Russian and Newly Independent States (NIS) scientists and engineers with knowledge and skills of WMD or missile delivery systems, opportunities to redirect their talents to peaceful activities such as fundamental research, international programs and innovation, and commercialization.

treaty, i.e., what the treaty would ban or allow. PDD-11* was the governing document that the negotiators followed; it set the U.S. agenda for what the U.S. would negotiate at the CD in Geneva. As noted earlier in this history, Alonso[159] wrote that when President Clinton issued PDD-11, he requested studies to examine what experiments should be permitted, what would be required for verification, and what would be required for stockpile stewardship.

Most interesting in Donnelly's history is the background material she provides on what occurred in meetings in the U.S. that led to the formulation of the U.S. negotiating positions. Donnelly recalled that the Russians were very interested in allowing PNEs in a CTBT regime, and in a meeting that she and Dunlop had with Ryabev, Ryabev promoted laboratory and test site research activities as PNE activities. Donnelly and Dunlop reminded him that PNEs were not in the U.S. culture, and that the U.S. could never agree to such activities. She also recalled an announcement in October 1995 that in June 1996, DOE would begin to conduct subcritical experiments at the NTS in support of its stockpile stewardship efforts. She said that the announcement caused a "firestorm" of news articles and commentary that led to quite a stir at the Geneva discussions. The U.S. delegation, including scientists from the laboratories, had to explain that the planned experiments were consistent with a CTBT; i.e., had a zero yield.

LLNL physicist Carl Poppe and LANL scientist Jay Norman wrote an unclassified addendum, *Stockpile Stewardship Activities under a CTBT*, that appears in Donnelly's history. Both scientists had been on assignment to the DOE Office of Arms Control. The addendum, dated April 13, 1994, discussed permitted activities using computations, hydrodynamic testing, hydronuclear experiments, ICF, pulsed power for weapon physics and weapon effects, other weapon physics, and pulsed nuclear reactors. The addendum was no doubt based on similar documents that LLNL and LANL had written on the subject of permitted experiments.

Also included in Donnelly's history is a letter that Kidder wrote to two long-time critics of research at the weapons laboratories—Richard Garwin, a science adviser to the U.S. government, and Chris

* The press release is given in **Appendix C**.

Paine of the Natural Resources Defense Council. Kidder described a conversation he had had with French officials from their nuclear weapons establishment concerning French nuclear testing needs and plans, and "apparent misconceptions of U.S. nuclear weapons simulation plans and capabilities." The French told Kidder that they needed an additional 10–20 tests over a 1–2-year period to ensure that the French stockpile would be sufficiently robust under a CTBT. They also said that an alternative to doing such tests would be to have a CTB that allowed testing up to 100 ton yield to keep their stockpile robust during a CTBT regime. Kidder said that he was convinced that the French had reasonable grounds to say what they told him. The French were quite confident about their simulation and experimental capabilities vis-à-vis the U.S.

Bill Dunlop's Contributions in Geneva

Bill Dunlop spent several years with the negotiating team in Geneva. According to Ledogar, all the nuclear weapon states had different ideas as to what the scope of the treaty should be. The U.S. delegation received no instructions from Washington on what was meant by a "zero yield" treaty, and Dunlop had to help develop the U.S. position in real time while engaging in discussions with representatives from the other P-5 countries. The discussions started by addressing what would be prohibited, but they soon transitioned into discussions of activities that would be allowed.

Much of what is written here is captured in the testimony Ledogar gave to the SFRC on October 7, 1999 (**Appendix D**). Ledogar addressed the disparity amongst the weapon states as to what the treaty should allow and the discussions that took place. Dunlop played a key role in those discussions. Ledogar stated, "It is important to recall that each of the five nuclear weapon states began the CTBT negotiations desirous of a quiet understanding among themselves that some low-level nuclear explosions/experiments that did produce nuclear yield would be acceptable at least among themselves despite the broad treaty prohibition of 'any nuclear weapon test explosion or any other nuclear explosion.'

Ledogar continued, "In the confidential negotiations among the five nuclear weapon states that went on the entire time the broader CTBT negotiations continued, it was clearly understood, and that the boundary line—the "zero line" between what would be prohibited to all under the treaty and what would not be prohibited—was precisely defined by the question of nuclear yield or criticality. If what you did produced any yield whatsoever, it was not allowed. If it didn't, it was allowed."

In discussions with the P-5 states, Ledogar clarified that discussions of zero yield applied to nuclear weapon tests, not to nuclear reactors, as such reactors were not precluded by the treaty as spelled out in the State Department's article-by-article analysis of the CTBT (**Appendix E**). Ledogar's testimony also unequivocally stated that the nuclear weapons states, including Russia, did agree that hydronuclear experiments were not allowed under the treaty. Since hydronuclear experiments are done in a weapon configuration, and they step up in stages from subcritical (i.e., unable to sustain a nuclear chain reaction) to slightly supercritical. The P-5 states agreed that criticality was all right as long as it was not in a weapons configuration. It was Dunlop who introduced the concept of criticality into the discussions among the P-5 states. This was a substantial contribution that allowed the U.S. to advance its position of zero yield in the CTBT negotiations. By using the notion of criticality to separate what was and what was not a nuclear explosion, the U.S. was able to get around the need to define what actually constituted such an explosion; requiring such a definition would have been problematic, as explained in Appendix E.

At one point during the negotiations, Ledogar asked Dunlop for an example of a cost–benefit analysis regarding verification of the treaty. Dunlop turned to LLNL seismologist Marvin Denny to provide the requested analysis. Denny was asked to consider what it would take to verify the three yields levels of 10 kt, 1 kt, and 0.1 kt. The analysis was presented to the U.K.'s Peter Marshall, Friend of the Chair on Technical Verification in the Verification Working Group of the CD. Marshall presented Denny's work in one of the CD sessions; the CD adopted the 1 kt goal.

Jay Zucca's Contributions in Geneva

Victor Slipchenko, Russia's deputy chief negotiator in Geneva, served as Friend of the Chair to the Certification Working Group on OSIs. He appointed Jay Zucca to head a group of experts to address the evidence that might be available after a clandestine nuclear detonation. Zucca describes his group as a "tiger team." He worked closely with

Russian scientist Vitaly Shchukin from the Russian nuclear weapons institute at Snezhinsk (VNIITF or Chelyabinsk-70).

Years earlier, Zucca wrote a report on OSIs. It came in handy when years later, DOE asked for a paper on OSIs, and Zucca's report was sent. The report formed the basis for the U.S. position on OSIs at the CTBT negotiations. In testimony, Ledogar said of Zucca's report, "The U.S. crafted a complicated, highly detailed proposal that balanced our offensive and defensive needs. There was resistance from some of our negotiating partners. However, by the time we were through, the treaty read pretty much like the original U.S. paper put together jointly by the Departments of Defense, Energy, and State, the Intelligence Community, and the then existing Arms Control Agency."

Most of the U.S.'s technical position was adopted at the negotiations, with the exception of the decision-making process that the executive council of the Comprehensive Test Ban Treaty Organization (CTBTO) used in approving an OSI. According to Rebecca Johnson's history[160] of the CTBT negotiations, the options were a "red light" or a "green light" approach. In the red light approach, the council would have to vote to deny an OSI from proceeding. In the green light approach, the council would have to vote to approve an OSI. The red light approach was considered to be less prohibitive, because it would allow the OSI to occur unless a majority of the council voted to stop it. The U.S. preferred the red light approach; however, the green light approach was adopted.

For two weeks, the tiger team worked at a grueling pace for three-hour sessions twice a day. Dunlop played an instrumental role in helping Zucca in the deliberations. In one instance, the French had a problem with the way the report was evolving. A member of the U.S. delegation spoke to a member of the French delegation and reported to Dunlop that the French felt they were not consulted on a particular issue. Dunlop arranged for the P-5 parties to discuss the related issues over lunch at the U.S. mission. The tiger team was then able to get through the impasse.

Backstopping Support Back Home

While in Geneva, Zucca and Dunlop relied on backstopping at DOE headquarters from Poppe, then later by LANL scientist Jay Norman. Zucca has more recently served as deputy to Vitaly Shchukin, head of the Laboratory of the Theoretical Division at the Russian Federal Nuclear Center—VNIITF, and leader of the CTBTO's Working Group B in Vienna, Austria. This working group addresses OSI capabilities, including planning for OSI field exercises.

At LLNL, a backstopping effort that involved a large number of Laboratory staff took place. Scientists provided time-critical responses on various issues to the negotiating team in Geneva and provided feedback on suggested negotiation positions, such as the types of experiments (e.g., ICF) that would be permitted under a CTBT. Laboratory researchers kept abreast of the progress at the Geneva meetings so that they would be ready to respond when asked for information. The many LLNL individuals who were on assignment to various offices in Washington during the years leading up to the CTBT and its ratification hearings are listed in **Appendix F**.

CTBT Ratification Hearings

President Clinton was the first to sign the CTBT on September 24, 1996. He used the same pen that former president Kennedy used to sign the LTBT. Over the next two days, 70 other nations, including the other P-5 nations also signed. A year later, on September 22, 1997, Clinton transmitted the CTBT to the U.S. Senate for Advice and Consent to ratify the treaty.

Hecker recalls that when the Senate was deliberating on the ratification of the CTBT, Senator Kyl requested input from the weapons laboratories and submitted 21 questions for the record that Hecker said were key. The classified questions were sent to LANL scientist Dave Watkins. Hecker either wrote the answers or heavily edited them. In Hecker's mind, this was the most important document laying out how he felt. Tarter provided a similar set of answers (**Appendix G**). Tarter's letter was a very strong endorsement of the SSP and its possibilities. Paul Brown recalls a table that he (Brown) and Watkins produced for the answer to Kyl's Question 21 (see Appendix G). detailing what nations of varying technical capabilities could gain by testing at various yield levels. That table was referenced for a number of years in responding to requests from Congress. This table could certainly be updated to reflect advances in available knowledge since that time.

The CTBT languished in the Senate for two years until the Senate Republican leadership, namely SFRC Chairman Jesse Helms and Majority Leader Trent Lott, suddenly agreed to conduct ratification

On September 24, 1996, President Clinton was the first to sign the Comprehensive Test Ban Treaty. (photo credit: Comprehensive Test Ban Treaty Organization)

hearings. Helms did not support the treaty and had been pressured by Senate Democrats as recently as June of 1996 to conduct hearings. In a surprise move, the Republicans finally decided to conduct hearings from October 5 to October 7, 1999 in the SFRC and the SASC.

Tarter testified on October 7 before the SASC. One of the main points he made was that a "strongly supported, sustained SSP has an excellent chance of ensuring that this nation can maintain the safety, security, and reliability of the stockpile without nuclear testing." Tarter emphasized the importance of having all the necessary tools in place before the nuclear test veterans were gone. He expressed optimism about the progress made to date in the SSP, and that future success would depend in large part on having an outstanding, dedicated staff. Tarter also emphasized the importance of Presidential Safeguard F* that would allow nuclear testing to resume in the future if the president, in consultation with Congress, agreed that nuclear testing should be resumed.[161] Tarter went on to highlight the success that the SSP had made thus far, and areas where more work was needed. He asserted that we were in a race against time to get to where we needed to be before the nuclear test veterans would be gone.

LLNL's Ron Lehman also testified on October 7 before the SFRC. Lehman had been director of the Arms Control and Disarmament Agency under President George H.W. Bush from 1989 to 1993. Prior to that, from 1985 to 1988, he served under President Reagan in the State Department as chief negotiator for the first Strategic Arms Reduction Treaty (START I),† where he earned the title of ambassador. In his testimony,[162] Lehman emphasized that the U.S. had failed after the Cold War in dealing with trends such as globalization and technological advances, and in dealing with "the legacies of the past, such as regional instabilities, ethnic conflicts, economic

* Safeguard F, 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."

† START I, a bilateral treaty between the U.S. and Russia, entered into force in 1994, limiting the number of warheads and delivery vehicles the signatories could deploy to an aggregate limit of 1,600 delivery vehicles and 6,000 warheads. The treaty expired in 2009 and the U.S. and Russia decided not to extend it. The START II treaty did not enter into force.

resentments, geopolitical ambitions, and domestic, political divisions overseas and at home."

Lehman said that the debate over the "zero yield" CTBT essentially neglected the basic principles that had led to the success that the U.S. had achieved in arms control at the end of the 1980s and into the 1990s. He emphasized the impact of test restrictions that were at too low of a yield to allow the U.S. to maintain an effective deterrent. He stated that differences of opinion about stockpile issues will occur between physicists and that "Nuclear testing has often been the only way certain disputes could be resolved with the necessary finality." Lehman also questioned the link between nonproliferation and the need to test. He summarized his views by saying, "It is my personal view that the arms control arguments for a zero yield CTBT are not compelling, and that the nonproliferation impact of any CTBT can be very uncertain and involve foreseeable dangers as well as unintended consequences. A better way to proceed is a step-by-step process in which constraints are related to advances in verification, advances in a validated stockpile stewardship program, development of an appropriate weapons stockpile for a post-cold war and testing limited environment, and advances in global and regional security."

While no record could be found of their having testified, former LLNL directors Batzel and Nuckolls responded to Senator Helms's requests for information.[163] Batzel wrote, "I urge you to oppose the Comprehensive Test Ban Treaty (CTBT). No previous administration, either Democrat or Republican, ever supported the unverifiable, zero yield, indefinite duration CTBT now before the Senate. The reason for this is simple. Under a long-duration test ban, confidence in the nuclear stockpile will erode for a variety of reasons."

Nuckolls wrote, "Without nuclear testing, confidence in the stockpile will decline. The U.S. capability to develop weapons will be degraded by the eventual loss of all nuclear test-experienced weapons experts who developed the stockpile." He continued, "For the U.S., the CTBT would be a 'catch-22': without nuclear testing, experts cannot qualify this uncertainty."

It is important to note that former LLNL scientists Robert Barker and Kathleen Bailey, who served in the DoD and Department of State, respectively, also testified against CTBT ratification before the SASC, essentially arguing that the CTBT was not in U.S. interests.

CTBT Ratification Fails

On October 13, the Senate failed to ratify the CTBT by a vote of 51–48. It is generally acknowledged that the Republican leadership decided to call the bluff of the Democrats, knowing full well that they lacked enough support to achieve ratification. The Democrats were caught by surprise. Two weeks after the CTBT was turned down, Tarter again testified on October 27 before the Subcommittee on International Security, Proliferation, and Federal Services of the Governmental Affairs Committee. Tarter spoke on the progress that the Laboratory had made in DOE's Stockpile Stewardship and Management Program (SSMP). He again pointed out that in the event that SSMP failed to meet its objectives, important safeguards existed for the U.S. to resume testing if the deterrent were judged to be at risk. He argued about the importance of continued, sustained (budgetary) support to allow the success of SSMP to continue. In assessing all of the differing points of view expressed by Laboratory personnel in testimony, when all is said and done, it is important to realize that the most influential testimony by any one individual from the Laboratory is that of the person who has to certify the stockpile weapons that are his responsibility. That person is the Laboratory director.

On October 2, 1998, LLNL staff members briefed* Vic Reis on the potential utility of hydronuclear testing for simpler designs, such as those that might be pursued by other countries. John White gave the presentation. Reis thanked the briefers for the insights that they provided. However, Reis unequivocally stated that hydronuclears were not going to be included in any of his budgetary plans for stockpile stewardship, implying that there were better uses for the money.†

Policy Issues, New Design Warheads

In July 1999, the U.C. National Security Panel—the committee that oversaw LLNL and LANL—expressed concern as to whether the work being done at the laboratories was in keeping with the spirit of the

* Paul Brown was present at the briefing.

† In a memo Paul Brown wrote to Associate Director Mike Anastasio on September 14, 1998, Brown conveyed the disagreement that B Division Leader Bruce Goodwin and John White had on what hydronuclears could achieve. White briefed Anastasio on the subject, and Anastasio said the briefing should be presented to Reis and that Brown should accompany White.

CTBT in so far as new weapon designs was concerned. Paul Brown, then the assistant associate director for arms control in the National Security Directorate at LLNL, and Thomas Scheber, the project leader for stockpile studies at LANL, collaborated on a joint presentation to the U.C. panel entitled "Policy Issues: New Design Warheads." Brown and Scheber explained that there was no explicit legislation that barred new warhead designs other than a 1993 law* that precluded "R&D which could lead to the production by the U.S. of a new low-yield (5 kt) nuclear warhead, including a precision low-yield warhead." They also pointed out that the Nuclear Posture Review of 1994 and a subsequent PDD mandated that the U.S. maintain the capability to develop and certify certain new warheads. Brown and Scheber published their findings as a joint LLNL–LANL publication.[164]

Brown and Scheber argued that the CTBT simply bans nuclear explosions, which effectively constrains the development and qualitative improvement on nuclear weapons and ends the development of advanced, new types of weapons. As borne out by the Article-by-Article Analysis of the CTBT[165] prepared by the State Department, the treaty language does not prohibit the development of new weapons or the improvement of existing weapons, even without the benefits of nuclear explosion tests. Brown and Scheber also pointed toward confirmation provided by the negotiating record and by a list of "Activities not Affected by the Treaty" provided in the Article-by-Article Analysis of the CTBT.[166] The authors also addressed a number of misinterpretations of various presidential actions that took place in 1992 and 1993 that some have construed as tantamount to a ban on new designs.

An important point the authors raised in the paper was what constituted a new nuclear weapon design. An existing warhead undergoing refurbishment or remanufacture would definitely not be considered a new design, while a warhead that has never been in the stockpile and undergoes development using an untested physics package (i.e., the actual nuclear explosive) is a new design (and by convention would have to have a new warhead designation number). The problem is that there is a whole spectrum of possibilities in between these two extreme cases, the interpretation of which is in the eyes of the beholder, making the definition of what is a "new design" an exercise in futility. The authors said that rather than debating definitions of what a "new design" is, the approach should be to identify capabilities that will exist under the SSP to develop weapons that are currently not in the stockpile, and to make certain that anything that the nuclear weapon laboratories do is consistent with national policy guidelines. These guidelines are well set by a formal legal procedure that must be followed by the Executive and Legislative branches of the government. Brown and Scheber also gave examples of weapons that were currently undergoing life extension programs (LEPs) in the current stockpile.

The Brown and Scheber publication served a useful purpose on several occasions after its release. For example, it was used as input by the National Academy of Sciences (NAS) in an NAS study published in 2002 on CTBT. Wolfgang Panofksy, director emeritus of the Stanford Linear Accelerator said the NAS appreciated the authors' document very much, and that it helped them form their necessary conclusions.

In September 2000, Paul Brown and David Watkins of LANL had given a classified briefing[167] to NAS on the technical capabilities of foreign states possessing different degrees of nuclear infrastructure development. They addressed three types of states: those with a moderate technology base, such as North Korea, India, and Pakistan; states with a highly developed technology base, such as Japan or Germany; and nuclear weapon states. Watkins and Brown addressed what each of these three types of states might achieve with clandestine nuclear tests at varying testing levels from zero to about several kilotons. They also addressed what could be achieved in the way of weapon development and maintenance of existing weapons for designs ranging from the earliest Hiroshima and Nagasaki designs to more advanced modern devices at the various yield levels, as well as what could be achieved without any CTBT at all.

In 1999, when DOE's Office of Defense Programs was reorganized by Congress as the NNSA, a semi-autonomous organization within DOE, Bob Perret was still serving as a science adviser to Senator Reid.[168] Perret attended all of the Senate subcommittee meetings with representatives from the DoD and DOE, including Secretary of Energy Bill Richardson. Perret briefed Reid on the issues and frequently met with Richardson prior to the meetings to brief

* Public Law 103-60, November 1993.

him on Perret's perception of the positions of legislative members. The briefings with Richardson were conducted with tacit approval by Senator Reid in an effort to move the issues forward. A number, but not majority, of the members were in favor of reversion of federal oversight of nuclear weapons activities to an "AEC-like" entity, but concerns about funding levels for a program without major discretionary spending capability prevailed against such a simplistic solution. DOE had the largest discretionary budget of any federal department, and that alone made it almost imperative to continue DOE in the role of oversight if not direct management of research, development, testing, and evaluation of nuclear weapons. The major sticking point in creating NNSA was defining a structure in which the secretary of energy would have a role, but not necessarily the dominant role, in decision making for nuclear weapons activities. This sticking point was resolved with only partial success, and its debate in the meetings resulted in considerable animosity between many legislative members and the energy secretary. There was some debate as to whether the NNSA solution was the best. Perret said, "Some declared success on the grounds that nobody was happy with the outcome." NNSA officially began operation on March 1, 2000.

In 2000, twenty-three years after he articulated his anti-CTBT argument to the U.S. Senate, former LLNL director Michael May participated in a roundtable discussion[169] at Stanford University and gave a presentation based on a study that he led in 1996 at the request of Vic Reis. The study assessed the assurance that the then nascent science-based SSP could provide on the safety and reliability of the stockpile, what could be done to improve that assurance, and how responsible parties in Washington would know if the program failed. May assembled a group of former nuclear weapon designers to address the relevant questions.

The group examined how aging or potential new military requirements might affect the safety and reliability of stockpile weapons. They reviewed past nuclear test data to see "how actual results differed from what could be explained with calculations assisted by non-nuclear experiments, and what that implied for the ability to predict the effects of both kinds of changes." May said that their job was "to compare predictability of the effects of changes in the weapons to the margin those weapons' performance had to lie within."

The group recommended a program that would establish limits on permissible changes in the future. They called it the "rebaselining program," which would make use of the skills of retiring and experienced designers and a cadre of newer, talented scientists. The following were their recommendations:

"1. The rebaselining program should be carried through at high priority as soon as possible. In our view, it was better to do without some of the new capabilities than to do without the help of retiring and aging experienced scientists. Even at high priority, we anticipated that at least five years would be needed to do the program. Given the other obligations of the laboratories, it is likely to take longer.

2. The top management priority, in addition to supporting and protecting the program noted above, should be to hire first-class scientists. The best guarantee of an effective program is good scientists. It would be better to have a cadre of first-class scientists available to help make key technical recommendations, even if these scientists only worked on nuclear design part-time or occasionally, rather than to have less-able scientists on a full-time basis, although the latter would be needed also.

3. While rebaselining was going on, changes should be made with extreme caution. The laboratories should be set up so that there is a minimum of pressure to accommodate new requirements. The dynamics of the system have historically gone the other way. After rebaselining is complete, and criteria for permissible changes established, changes should be made with even more caution, since test-experienced designers will no longer be around."

May summarized by saying:

"Over the years, the need to certify the reliability of weapons which have been the subject of more and more changes, with the tests more and more distant in the past,

and the new tools more and more expensive and needing justification, all this may eventually have a corrosive effect on laboratory leadership and scientific personnel. The best scientists may stay away from that situation. I don't know how future military leaders responsible for procuring new weapons systems will respond. Changes are still being called for. The history of procuring untested weapon systems is not conducive to optimism. This culture must change. The stewardship program is just what the words imply, a program to maintain what exists, not a program to replace nuclear tests for the purpose of further weapons development. It could not do the latter now, and it will be even less able to do it in the future."

May's words of wisdom have only been partly followed. As the SSP has progressed, so has the optimism of those involved. May has been a longtime advocate of arms control but not of a CTB.

Evolution of Themes in Laboratory Directors' Testimonies to Congress

Early after the Senate failed to ratify the CTBT in 1999, the emphasis was on the new nature of the SSP and the challenges that needed to be addressed. A "can-do" attitude that, given enough funding, the job will get done, prevailed. There was also a sense of urgency to develop the necessary stockpile stewardship tools before test-experienced design experts retired. The increasing age of the stockpile has been a consistent theme. However, almost two decades later, there has been no "sky is falling" concerns over the health of the stockpile. Stockpile stewardship research has increased the weapon physics knowledge, and the emphasis has changed to the SSP's accomplishments. There is also an increasing emphasis on the need to satisfy new military requirements that might arise, the need for a strongly supported and sustained program, and the need for competent, scientific and engineering personnel, something that is in the purview of Congress to fund. Throughout this period of time, Laboratory directors have consistently provided to the president stockpile certifications without the need for nuclear testing. **Appendix H** provides snapshots of Laboratory director testimony to Congress between 1999 and 2014, showing both consistency and evolution of their thinking regarding the SSP and certification.

Conclusion

Sixty years ago, a CTBT was regarded by many countries, as well as by many individuals in the U.S., as the most important issue in arms control. Health effects associated with atmospheric testing posed additional issues of concern. The Laboratory and the majority of its scientists regarded a test ban as "technology control," and felt that there were other more important and strategically stabilizing arms control measures to pursue such as the NPT, the ABM treaty, and eventually, arms reduction treaties such as the INF treaty and the Strategic Arms Reduction treaties. There was also a serious concern in the 1950s through the 1980s about strategic technological advantages that the Soviets had achieved and the need for the U.S. to match those advantages through its own nuclear weapons development and nuclear testing. In the early days, we also lacked a lot of the useful computational and experimental tools that we have in today's SSP, as well as the nuclear test database that has been built up over the years, and so confidence was lacking.

A lot has happened over the years, including the breakup of the Soviet Union and several successful arms reduction treaty negotiations. This was all achieved with the help of Laboratory scientists. The SSP that began in the mid-1990s has been a great success, and it continues to grow in its capabilities. So far, Laboratory directors have been able to certify the stockpile as safe, secure, reliable, and effective—without the need for nuclear testing—with confidence each year. The main limitation to our self-imposed nuclear test moratorium has been the inability to work on some advanced nuclear weapon technologies.

The U.S. and Russia haven't conducted a nuclear test since the moratorium of 1992. The CTBT that we signed in 1996 remains unratified, and there are still states that haven't signed the CTBT; 183 states have signed and 166 have ratified the treaty. Of the 44 designated "nuclear-capable states" listed in Annex 2[170] of the treaty, India, Pakistan, and North Korea have not signed; 36 have ratified. Since 2000, a number of other CTB activities have taken place and are documented[*] that amply describe the roles of key participants and stakeholders to date. We are essentially living with a de facto CTB and doing our best to maintain a robust U.S. stockpile for our strategic deterrent, while we anticipate potential threats from other countries. The U.S. still has legitimate, strategic concerns about the threats we face from Russia and China, and proliferation concerns posed by countries such as North Korea and Iran. However, the Laboratory and many in Washington feel that we can address these issues without having to return to testing.

A ratified CTBT and a treaty observed by all countries would offer certain advantages in terms of the treaty's provisions, such as providing for OSIs. However, the world has become a much more complex place in the past sixty years, as witnessed from the increased interest from certain countries to obtain their own nuclear deterrent, along with lingering threats of nuclear terrorism in the world. This history has provided a chronicle of LLNL's contributions along with the author's judgments and key insights based on his experiences and the experiences of those mentioned in this history spanning nearly five decades of U.S. nuclear security policy. It is hoped that this history will help both scholars and practitioners to better understand the challenges of nuclear security in a rapidly changing geopolitical landscape that we face today.

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Epilogue

Paul Brown's excellent account of LLNL's involvement with the CTBT provides not only a detailed history of the Laboratory's technical contributions to and interactions with a complicated policy issue, but it also provides insight into three important themes that are critical to the Laboratory's role in the national security enterprise of the country. These themes are: the culture of academic freedom derived from the Laboratory's long association with the U.C.; the complicated interaction of adversary threats, technology, and policy goals that provide context for most of the initiatives in the national security arena; and the critical but often unstated tension between risk and confidence.

U.C. founded and managed LLNL for most of the Laboratory's history. Three individuals who were instrumental in forming and shaping the early Laboratory were Earnest Lawrence, Edward Teller, and Herb York. These men, who came from a university background, shaped a Laboratory that was dominated by intense technical debate that cultivated alternate points-of-view. This culture was in contrast to that of Los Alamos National Laboratory, which was established during WWII and developed under the influence of the U.S. Army Corps of Engineers. Thus, throughout the discussion of the CTB, the Laboratory simultaneously supported continued nuclear testing while vigorously pursuing technical verification methods that would make a treaty possible. Working on "both sides of the coin" continues to be extremely important to areas such as treaty verification technologies that are informed by an intimate knowledge of implications of the various limitations of that technology, non-proliferation, anti-terrorism, intelligence and counter-intelligence, and defensive technologies such as anti-ballistic missiles. For example, during the SDI, the Laboratory simultaneously worked on several advanced technologies while recommending against early deployment because the technologies were not at a sufficient level of maturity.

Critical to this approach is technical rigor and an openness to all viewpoints, regardless of the policy implications. Examples include Director Roger Batzel's decision to support not only Ray Kidder's report to Congress and subsequent testimony (supporting significant restrictions on nuclear testing and the ease of remanufacturing warheads) but also the alternate view expressed by Alonso, Brown, and Miller. Director Batzel also continued to support nuclear testing while testifying that the Russians were obeying a limit under the TTBT that was consistent with 150 kt (the view of the Reagan administration at the time was to continue nuclear testing, and that the Russians were cheating). Similar examples can be found in evaluations of the uranium enrichment activities of Iraq—the famous "tubes."

A review of the opinions expressed by the Laboratory directors over the decades shows an evolving set of perspectives. Often overlooked is that this evolution reflects not only a change in technical understanding with respect to nuclear weapons, but also a changing environment with respect to the threats presented by the nation's adversaries and the policy goals being pursued. Through the 1970s and 1980s, there were many aspects of proper functioning of nuclear weapons that were poorly understood. The restrictions on nuclear testing were always a potential reality. Dedicated programs existed to pursue enhanced understanding as good, technical management and as preparation to carry out the Laboratory's mission responsibilities as best it can whatever policy actions were taken. Progress was limited by the difficulty of conducting detailed measurements on a nuclear test, the inability to create representative physical conditions in non-nuclear experimental facilities, the limitations of existing and planned computational resources, and the extreme complexity of a nuclear device's physics. By the 1990s, some progress had been made and significant additional improvement was viewed as possible, allowing a supportive approach to the proposed SSP.

The nature of the competition with our adversaries also significantly influenced what the weapons laboratories were expected to accomplish. Over the five decades of active nuclear weapon and delivery system development, 88 different design types were assigned distinct weapon designators. This rapid evolution was the result of advances in capabilities to design weapons and in response to developments, real or perceived, by our adversaries, principally

by the Soviet Union. Advances were only possible through nuclear testing, and the Laboratory directors' responses to the implications of nuclear testing restrictions were explicitly and implicitly in the context of whether this type of competition was expected to continue. Again, by the 1990s, the nature of our competition with the Soviet Union had changed, and the focus became maintaining the existing stockpile rather than developing new weapon systems.

Finally, the directors' responses have always been made in the context of then-current policy goals. In particular, the consequences of a cessation of nuclear testing are very different if the goal is to constrain the developments of a well-established nuclear weapon state (vertical proliferation of the U.S. or the Soviet Union), a developing nuclear state (vertical proliferation of France, the U.K., or China at various times in their history) or of a non-nuclear state or terrorist group (horizontal proliferation). Other important policy considerations include whether or not continued maintenance of a strong nuclear deterrent is desired or whether or not the deterrent is expected to gradually atrophy as a part of the transition to zero nuclear weapons is anticipated.

Former Laboratory director Michael May, in the July 2000 Stanford roundtable highlighted earlier, perhaps expressed the most important comment with respect to the future of the Laboratory's nuclear weapons program:

> *"Over the years, the need to certify the reliability of weapons which have been the subject of more and more changes, with the tests more and more distant in the past, and the new tools more and more expensive and needing justification, all this may eventually have a corrosive effect on laboratory leadership and scientific personnel. The best scientists may stay away from that situation. I don't know how future military leaders responsible for procuring new weapons systems will respond. Changes are still being called for. The history of procuring untested weapon systems is not conducive to optimism. This culture must change. The stewardship program is just what the words imply, a program to maintain what exists, not a program to replace nuclear tests for the purpose of further weapons development. It could not do the latter now, and it will be even less able to do it in the future."*

Years earlier, I distinctly remember similar words from May associated with a briefing I presented to Roger Batzel, Carl Haussman, and May on the design implications of the TTBT. Paraphrased, May said:

> *"I'm not so much worried about you and the judgments you will make, although I'm a little worried even then, but about the designers who come after you and the ones after that. They will begin to believe their calculations of increasing sophistication and make errors in judgment based on their misplaced confidence in themselves."*

Often missing in an explicit fashion is clear discussion of risk; the risk question is often cast in confidence terms; e.g., "Do you have confidence that the system will work?" From a technical point of view, there is no such thing as a "risk-free" decision, so it's about having an acceptable level of risk. The real discussion, in my view, should be about risks and benefits. The complicating factor is that the risks are often technical, and the benefits are often political; e.g., inhibition of a particular behavior. In response to a recent article advocating a return to nuclear testing, I wrote to the author:

> *"In my view, the question of nuclear testing (as well as many other aspects of the Stockpile Stewardship Program) is all about risk management. There were plenty of risks even with nuclear testing.*
>
> *As a technical person, I think data is the heart of our enterprise—data of all types. However, data is not free; within the context of most federal programs, to get more data of one type, you have to sacrifice something else. Balancing across all the needs is paramount—e.g., if you have to give up continuing to advance computing or all "laboratory experiments" to afford full-scale nuclear testing, it's a poor bargain, in my opinion.*
>
> *With very few exceptions, no stockpiled weapon was ever tested in anything that resembles the way it was intended to be used. Compromises, in some cases extensive ones, were*

made. Technical judgment, computations etc., were used to infer the relationship of the actual tested device to the stockpile.

Which brings me to my most important perspective: nuclear weapons were never certified by nuclear tests; nuclear tests were important, but frequently not even the most important part of the process because there were never enough nuclear tests over the full range of conditions to provide certification based on the empirical data from those tests. Certification was a statement of confidence and the judgment of technical experts based on a rigorous process that considered all the available data, computational simulations, considerations of margins, etc.

So my biggest worry is: How do you have confidence in the judgment of the people making the certification decisions? There is, in my view, a very long discussion that needs to take place about this issue. While I have my own views about how much confidence is justified based on the current approach and the risks we are taking, I believe strongly that a serious review by serious, knowledgeable people is appropriate at this juncture."

Stated most simply, my biggest worry is becoming overconfident. Absent the humility and necessity for self-evaluation, overwhelming rigor, and extensive review that come from confronting mother nature and failing, I worry about errors of judgment. My hope is that the U.C. and the Laboratory culture of extensive, technical rigor and review will continue to be applied to the Laboratory's vital national security activities.

So, three themes are important to an understanding of the Laboratory's role in the evolution of the CTBT and the Laboratory directors' willingness to pursue the SSP and its attendant risks. These themes are:

- The culture of academic freedom derived from the Laboratory's long association with the U.C. and other like-minded universities;

- The complicated interaction of adversary threats, technology, and policy goals that provide context for most of the initiatives in the national security arena; and

- The critical, but often unstated, tension between risk and confidence.

Together, these enduring themes are critical to the Laboratory's role in the national security enterprise of the U.S. Although the Laboratory is no longer managed solely by the U.C., the spirit of academic freedom that was inspired by Lawrence, Teller, and York remains. As these themes continue to be an integral part of the planning and execution of the technologies and intelligence products that LLNL's scientists and engineers develop under the leadership of the Laboratory's directors, LLNL will remain successful in fulfilling its missions for our country.

George Miller
LLNL Director Emeritus

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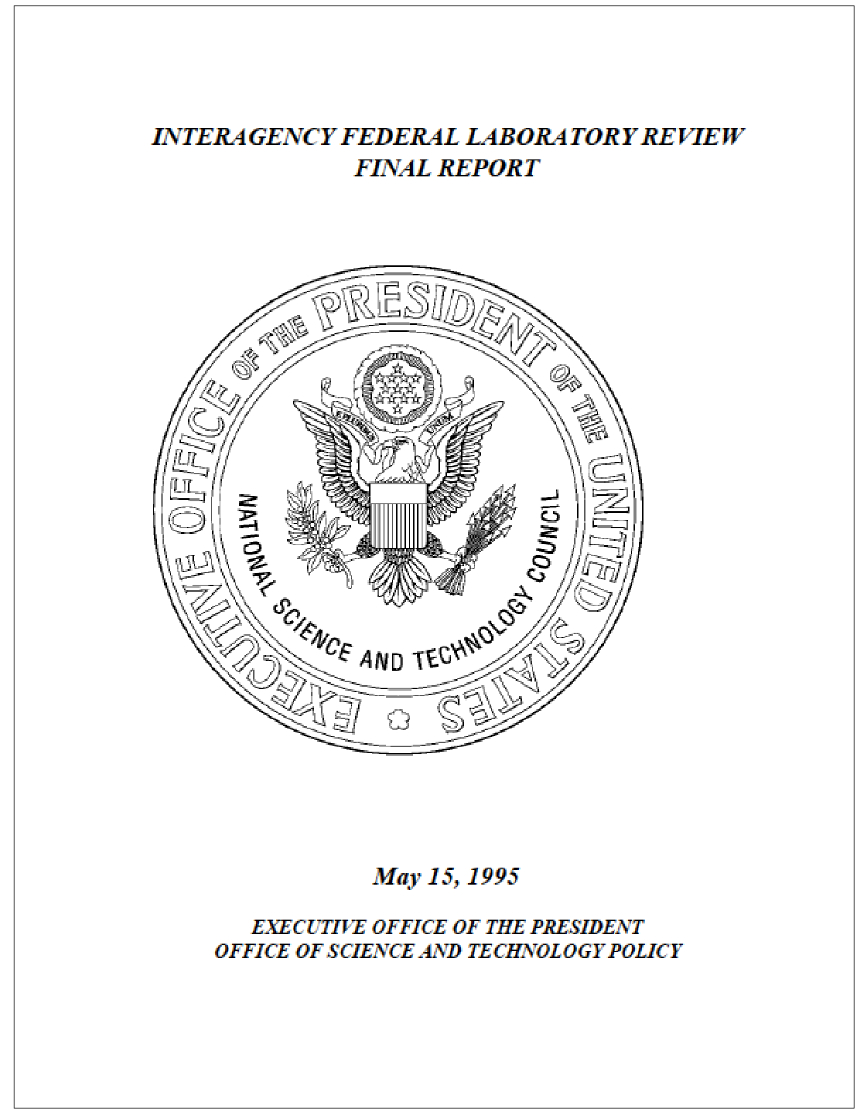
Appendix A: 1995 Federal Laboratory Review—Recommendations for DOE Laboratories

(The White House initiated the Interagency Federal Laboratory Review in 1995, which includes participation from the DoD, DOE, and NASA. It is a broad study by the National Science and Technology Council (NSTC) on ways to improve the efficiency and effectiveness of the federal R&D investment.)


INTERAGENCY FEDERAL LABORATORY REVIEW
FINAL REPORT

May 15, 1995

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY

II. Modernizing the Laboratories for the Post-Cold War Era

A. The Nuclear Weapons Responsibility

Most of DOE's large multi-program laboratories had their origin in the Manhattan Project, to develop nuclear weapons during and after World War II. The three largest laboratories in the system -- Lawrence Livermore, Los Alamos, and Sandia National Laboratories -- have remained the main locus for the design and development of nuclear weapons.

The end of the Cold War has brought great change. No new nuclear weapons are being designed in the United States, and this country is working with other nations to conclude a Comprehensive Test Ban Treaty and a Fissile Materials Production Ban, and has achieved the indefinite extension of the Non-Proliferation Treaty. The major responsibilities for DOE's nuclear weapons program today and into the next century are:

- o to ensure the safety, reliability and security of the Nation's nuclear weapons stockpile, in the absence of nuclear testing;
- o to provide technical support in the areas of non-proliferation, counter-proliferation, verification, and intelligence.

As part of the safety, reliability, and security program, the laboratories may become more involved in some aspects of materials and components production and remanufacture of stockpiled weapons. DOE has already closed some of its large-scale nuclear weapons production facilities and may close others, with transfer of much smaller scale production operations to the weapons labs.

Over the many years that the United States was in direct military competition with the Soviet Union, two DOE laboratories -- Los Alamos and Lawrence Livermore -- were responsible for the design of the nuclear warhead in a system of competition, peer review, and planned redundancy. Sandia's job was to integrate the warheads into a weapons system. Today, all three labs are involved in DOE's science-based stockpile stewardship program, the approach chosen by DOE to ensure safety, reliability, and security, without nuclear testing, of the enduring stockpile after START I and START II reductions.

Since the dissolution of the Soviet Union, spending for core nuclear weapons activities at the three weapons labs has dropped substantially, and staff levels for these core activities are about half what they were at their peak in the 1980s. However, these laboratories also carry out R&D for other DOE programs and other federal agencies. The total employment and budgets, for all activities at the weapons labs, have declined far less from the mid-1980s peak. In constant dollars, total budgets for the three weapons labs were still one-fourth higher in 1995 than they were in 1979; much of that increase comes from work for agencies other than DOE.

The Galvin Task Force concluded that the labs possess excess capacity in areas associated with nuclear weapons design and development; that many of these activities would be transferred, as cost-efficiency allows, from Lawrence Livermore to Los Alamos; and that alternative approaches should be explored for peer review of safety and reliability issues within

an aging stockpile. Lawrence Livermore would retain its current responsibilities for non-proliferation, arms control, and related work.

Other experts hold a contrary opinion. A national security advisory panel to the President of the University of California (the contractor that operates Lawrence Livermore and Los Alamos) recommended that Lawrence Livermore retain its weapons design capability for approximately ten years and continue during this period to provide peer review for the science-based stockpile stewardship program.[1] The argument is that the scientific basis for assuring safety and reliability of the stockpile, without nuclear testing, is not yet well developed. Indeed, there remains considerable technical debate over the kinds of non-explosive testing and evaluation that are most needed.

Another factor is that DOE has taken the first major step toward building a very high power laser, the National Ignition Facility (NIF), at Lawrence Livermore.[2] Through physics experiments involving extremely high temperatures in condensed matter, the NIF can help to maintain expertise in an area of experimental physics fundamental to nuclear weapons design. It can also make important contributions to astrophysics and science generally, and it could help to attract the bright scientific minds that are essential to the science-based stewardship program. A decision to proceed with construction of the NIF is scheduled to be made with the FY 1998 budget, following reviews of non-proliferation and environmental issues. Current estimates are $1.1 billion for construction of the NIF, and $115 million per year for operation, maintenance, and research activities. The Galvin Task Force recommended proceeding with the NIF as a research facility, prioritized with respect to other major research activities.

Budget constraints are a driving force in decisions on eliminating redundancy and restructuring the weapons labs for the post-Cold War era. The Galvin Task Force recommendation favored measured withdrawal (over "several years" in some cases, "five years" in others) of Lawrence Livermore from many weapons activities, largely because it felt redundancy is no longer justifiable. Another way of looking at the budget issue is that, given constrained resources, one lab with the primary weapons design capability could more easily be funded at a robust level than two.

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[1] Letter to Dr. Jack Peltason, President, University of California, from Sidney D. Drell, Chairman, National Security Panel of the U.C. President's Council on the National Laboratories, dated February 16, 1995. All but one of the members of the Panel supported this recommendation. The member who disagreed was a member of the Galvin Task Force.

[2] In October 1994, Secretary of Energy Hazel O'Leary approved Key Decision-1 for the NIF, which authorizes engineering design studies, conditional on the results of a study of proliferation implications of the NIF.

DOE has expressed an "initial favorable disposition" for considering a careful phase-down of some of Livermore's nuclear weapons work, combined with a re-emphasis on non-proliferation and related activities. However, the timing and details of proceeding down this path must depend on assessments of how best to meet our continuing national defense requirements in a wholly new era, the Department said. DOE is examining options, including the Galvin Task Force recommendations, for changes in the configuration of activities at its weapons laboratories.

Recommendations

The serious disagreement among very able and knowledgeable people on whether two nuclear weapons design centers are needed should be resolved.

DOE will develop detailed recommendations for possible changes in configuration of nuclear-weapons-related activities among the three weapons labs, taking into consideration the recommendations of the Galvin Task Force. These recommendations shall be considered by an interagency working group chaired by DOE and including (although not necessarily limited to) DOD, the Department of State, the Office of the Vice President, the staff of the NSC, OMB, OSTP, and the Arms Control and Disarmament Agency. Calling on outside experts as needed, the interagency working group will, by September 30, 1995, address and produce recommendations for resolution of the following issues:

o In order to assure the safety and reliability of the nuclear stockpile in the absence of nuclear testing -- and the security interests of the Nation -- what is our best projection of the functions and capabilities that should be maintained at Lawrence Livermore? Can the essential scientific expertise be maintained in a less costly fashion? The analysis will include a discussion of the comparative costs of keeping two nuclear weapons design centers in full operation at two labs, compared to moving toward one.

o What alternative primary mission or missions (e.g., fundamental science, applied energy programs in conservation and renewables, environmental science and technology) might take advantage, in an efficient and productive manner, of the laboratory's outstanding human talents and facilities? The analysis will also examine the relationship between Lawrence Livermore's mission(s) and a decision on whether to build the National Ignition Facility at Lawrence Livermore.

Recommendations on these issues will be coordinated with the NSC Interagency Working Group, pursuant to its annual review of the stockpile stewardship program. The two reviews shall be considered together, if necessary by a joint NSTC/NSC process, to arrive at recommendations to the President by October 31, 1995.

Appendix B: JASON Report on Nuclear Testing—Summary and Conclusions

We* have examined the experimental and analytic bases for understanding the performance of each of the weapon types that are currently planned to remain in the U.S. enduring nuclear stockpile. We have also examined whether continued underground tests at various nuclear yield thresholds would add significantly to our confidence in this stockpile in the years ahead.

Our starting point for this examination was a detailed review of past experience in developing and testing modern nuclear weapons, their certification and recertification processes, their performance margins (defined as the difference between the minimum expected and the minimum needed yields of the primary), and evidence of aging or other trends over time for each weapon type in the enduring stockpile.

CONCLUSION 1:

The United States can, today, have high confidence in the safety, reliability, and performance margins of the nuclear weapons that are designated to remain in the enduring stockpile. This confidence is based on understanding gained from 50 years of experience and analysis of more than 1000 nuclear tests, including the results of approximately 150 nuclear tests of modern weapon types in the past 20 years.

Looking to future prospects of achieving a Comprehensive Test Ban Treaty (CTBT), a stated goal of the United States Government, we have studied a range of activities that could be of importance to extending our present confidence in the stockpile into the future. We include among these activities underground experiments producing sub-kiloton levels of nuclear yield that might be permitted among the treaty-consistent activities under a CTBT.

Three key assumptions underlie our study:

(1) The U.S. intends to maintain a credible nuclear deterrent.
(2) The U.S. remains committed to the support of worldwide, non-proliferation efforts.
(3) The U.S. will not encounter new military or political circumstances in the future that cause it to abandon the current policy—first announced by President Bush in 1992–of not developing any new nuclear weapon designs.

CONCLUSION 2:

In order to maintain high confidence in the safety, reliability, and performance of the individual types of weapons in the enduring stockpile for several decades under a CTBT, whether or not sub-kiloton tests are permitted, the United States must provide continuing and steady support for a focused, multifaceted program to increase understanding of the enduring stockpile; to detect, anticipate, and evaluate potential aging problems; and to plan for refurbishment and remanufacture, as required. In addition, the U.S. must maintain a significant industrial infrastructure in the nuclear program to do the required replenishing, refurbishing, or remanufacturing of age-affected components, and to evaluate the resulting product; for example, the high explosive, the boost gas system, the tritium loading, etc. Important activities in a stockpile stewardship program that will sustain a strong scientific and technical base, including an experienced cadre of capable scientists and engineers, are described in the body of this study.

The proposed program will generate a large body of technically valuable new data and challenging opportunities capable of attracting and retaining experienced nuclear weapons

* Committee members included: Sidney Drell (chair), John Cornwall, Freeman Dyson, Douglas Eardley, Richard Garwin, David Hammer, John Kammerdiener, Robert LeLevier, Robert Peurifoy, John Richter, Marshall Rosenbluth, Seymour Sack, Jeremiah Sullivan, and Fredrik Zachariasen. JSR-95-320, published August 3, 1995.

scientists and engineers in the program. This is the intent of DOE's currently planned stockpile stewardship program (see the 1994 JASON Report JSR-94-345 on "Science-Based Stockpile Stewardship"). For the success of this program, the management of the three weapons laboratories (LANL, LLNL, SNL) must motivate, support, and reward effort in an area that has lost some of its glamor and excitement in the absence of new nuclear design and test opportunities.

Nevertheless, over the longer term, we may face concerns about whether accumulated changes in age-affected weapons components, whose replacements might have to be manufactured by changed processes, could lead to inadequate performance margins and reduced confidence in the stockpile.

Enhancements of performance margins will add substantially to long-term stockpile confidence with or without underground tests. To cite one example, we can adjust the boost gas fill or shorten the time interval between fills (this is discussed more fully in the classified text).

CONCLUSION 3:

The individual weapon types in the enduring stockpile have a range of performance margins, all of which we judge to be adequate at this time. In each case, we have identified opportunities for further enhancing their performance margins by means that are straightforward and can be incorporated with deliberate speed during scheduled maintenance of remanufacturing activities. However, greatest care in the form of self-discipline will be required to avoid system modifications, if aimed at "improvements," that may compromise reliability.

This brings us to the issue of the usefulness, importance, or necessity of reduced-yield (less than 1 kiloton) underground tests for maintaining confidence in the weapon types in the U.S . stockpile over a long period of time.

For the U. S. stockpile, testing under a 500 ton yield limit would allow studies of boost gas ignition and initial burn, which is a critical step in achieving full primary design yield. The primary argument that we heard in support of the importance of such testing by the U.S. is the following: the evidence in several cases and theoretical analyses indicate that results of a sub-kiloton (approximately 500 tons) test of a given primary that achieves boost gas ignition and initial burn can be extrapolated to give some confidence in the yield of an identical primary with full boosting. Therefore, if a modified or remanufactured primary is introduced into the stockpile in the future to correct some aging problem, such tests on the modified system would add to confidence that the performance of the new primary is still adequate.

It follows from this argument that the utility to the U.S. of testing at yields of up to approximately 500 tons depends on such tests being performed on a continuing basis and yielding reproducible results. If they are permitted only for a few years, such tests could add to the theoretical understanding of the boosting process and the reliability of the computer codes that attempt to describe it, but would not contribute directly to the reliability of the weapon in the enduring stockpile in view of the possible manufacturing changes made at a later date. To gain evidence as to whether long-term changes in age-affected weapons components have any impact on boost-performance, the tests would have to be made with the remanufactured weapons themselves.

CONCLUSION 4:

In order to contribute to long-term confidence in the U.S. stockpile, testing of nuclear weapons under a 500 ton yield limit would have to be done on a continuing basis, which is tantamount to remaking a CTBT into a threshold test ban treaty. While such ongoing testing can add to long-term stockpile confidence, it does not have the same priority as the essential stockpile stewardship program endorsed in Conclusion 2, nor does it merit the same priority as the measures to enhance performance margins in Conclusion 3. In the last analysis the technical contribution of such a testing program must be weighed against its costs and its political impact on the non-proliferation goals of the United States.

CONCLUSION 5:

Underground testing of nuclear weapons at any yield level below that required to initiate boosting is of limited value to the United States. However, experiments involving high explosives and fissionable material that do not reach criticality are useful in improving our understanding of the behavior of weapons materials under relevant physical conditions. They should be included among treaty-consistent activities that are discussed more fully in the text (of the full report).

This conclusion is based on the following two observations:

(a) So-called hydronuclear tests, defined as limited to a nuclear yield of less than 4 lb. TNT equivalent, can be performed only after making changes that drastically alter the primary implosion. A persuasive case has not been made for the utility of hydronuclear tests for detecting small changes in the performance margins for current U.S. weapons. At best, such tests could confirm the safety of a device against producing detectable nuclear yield if its high explosive is detonated accidentally at one point. We find that the U.S. arsenal has neither a present nor anticipated need for such re-confirmation. The existing, large, nuclear test database can serve to validate two-and three-dimensional computational techniques for evaluating any new, one-point safety scenarios, and it should be fully exploited for this purpose.

(b) Testing with nominal yields up to a 100-ton limit permits examination of aspects of the pre-boost fission process. However, this is at best a partial and possibly misleading performance indicator.

An agreement to limit testing to very low yields raises the issue of monitoring compliance. We have not made a detailed study of this issue, but note the following: cooperative, onsite monitoring would be necessary, and relevant measurements, including, for example, neutron yields, could be made without compromising classified information on bomb designs.

We have reviewed the device problems which occurred in the past and which either relied on, or required, nuclear yield tests to resolve.

CONCLUSION 6:

For the weapon types planned to remain in the enduring stockpile, we find that the device problems which occurred in the past, and which either relied on, or required, nuclear yield tests to resolve, were primarily the result of incomplete or inadequate design activities. In part, these were due to the more limited knowledge and computational capabilities of a decade, or more, ago. We are persuaded that those problems have been corrected, and that the weapon types in the enduring stockpile are safe and reliable in the context of explicit military requirements.

Should the U.S., in the future, encounter problems in an existing stockpile design (which we do not anticipate at present) that are so serious as to lead to unacceptable loss of confidence in the safety, effectiveness, or reliability of a weapon type, it is possible that testing of the primary at full yield, and ignition of the secondary, would be required to certify a specified fix. Useful tests to address such problems generate nuclear yields in excess of approximately 10 kt. DOE's currently planned enhanced surveillance and maintenance program is intended to alert us to any such need that may arise. A "supreme national interest" withdrawal clause that is standard in any treaty to which this nation is a signatory would permit the U.S. to respond appropriately should such a need arise.

CONCLUSION 7:

The above findings, as summarized in Conclusions 1 through 6, are consistent with U.S. agreement to enter into a comprehensive Test Ban Treaty (CTBT) of unending duration, that includes a standard "supreme national interest" clause. Recognizing that the challenge of maintaining an effective nuclear stockpile for an indefinite period without benefit of underground tests is an important and also a new one, the U.S. should affirm its readiness to invoke the supreme national interest clause should the need arise as a result of unanticipated technical problems in the enduring stockpile.

Appendix C: PDD/NSC-11—Moratorium on Nuclear Testing

(PDD/NSC-11 text is not available. Below is the press release.)

THE WHITE HOUSE

Office of the Press Secretary

For Immediate Release July 3, 1993

Background Information:

U.S. Policy on Nuclear Testing and a Comprehensive Test Ban

The President announced in his weekly radio address today that his Administration had completed its review of U.S. policy on nuclear testing and a Comprehensive Test Ban (CTB).

Last year, Congress passed the Hatfield-Exon-Mitchell Amendment that directed that a CTB be negotiated by 1996. To allow time to review whether further tests were needed, the Amendment also established an interim moratorium on nuclear testing through July 1, 1993. The Amendment provides that between 1993 and 1996, the United States could carry out up to twelve tests to improve the safety and confirm the reliability of U.S. nuclear weapons. Three other tests could be conducted in cooperation with the United Kingdom.

During the campaign, the President underscored his commitment to achieving a CTB, a commitment that he reaffirmed with President Yeltsin at the Vancouver summit. On April 23, President Clinton announced that we would be starting a consultative process with Russia, our allies and other states, aimed at commencing CTB negotiations at an early date.

After a thorough review, the Administration determined that the nuclear weapons in the United States arsenal are safe and reliable. Additional nuclear tests could help us prepare for a CTB and provide some additional improvements in safety and reliability. However, the President determined that these benefits would be outweighed by the price we would pay in conducting those tests now -- through undercutting of our nonproliferation goals.

The President has therefore decided to extend the current moratorium on U.S. nuclear testing at least through September of next year as long as no other nation tests. He has called on th other nuclear powers to do the same. The President believes tha if these nations join the United States in observing this moratorium, we will be in the strongest possible position to negotiate a CTB treaty.

The President will decide next year whether to extend this "no first test" policy beyond September 1994. His decision will depend on a number of factors, including the status of the CTB negotiations and the willingness of the other nuclear powers to show reciprocal restraint in foregoing their own testing plans. If, however, this moratorium is broken by another state, the President stated that he would direct the Department of Energy (DOE) to prepare to conduct additional tests while he seeks approval by Congress to test pursuant to the Hatfield-Exon-Mitchell Amendment. He has, therefore, directed DOE to maintain a capability to resume testing.

To assure our nuclear deterrent remains unquestioned under a CTB the President has also directed DOE to explore other means of maintaining our confidence in the safety, reliability and performance of our nuclear weapons and to refocus much of the talent and resources of our nation's nuclear laboratories on new technologies to curb the spread of nuclear weapons and verify arms control treaties.

Appendix D: Statement by Ambassador Stephen J. Ledogar (Ret.), Chief U.S. Negotiator of the CTBT

S. Hrg. 106–262

FINAL REVIEW OF THE COMPREHENSIVE NUCLEAR TEST BAN TREATY (Treaty Doc. 105–28)

HEARING

BEFORE THE

COMMITTEE ON FOREIGN RELATIONS
UNITED STATES SENATE

ONE HUNDRED SIXTH CONGRESS

FIRST SESSION

OCTOBER 7, 1999

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which, through the testing that they can do, whether they promise to or not, will make them effective.

There is an extraordinarily naive editorial, which I have to call your attention to, in the New York Times. It says, the treaty's main effect would be to halt programs in other countries. It adds, that since no new nuclear weapons can be reliably developed without testing, ratification of the treaty by enough countries would freeze the nuclear weapons race worldwide. That to my mind is a degree of naivete that is extremely dangerous and is also, incidentally, not very true.

You have countries that have tested. You have two countries in the last year that have tested and demonstrated that they had nuclear capability in India and Pakistan. We have a number of weapons in our stockpile that have essentially been rebuilt, essentially been inspected from time to time, and deterioration has been found.

As is inevitable, the aging process affects weapons also, Mr. Chairman, unfortunately, and when a new component is put in to replace an old component, you do not know if it is going to work. You do not know if they are going to mesh together.

There is something—I do not know how many, but close to, I think it is safe to say, thousands of moving parts in these terrible weapons, and you have no way of knowing that all of these things are going to mesh by consulting a computer, particularly not if you have to wait till 2008 to get the kind of computer that will be reasonably reliable. So the question really comes down to is the kind of testing that is being done.

Other countries will test, other countries may be sure, or they may not be sure that theirs will work. If they are sure we have not received the absolute assurance that ours will work, we will not have any idea of being able to stop the proliferation of those countries trying. Any uncertainty about the effectiveness of our deterrent weakens that deterrent.

The whole point of a deterrent is the ability to be able to let hostile nations know, and let the world know that should an attack come, we have the capability of responding. Not a pleasant concept, not a good idea, but we do not make the world in which we live. We have to rely on the kinds of weapons we have to keep the peace.

And so I think the important thing to bear in mind here, Mr. Chairman, is really what the treaty means, and in the essence, the treaty means we would be committing ourselves in perpetuity, forever, not to use the most effective means of being able to assure us and the world that our stockpile works, and for that reason I would very much oppose the treaty, and I would hope the Senate would, too.

Thank you, sir.

The CHAIRMAN. Thank you, sir. Mr. Ambassador, we would be glad to hear from you.

STATEMENT OF HON. STEPHEN J. LEDOGAR, FORMER CHIEF NEGOTIATOR OF THE COMPREHENSIVE TEST BAN TREATY

Ambassador LEDOGAR. Mr. Chairman, distinguished members of the committee. Thank you for this opportunity to speak to you

about the Comprehensive Test Ban Treaty which is before the committee for consideration.

First, a few things about my background, which I would mention only because I think they are relevant to what I'll say about the treaty. After 4 years as an active duty Naval aviator and 5 years in private industry as a lawyer, I joined the Foreign Service and served for 38 years before retiring 2 years ago.

Most of my career I worked in political-military affairs and arms control, including stints as deputy chief of mission to NATO, press spokesman and member of the delegation to the Vietnam Paris peace talks.

And I'd like to point out that I'm a strong believer in nuclear deterrence and I know how central nuclear deterrence is to NATO. During my last 10 years of full time service, I was privileged to be an ambassador under Presidents Reagan, Bush and Clinton, serving in turn as head of several U.S. delegations in Vienna and Geneva. I was chief U.S. negotiator from start to finish of the CTBT. Currently, I'm a part time consultant to the Department of State on national security matters.

As I understand your invitation, Mr. Chairman, I'm not here to give this committee the authoritative administration pitch on CTBT. Secretary Albright and others will do that. Rather, I'm here primarily as a resource to help recall and detail key elements of the treaty as they were fought out in the negotiating trenches between 1993 and signature in September 1996.

I should say, however, that not surprisingly, I fully support the treaty, believing that it is very much in the security interests of the United States. It was carefully negotiated by me and my multi agency delegation throughout, always acting on fully cleared front channel instructions. And I'm prepared to try to explain and defend all of it's key provisions and, if my memory serves, to try to give you any background you might be interested in having.

In the short time I have in this opening statement, I'll limit my discussion to just three issues that I believe are sources of some confusion. Over the course of the last few days, I have heard opinions expressed on the question of the CTBT's scope, it's verification provisions, and it's entry into force provisions. Some of the debate suggests to me that aspects of the negotiations have not yet been fully understood. I hope that I may help to shed some light on these issues. Last, I would like to address the likely international repercussions should the Senate fail to give its consent to ratification.

First of all on the scope. Let me address that issue as it develops in the negotiation. As the name suggests, the treaty imposes a comprehensive ban on all nuclear explosions, of any size, in any place. I have heard some critics of the treaty seek to cast doubt on whether Russia, in the negotiating and signing of the treaty, committed itself under treaty law to a truly comprehensive prohibition of any nuclear explosion, including an explosion or experiment or event of even the slightest nuclear yield. In other words, did Russia agree that hydronuclear experiments which do produce a nuclear yield, although usually very, very slight, would be banned and that hydrodynamic explosions, which have no yield because they do not reach criticality, would not be banned.

The answer is a categoric "yes." The Russians as well as the rest of the P–5 did commit themselves. That answer is substantiated by the record of the negotiations at almost any level of technicality and national security classification that is desired and permitted. More importantly, for the current debate, it is also substantiated by the public record of statements by high level Russian officials as their position on the question of thresholds evolved and fell into line with the consensus that emerged.

It is important to recall that each of the five nuclear weapons states began the CTBT negotiations desirous of a quiet understanding among themselves that some low level of nuclear explosions or experiments that did produce nuclear yield would be acceptable, at least among themselves, despite the broad treaty prohibition of "any nuclear weapon test explosion or any other nuclear explosion." Until August 1995, the beginning of the final year of negotiations, the U.S. pushed for agreement on a very low threshold of nuclear yield.

Our position was not popular among the P–5. Because of our greater test experience and technical capabilities, we could conceivably gain useful data from events of almost insignificant yield. The other four argued that they needed a higher threshold in order to gain any useful data. In some cases, the thresholds they pushed for were politically impossible to square with the notion of a comprehensive test ban. Russia, for example, insisted that if there was going to be any threshold among the five, it would have to allow for so called experiments with nuclear yields of up to 10 tons of TNT equivalent.

The dispute among the five threatened to halt the negotiations, as it became increasingly known to others that the five were squabbling with each other about how much wiggle room would be left to them when they signed onto a text that said simply that nuclear explosions would be banned.

And as the arcane and jargon filled complexities of the nuclear testing communities in Novaya Zemyla, Lop Nor, Mururoa and Nevada became more widely understood, the non nuclear states and broad public opinion increasingly insisted that the five should be allowed no tolerance, not even for the smallest possible nuclear yields. A ban should be a ban. The answer to this dilemma should be no threshold for anybody. In other words, zero should mean zero.

On August 11, 1995 President Clinton announced that the United States was revising its prior position on the threshold question and would henceforth argue to the other four nuclear weapons states that no tests that produced a nuclear yield should be allowed to anyone under the treaty. The Russians, who were miffed at being taken by surprise, climbed down from their original positions slowly and painfully. It took until April 1996 before they signed onto the sweeping categoric prohibition that is found in the final text. They never did like the word "zero" which was bandied about in public and actually once used by Boris Yeltsin.

Instead, they announced that they embraced a treaty with no thresholds whatsoever. In the confidential negotiations among the five nuclear weapons states that went on the entire time the broader CTBT negotiations continued, it was clearly understood that the

boundary line, that is, the zero line, between what would be prohibited to all under the treaty and what would not be prohibited, would be precisely defined by the question of nuclear yield or criticality. If what you did produced any nuclear yield whatsoever, it would not be allowed. If it didn't, it was allowed.

Another issue I would like to address is how the treaty's verification regime developed and how it benefits the United States. I will leave it to others more expert than I to provide more precise assessments of U.S. monitoring capabilities. The point I would like to stress here is that the U.S. succeeded in the negotiations in getting virtually every thing the intelligence community and other parts of the government wanted from the treaty, wanted and were prepared to pay for, to strengthen our ability to detect and deter cheating and to seek appropriate redress if cheating did occur.

At the same time, we succeeded in getting virtually everything the Defense Department and others wanted to insure the protection of sensitive national security information. Let me give you several examples.

Concerning the use of national technical means, the United States fought like mad to win acceptance of a state's rights to use evidence acquired through national technical means as it saw fit when requesting an onsite inspection. But we did not want to be forced to reveal any information we believed would be better kept private. Now, this was a "red line" issue for the United States. Many of our negotiating partners were adamantly opposed to giving the U.S. what they considered was a clear advantage and a license to spy.

Yes, it is true that the U.S. has satellite surveillance and intercept capabilities that surpass anything others have, but is it logical to penalize and ignore the evidence of the tall person with good eyesight who can see the crime committed across the room? Eventually the U.S. position prevailed and is incorporated in the treaty.

This treaty provides for onsite inspections on request by any treaty party with the approval of the executive council. No state can refuse an inspection. The U.S. position from the start was that onsite inspections were critical to provide us with added confidence that we could detect violations. And, if inspections were to be effective, they had to be conducted absolutely as quickly as possible after a suspicion arose, using a range of techniques with as few restrictions as possible.

However, the U.S. also had to be concerned with its defensive posture as well as an offensive one. It was necessary to insure that sensitive national security information would be protected in the event of an inspection on U.S. territory. The U.S. crafted a complicated, highly detailed proposal that balanced our offensive and defensive needs. There was resistance from some of our negotiating partners. However, by the time we were through, the treaty read pretty much like the original U.S. position paper that had been put together jointly by the Departments of Defense, Energy and State, the intelligence community and the then existing Arms Control Agency.

I would like to touch on the composition of the International Monitoring System, four networks of different types of remote sensors encompassing 321 stations. I believe I have heard questions about its value added. The intelligence community, working through the larger interagency community, had a list of requirements. They wanted certain technologies and they wanted certain stations that would fill gaps and complement existing national monitoring capabilities.

The U.S. delegation delivered nearly everything requested. You have only to look at the coverage that would be established if the treaty enters into force, the coverage in Russia, China and the Middle East, to see the augmentation of U.S. capabilities and the range of technologies to appreciate the potential value added of an International Monitoring System.

Some people have criticized the treaty because it does not provide for sanctions against the state, it has violated it. This criticism strikes me as ill-informed. Consistent with traditional U.S. policy, I was under strict instructions to object to the inclusion of sanctions. The U.S. view, which I believe this committee strongly endorses, is that we will not agree to appoint an international organization to be not just the investigator and special prosecutor, but also the judge, jury and jailer. The U.S. reserves for itself the authority to make judgments about compliance. And, we reserve for a body higher than the one established by this treaty, namely, the United Nations Security Council, in which we have a veto, the authority to levy sanctions or other measures. This is U.S. policy and this policy is reflected in the treaty.

Now a word on the treaty's entry into force requirements. These have been the topic of much discussion and have even been offered as a reason for why the U.S. should postpone its ratification. As you know, the treaty does not enter into force until 44 named states have deposited their instruments of ratification. The named states are those that have nuclear research or power reactors and were at the same time members of the Conference on Disarmament.

It is true that this requirement erects a high barrier. It also, in my opinion, reflects a core reality from which there is no escape. The treaty would not work without the participation of all five nuclear weapons states and the three so-called threshold states, India, Pakistan and Israel, who are not yet bound by the nonproliferation treaty.

The U.S. would not foreswear all future testing if China and Russia were not similarly bound, and vice versa. China ties its adherence to India, India to Pakistan, and so forth. It's an interlocking reality a political reality among the eight. Israeli adherence is demanded by all. In my opinion, it did not much matter what exact formulation was used. The reality was that all eight were required.

It does not follow that the U.S. can afford to wait until the other 43 have ratified the treaty. I have always believed that if you want something, you must get out in front. That is the American way. We must lead, not follow meekly behind. It is our burden and our advantage that other states will follow our lead. The day the United States submitted its ratification of the Chemical Weapons Convention, China and four other countries followed, the same day. Cuba, Iran, Pakistan and Russia followed shortly thereafter.

What if the U.S. chooses not to ratify this treaty? I believe my experience in the CTBT negotiations and many years of representing the United States in multilateral diplomacy render me competent to speculate on the international reaction to such a possibility. I am not given to hyperbole, but I believe it is not an exaggeration to say that there will be jubilation among our foes and despair among our allies and friends.

Iran, Iraq, North Korea and other states that harbor nuclear aspirations surely will feel the constraints loosening. Our allies and other friends will feel deserted and betrayed. The global nuclear nonproliferation regime will be endangered. Some isolationists may not believe this regime is worth protecting and that the U.S. can take care of the problem itself. But we need cooperation in my judgment from states like Russia and our European allies, if only to help control exports if we are to prevent states from acquiring nuclear weapons. France, for example, which has already ratified the CTBT, will be even less responsive to U.S. pleas to contain Iraq and Iran if the U.S. walks away from this treaty, whose successful negotiation the United States led.

I am not an expert on South Asian policy, but I believe that if the U.S. fails to ratify the CTBT, we should brace ourselves for more Indian tests. Pakistan, of course, would match India test for test.

The CHAIRMAN. Mr. Ambassador, would you forgive me please? We have a vote on and I suggest that Senators go cast their votes and I will stay here, then it may save time.

Senator BOXER. Mr. Chairman, I just wondered, when we come back, we will have an opportunity to question, is that correct?

The CHAIRMAN. Sure.

Ambassador LEDOGAR. I only have about two more sentences.

China will not ratify the test ban if the U.S. does not. We can expect China to put itself in a position to resume testing, especially if India tests, and the chain reaction may not end there. Japan could face pressure to reconsider its nuclear abstinence if China and India buildup their nuclear forces. And Russia, of course, remains a wild card.

I trust you will have questions and I am prepared to respond.

[The prepared statement of Ambassador Ledogar follows:]

PREPARED STATEMENT OF HON. STEPHEN J. LEDOGAR

Mr. Chairman, distinguished members of the committee, thank you for this opportunity to speak to you about the Comprehensive Nuclear Test Ban Treaty, which is before your committee for consideration.

First, a few things about my background which I mention only because I think they are relevant to what I will say about the Treaty. After four years of active duty as a Naval Aviator and five years in Private Industry as a lawyer, I joined the Foreign Service and served for 38 years before retiring two years ago. Most of my career, I worked in Political-Military Affairs and Arms Control including stints as Deputy Chief of Mission to NATO, and press spokesman and member of the delegation to the Vietnam Peace Talks in Paris. I am a strong believer in nuclear deterrence and I know how central it is to NATO. During my last ten years of full time service, I was privileged to be an Ambassador under Presidents Reagan, Bush and Clinton, serving in turn as head of several U.S. delegations in Vienna and Geneva. I was chief U.S. negotiator from start to finish of the CTBT. Currently, I'm a part-time consultant to the Department of State on national security matters.

As I understand your invitation, Mr. Chairman, I'm not here to give this committee the authoritative administration pitch on the CTBT. Secretary Albright and others will do that. Rather, I'm here primarily as a resource to help recall and detail key elements of the Treaty as they were fought out in the negotiating trenches between 1993 and signature in September 1996. I should say, however, that, not surprisingly, I fully support the Treaty believing that it is very much in the security interests of the United States. It was carefully negotiated by me and my multi-agency delegation throughout, always acting on fully cleared front channel instructions. I'm prepared to try to explain and defend all its key provisions, and if memory serves to try to give you any background you might be interested in having.

In the short time I have in this opening statement, I will limit my discussion to just three issues that I believe are sources of some confusion. Over the course of the last few days, I have heard opinions expressed on the question of the CTBT's scope, its verification provisions, and its entry into force provisions. Some of the debate suggests to me that aspects of the negotiations have not yet been fully understood. I hope that I may help to shed some light on these issues. Lastly, I would like to address the likely international repercussions should the Senate fail to give its consent to ratification.

SCOPE OF THE CTBT

First, let me address the scope of the CTBT. As the name suggests, the Treaty imposes a comprehensive ban on all nuclear explosions, of any size, in any place. I have heard some critics of the Treaty seek to cast doubt on whether Russia, in the negotiation and signing of the Treaty, committed itself under treaty law to a truly comprehensive prohibition of any nuclear explosion, including an explosion/experiment/event of even the slightest nuclear yield. In other words, did Russia agree that hydronuclear experiments (which do produce a nuclear yield, although very, very slight) would be banned, and that hydrodynamic explosions (which have no yield because they do not reach criticality) would not be banned?

The answer is a categoric "yes." The Russians, as well as the other weapon states, did commit themselves. That answer is substantiated by the record of the negotiations at almost any level of technicality (and national security classification) that is desired and permitted. More importantly for the current debate, it is also substantiated by the public record of statements by high level Russian officials as their position on the question of thresholds evolved and fell into line with the consensus that emerged.

It is important to recall that each of the five nuclear weapon states began the CTBT negotiations desirous of a quiet understanding among themselves that some low level nuclear explosions/experiments that did produce nuclear yield would be acceptable at least among themselves despite the broad treaty prohibition of "any nuclear weapon test explosion or any other nuclear explosion." Until August of 1995, the beginning of the final year of negotiations, the U.S. pushed for agreement on a very low threshold of nuclear yield. Our position was not popular among the P 5. Because of our greater test experience and technical capabilities, we could conceivably gain useful data from events of almost insignificant yield. The other four argued that they needed a higher threshold in order to gain any useful data. In some cases the thresholds they pushed for were politically impossible to square with the notion of a comprehensive test *ban*. Russia for example insisted that if there was going to be any threshold among the five it would have to allow for so-called experiments with nuclear yields of up to ten tons of TNT equivalent.

The dispute among the five threatened to halt the negotiations as it became increasingly known to others that the five were squabbling with each other about how much wiggle room would be left to them when they signed onto a text that said simply that nuclear explosions would be banned. As the arcane and jargon filled complexities of the nuclear testing communities in Novaya Zemyla, Lop Nor, Mururoa, and Nevada became more widely understood, the nonnuclear states and broad public opinion increasingly insisted that the five should be allowed no tolerance—not even for the smallest possible nuclear yields. A ban should be a ban. The answer to this dilemma should be no threshold for anybody; i.e., zero means zero.

On August 11, 1995, President Clinton announced that the United States was revising its prior position on the threshold question and would henceforth argue to the other four nuclear weapon states that no tests that produced a nuclear yield should be allowed to anyone under the treaty. The Russians, who were miffed at being taken by surprise, climbed down from their original position slowly and painfully. It took until April of 1996 before they signed onto the sweeping, categoric prohibition that is found in the final text. They never did like the "zero" word which was bandied around in public (and actually used once by Boris Yeltsin). Instead, they announced that they embraced a treaty with no threshold whatsoever. In the confidential negotiations among the five nuclear weapon states that went on the entire time the broader CTBT negotiations continued, it was clearly understood and

that the boundary line—the "zero line" between what would be prohibited to all under the treaty and what would not be prohibited—was precisely defined by the question of nuclear yield or criticality. If what you did produced any yield whatsoever, it was not allowed. If it didn't, it was allowed.

CTBT VERIFICATION REGIME

Another issue I would like to address is how the Treaty's verification regime developed and how it benefits the U.S. I will leave it to others more expert than I to provide precise assessments of U.S. monitoring capabilities. The point I would like to stress here is that the U.S. succeeded in the negotiations in getting virtually everything the intelligence community and other parts of the government wanted from the Treaty to strengthen our ability to detect and deter cheating and to seek appropriate redress if cheating did occur. At the same time, we succeeded in getting virtually everything the Defense Department and others wanted to ensure the protection of sensitive national security information. Let me give you several examples.

Concerning the use of National Technical Means, the U.S. fought like mad to win acceptance of a state's right to use evidence acquired through NTM, as it saw fit, when requesting an on-site inspection. But we did not want to be forced to reveal any information we believed would be better kept private. This was a "red line" position for the U.S. Many of our negotiating partners were adamantly opposed to giving the U.S. what they considered was a clear advantage and a license to spy. Yes, it is true that the U.S. has satellite surveillance and intercept capabilities that surpass others', but is it logical to penalize and ignore the evidence of the tall person with good eyesight who can see the crime committed across the room? The U.S. position prevailed.

This Treaty provides for on-site inspections on request by any Treaty party and with the approval of the Executive Council. No state can refuse an inspection. The U.S. position from the start was that on site inspections were critical to provide us with added confidence that we could detect violations. And, if inspections were to be effective, they had to be conducted absolutely as quickly as possible after a suspicion arose, using a range of techniques with as few restrictions as possible. However, the U.S. also had to be concerned with its defensive posture, as well as an offensive one. It was necessary to ensure that sensitive national security information would be protected in the event of an inspection on U.S. territory. The U.S. crafted a complicated, highly detailed, proposal that balanced our offensive and defensive needs. There was resistance from some of our negotiating partners. However, by the time we were through, the Treaty read pretty much like the original U.S. paper put together jointly by the Departments of Defense, Energy and State, the Intelligence Community, and the then-existing Arms Control Agency.

I would like to touch on the composition of the International Monitoring System—four networks of different types of remote sensors encompassing 321 stations—because I have heard questions about its value added. The intelligence community, working through the larger interagency community, had a list of requirements. They wanted certain technologies and they wanted certain stations that would fill gaps and complement existing national monitoring capabilities. The U.S. delegation delivered nearly everything requested. You have only to look at the coverage in Russia, China and the Middle East, and the range of technologies, to appreciate the potential value added of the IMS.

Some people have criticized the Treaty because it does not provide for sanctions against a state that has violated it. This criticism strikes me as ill informed. Consistent with traditional U.S. policy, I was under strict instructions to object to the inclusion of sanctions. The U.S. view, which I believe this Committee strongly endorses, is that we will not agree to appoint an international organization to be not just the investigator and special prosecutor, but also the judge, jury, and jailer. The U.S. reserves for itself the authority to make judgements about compliance. And we reserve for a higher body, the United Nations Security Council in which we have a veto, the authority to levy sanctions or other measures. This is U.S. policy. This is the Treaty's policy.

ENTRY INTO FORCE REQUIREMENTS

The Treaty's entry into force requirements have been the topic of much discussion and even offered as a reason for why the U.S. should postpone its ratification. As you know, the Treaty does not enter into force until 44 named states have deposited their instruments of ratification. The named states are those that have nuclear research or reactor reactors and were members of the Conference on Disarmament.

It is true that this requirement erects a high barrier. It also, in my opinion, reflects a core reality from which there was no escape. The Treaty would not work without the participation of the five nuclear weapon states and the three so-called threshold states, India, Pakistan and Israel, who are not yet bound by the NPT. The U.S. would not foreswear all future testing if China and Russia were not similarly bound. China ties its adherence to India, India to Pakistan. And Israeli adherence was demanded by all. In my opinion, it did not much matter what the exact formulation was. The reality stood that all eight were required.

It does not follow that the U.S. can afford to wait until the other 43 have ratified the Treaty. I have always believed that if you want something, you must get out in front. This is the American way. We must lead, not follow meekly behind. It is our burden and our advantage that other states will follow our lead. The day the United States submitted its ratification to the Chemical Weapons Convention, China and four other countries followed. Cuba, Iran, Pakistan, and Russia followed shortly thereafter.

What if the United States chooses not to ratify this treaty? I believe that my experience in the CTBT negotiations and many years of representing the U.S. in multilateral diplomacy, render me competent to speculate on the international reaction to such a possibility.

I am not given to hyperbole, but I believe it is not an exaggeration to say that there will be jubilation among our foes and despair among our friends. Iran, Iraq, North Korea and other states that harbor nuclear aspirations surely will feel the constraints loosening. Our allies and friends will feel deserted and betrayed. The global nuclear nonproliferation regime will be endangered. Some isolationists may not believe this regime is worth protecting: that the U.S. can take care of the problem itself. But we need cooperation from states like Russia and our European allies in controlling exports if we are to prevent states from acquiring nuclear weapons. France, for example, which has already ratified the CTBT, will be even less inclined to heed U.S. pleas to contain Iraq and Iran if the U.S. walks away from the Treaty, whose successful negotiations the U.S. led.

I am not an expert in South Asia policy, but I believe that if the U.S. fails to ratify the CTBT we should brace ourselves for more Indian tests. Pakistan, of course, would match India test for test. China will not ratify the test ban if the U.S. does not. We can expect China to ready itself to resume testing, especially if India tests. And the chain reaction may not end there. Japan will face pressure to reconsider its nuclear abstinence if China and India are developing nuclear forces. And Russia, of course, remains a wild card.

I trust you have questions about the negotiating history or certain Treaty elements. I would be pleased to provide whatever information I can.

The CHAIRMAN. All right. We are going to hopscotch on this. The Senator from Minnesota will take his 5 minutes and then I will go and Chuck Hagel has already gone and will come back. We have to play a tag game here.

Senator GRAMS. Thank you very much. I will not be able to come back, so I am going to stay and keep the hearing going until some of the others come back so I have the opportunity to ask some questions and again, I appreciate your being here and your testimony.

You know the original official negotiating position of the Clinton administration in Geneva was to have a treaty which, one, had a definite duration, 10 years; two, permitted low yield tests, 4 pounds, and was also verifiable. Those were some of the conditions they set out with.

If the administration had negotiated a treaty along those lines, I think it would have had a better chance of being ratified today. Instead, I think we have ended up with a treaty of unlimited duration, zero yield, which is clearly unverifiable. So my question is, and I'll start with Ms. Kirkpatrick, do you think it was wise for the Clinton administration to move so far from what was our original position?

Ambassador KIRKPATRICK. No, Senator Grams, I do not. I think the original position was a reasonable one, which provided—first of all, it provided for verification and verifiability, but it also provided

Appendix E: Article-by-Article Analysis of the Comprehensive Nuclear Test Ban Treaty, Article I—Basic Obligations, Activities Not Affected by the Treaty

(source: http://www.state.gov/t/avc/trty/16522.htm)

Activities Not Affected By The Treaty

The U.S. decided at the outset of negotiations that it was unnecessary, and probably would be problematic, to seek to include a definition in the Treaty text of a "nuclear weapon test explosion or any other nuclear explosion" for the purpose of specifying in technical terms what is prohibited by the Treaty. It is important to emphasize that Article I prohibits only nuclear explosions, not all activities involving a release of nuclear energy. It is clearly understood by all negotiating parties, as a result of President Clinton's announcement on August 11, 1995, that the U.S. will continue to conduct a range of nuclear weapon-related activities to ensure the safety and reliability of its nuclear weapons stockpile, some of which, while not involving a nuclear explosion, may result in the release of nuclear energy. Such activities, a number of which are planned as part of the Stockpile Stewardship and Management Program (SSMP), could include: computer modeling; experiments using fast burst or pulse reactors; experiments using pulse power facilities; inertial confinement fusion (ICF) and similar experiments; property research of materials, including high explosives and fissile materials, and hydrodynamic experiments, including subcritical experiments involving fissile material. None of these activities will constitute a nuclear explosion. Similarly, activities related to the operation of nuclear power and research reactors and the operation of accelerators are not prohibited pursuant to Article I, despite the fact that such activities may result in the release of nuclear energy. The examples of activities not prohibited by the Treaty cited above are not all-inclusive, but are illustrative.

Concerning ICF, the U.S. statement made at the 1975 NPT Review Conference established that energy sources "involving nuclear reactions initiated in millimeter-sized pellets of fissionable and/or fusionable material by lasers or by energetic beams of particles, in which the energy releases, while extremely rapid, are designed to be and will be non-destructively contained within a suitable vessel" do not constitute "a nuclear explosive device within the meaning of the NPT or undertakings in IAEA safeguards agreements against diversion to any nuclear explosive device." Thus, such energy releases at the planned National Ignition Facility, as well as at existing facilities such as the NOVA laser facility, are not considered nuclear explosions and are not prohibited by the Treaty.

With respect to the obligation "not to carry out" any nuclear explosion, the negotiating record reveals that Article I does not limit in any way a State Party's ability to conduct activities in preparation for a nuclear weapon test explosion or any other nuclear explosion. During the negotiations, a proposal to prohibit such preparations was rejected as being unnecessary, too difficult to define, and too complicated and costly to verify. In addition, the U.S. opposed this proposal because it might interfere with its ability to maintain the basic capability to resume nuclear test activities prohibited by the Treaty should the United States exercise its "supreme interests" rights pursuant to Article IX and withdraw from the Treaty - one of the Treaty Safeguards announced by the White House on August 11, 1995.

Although preparations would not constitute non-compliance, a State Party could use the consultation and clarification procedures set forth in Article IV to address concerns about such preparations. In addition, irrespective of the CTBT, any state with information regarding another state's preparations to conduct a nuclear explosion could bring the matter directly to the attention of the UN Security Council.

The United States understands that Article I, paragraph 1 does not prohibit any activities not involving nuclear explosions that are required to maintain the safety, security, and reliability of the U.S. nuclear stockpile, to include: design, development, production, and remanufacture of nuclear weapons, replacement of weapon parts, flight testing of weapon components, engineering tests of the mechanical and electrical integrity of weapon components under a variety of environmental conditions, and changes to weapons. The United States also understands that the CTBT does not prohibit disposal or rendering safe of damaged weapons and terrorist devices, and experiments not involving nuclear explosions to develop render-safe methods.

Finally, the obligation "not to carry out any nuclear weapon test explosion or any other nuclear explosion" does not place limitations on the ability of the United States to use nuclear weapons. As noted above, the phrase "or any other nuclear explosion" is identical in meaning to that of the same text in the LTBT, where it was clearly understood that the phrase would not apply to a prohibition of the use of nuclear weapons in the event of war. Similarly, the CTBT negotiating record demonstrates that the prohibitions in Article I do not apply to the use of nuclear weapons. The U.S. position, which was repeated on numerous occasions, was that any proposed undertakings relating to the use of nuclear weapons were totally beyond the scope of this Treaty and the mandate for its negotiation. Moreover, the Preamble reflects this view in that it does not in any way address the issue of the use of nuclear weapons. Thus, Article I of the Treaty cannot be deemed to prohibit the use of nuclear weapons or restrict the exercise of the right of self-defense recognized in Article 51 of the Charter of the United Nations.

Appendix F: LLNL Staff on Assignment in Washington Leading up to and during Ratification Hearings of the CTBT

The following individuals were on assignment to DOE and other Washington agencies during the critical buildup to the CTBT and the deliberations (including ratification efforts) that followed its negotiation. The entries are listed in reverse chronological order, with the approximate year. It is not clear who on this list was directly involved in CTB issues.

Date	Laboratory employee	Assignment location
2002	Ted Saito	Department of Energy, National Nuclear Security Administration, Office of Defense Programs
2000	Wayne Hofer	Office of the Assistant to the Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs
1999	Wayne Hofer	Office of the Assistant to the Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs
	Al Holt	Office of the Secretary of Defense for Acquisition, Technology, and Logistics
1998	Kirk Levedahl	Department of Energy Office of Defense Programs
	Gerald Kiernan	Department of Energy Office of Arms Control
	Bill Slivinsky	Department of Energy Office of Arms Control and Nuclear Nonproliferation-30
	Wayne Hofer	Office of the Assistant Secretary of Defense for Atomic Energy
1997	Wayne Hofer	Office of the Assistant to the Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs
1995–1996	Paul Brown	Department of Energy Office of Arms Control (part time while Dorothy Donnelly was in Geneva)
	Dave Dorn	Department of Energy Office of Arms Control
	Bill Zagotta	Department of Energy Office of Arms Control
	Bill Slivinsky	Department of Energy Office of Arms Control, Nuclear Nonproliferation-30
	Wayne Hofer	Office of the Assistant to the Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs
	Bob Clough	Department of Energy Defense Programs and Nuclear Nonproliferation-40
	Robin Staffin	Office of the Assistant to the Secretary of Defense for Atomic Energy
	John Harvey	Office of the Assistant to the Secretary of Defense for Atomic Energy (though perhaps no longer working at LLNL at the time)
	Larry Ferderber	Senator Harry Reid's office
	Bob Perret	Senator Harry Reid's office
	Jim Morgan	Department of Energy Office of Arms Control
	Bill Bookless	Department of Energy Office of Defense Programs
	Craig Wuest	Department of Energy Office of Defense Programs Science Council
1994	Larry Schwartz	Department of Energy, Energy Programs
	Bill Zagotta	Department of Energy Office of Arms Control
	Robin Staffin	Department of Energy Defense Programs
	Alden (Jerry) Mullins	Department of State Arms Control and Disarmament Agency
1993	Carl Poppe	Department of Energy Office of Arms Control
	Edward Woolery	Office of the Assistant Secretary of Defense for Atomic Energy
	Alden (Jerry) Mullins	Arms Control and Disarmament Agency
	Gary Samore	Department of Energy Office of Nuclear Nonproliferation
1992	Carl Poppe	Department of Energy Office of Arms Control
	Edward Woolery	Department of Energy Office of Arms Control
	Tawny (TR) Koncher	Office of the Secretary of Defense, Policy
	Tom Ramos	Office of the Assistant to the Secretary of Defense for Atomic Energy
1991	Buddy Swingle	Office of the Assistant to the Secretary of Defense for Atomic Energy
	Frank Handler	Phase One Engineering Team (POET)

Appendix G: Letter to Senator Kyl with Questions and Responses from Bruce Tarter

S. Hrg. 105–267

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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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.

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 plu-

tonium 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.

[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.

[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.

Appendix H: Laboratory Director Testimony

Bruce Tarter testimony, October 1999

In October 1999, Laboratory Director Bruce Tarter testified[H1] before the SASC. Tarter's written testimony said:

"The bottom line remains the same as it has been in my previous testimonies before this committee. Namely, that a strongly supported, sustained stockpile stewardship program has an excellent chance of ensuring that this nation can maintain the safety, security, and reliability of the stockpile without nuclear testing. However, it is an extremely demanding program—from both technical and managerial perspectives—with ambitious goals and not without risks. To meet the challenge, there must be a strong sense of national importance, resources to sustain the pace and achieve the goals of the program, an environment that attracts and motivates outstanding people, and bipartisan support that is continuously reinforced.

"Two fundamental premises underlie the stockpile stewardship program. First, we must be able to develop a sufficiently detailed understanding of the science and technology that governs all aspects of nuclear weapons. By sufficiently detailed, I mean that future stockpile stewards must be able to certify the performance of U.S. nuclear weapons with confidence. They must be able to remanufacture parts and refurbish weapons as needed and deal with whatever issues arise using a set of computational and experimental tools that does not include nuclear explosive tests. Second, we must proceed expeditiously so that we have the necessary tools and scientific understanding in place within about a decade. It is a race against time. Before long, our nuclear-test veterans will be gone. We are counting on our current cadre of experienced scientists to help develop and install the new tools that only now are starting to come online. Those with experience must continue to work with their successors—both training them and evaluating their skills. The nation will be relying on these future stockpile stewards. Their judgments and decisions must be credible to others in the nuclear weapons community and to future administrations and congresses."

Strong and sustained support, and reliance on the experience of veterans with nuclear test experience were recurrent themes. In his testimony, Tarter emphasized the importance of the six safeguards that defined the conditions under which the U.S. could enter a CTBT:

"Safeguards A and B condition U.S. entrance into a CTBT on "the conduct of a science-based stockpile stewardship program to ensure a high level of confidence in the safety and reliability of nuclear weapons…" and on "the maintenance of modern nuclear laboratory facilities and programs in theoretical and exploratory nuclear technology which will attract, retain, and ensure the continued application of our human resources to those programs…"

Tarter also emphasized Safeguard F, which allowed the president, in consultation with Congress, to withdraw from the CTBT should it be deemed necessary to conduct a nuclear test, along with "the development of a framework to ensure its successful implementation if it is needed." This last statement can be translated into the maintenance of an adequate readiness program to resume testing. Tarter stated that since the inception of the SSP, he had been able to certify the LLNL-stockpiled weapons as safe and reliable without the need to do a nuclear test. The ability to certify the stockpile without nuclear testing would be another recurrent theme in subsequent directors' testimonies.

LLNL's annual nuclear weapons certification process involves reviewing the status of the nuclear stockpile based on the results of ongoing SSP efforts.[H2] The review begins in January and continues for most of the year. Scientists begin by drafting assessment reports for the designs in the stockpile. Over the following months, internal and external technical leaders at the other weapon laboratories and at NNSA review the draft reports, and in June, scientists deliver a presentation to the stockpile assessment team of the USSTRATCOM. The laboratory directors send their letters to the secretaries of Energy and Defense in the fall stating whether they believe weapon testing is necessary for the weapon designs in the stockpile. Finally, the energy and defense secretaries send an annual certification memorandum for the year to the president.

In his book, *The American Lab: An Insiders History of Lawrence Livermore National Laboratory*,[H3] Tarter says that in his verbal remarks, he spoke directly to the senators, using the analogy of aging people and how they needed diagnostic tests to assess medical conditions with the possibility of an operation. When asked about the probability of success of stewardship, he replied, "It's a very good bet, but it ain't a sure thing." He remembers that Senators Susan Collins and Olympia Snow paid particular attention to him. Secretary of Energy Richardson told him, "Good job, you really explained it well." However, after the session, Sid Drell and (future Secretary of Energy) Ernest Moniz approached him fuming because they felt the laboratory directors had undermined the treaty. Tarter was incredulous at their reaction because he testified as a technical person, not as a political person. The laboratory directors issued a clarifying statement saying that they were confident that a fully sustained and funded stewardship program would work. Tarter's written testimony did say this. In fact, Tarter notes in his recent book that he would have voted for the treaty, but he thinks C. Paul Robinson, who was the president of SNL at the time, would not have, and he was not sure how LANL Director John Browne would have voted. Again, the laboratories are all different.

Bruce Tarter testimony, April 2002

Three years later, Tarter again testified[H4] before the Strategic Subcommittee of the SASC. He said,

"The stockpile stewardship program continues to make excellent technical progress in the face of many challenges, some of the toughest of which likely lie ahead as weapons continue to age. A strongly supported and sustained Stockpile Stewardship Program is clearly needed to ensure that this nation can maintain the safety, security, and reliability of its nuclear deterrent over the long term."

Tarter presented a progress report of the program, illustrating that significant progress continued to be made since his 1999 testimony. He cited advances in: experimental and computational tools, including construction of the NIF; completion of the Contained Firing Facility at LLNL's Site 300; the Advanced Simulation and Computing Program; and LEPs for the W87 and W80 warheads. He also cited progress in understanding aging and its effects in nuclear weapons.

George Miller testimony, April 2008

In testimony[H5] before the Senate Appropriations Committee, Laboratory Director George Miller stated:

"The stockpile stewardship program was a very ambitious undertaking when launched a little over a decade ago. To date, it has been highly successful in its two major goals. First, we had to develop and use vastly improved tools to much better understand nuclear weapons performance. I am proud of our tremendous accomplishments in this area. Great progress has been made and even more will come with quadrillion-operations-per-second (petascale) computers and high-fidelity simulations and the capability, beginning in 2009, to conduct thermonuclear weapons physics experiments at the National Ignition Facility. These tools are critically important to maintain confidence in our deterrent without nuclear testing. Second, we have to sustain the expertise—people—to ensure that the U.S. nuclear stockpile remains

healthy by applying our improved understanding of weapons performance to deal with issues that arise in aging weapon systems without resorting to nuclear tests. So far, we have been able to do that. The first weapon system to successfully complete a life extension program under the Stockpile Stewardship Program without nuclear testing was Lawrence Livermore's and Sandia's W87 ICBM warhead. Although the job is not over, I remain confident that science-based stockpile stewardship will continue to be a technical success, provided that the nation continues its investments in the science-based programmatic activities."

Miller further stated:
"A key focus of stockpile stewardship has been to fill the gaps in our knowledge to reduce our uncertainties about nuclear weapons safety, security, and performance as the stockpile ages. There are four major areas of investment in improved capabilities: more powerful computers, enhanced hydrodynamic testing capabilities to experimentally study the performance of (mock) primaries prior to nuclear explosion, an experimental facility to study the high-energy-density and thermonuclear processes in weapons (the National Ignition Facility), and tools to better understand the properties of plutonium. With these tools, we are striving to develop a better understanding of the physics, improve our simulation models, and use non-nuclear experiments and past nuclear test data to validate those model improvements. To date, some of the unknowns about nuclear weapons performance have been resolved, others we are close to resolving, and still others will require more time and effort. Greater knowledge increases the likelihood that we can resolve with confidence a problem that arises in stockpiled weapons without having to resort to a nuclear test."

Miller detailed the progress made in the various elements of the program, including NIF, advanced hydrodynamic testing, advanced simulation and computing, materials research, LEPs, and warhead certification efforts.

Penrose (Parney) Albright testimony, April 2012

In his testimony[H6] to the Subcommittee on Strategic Forces of the SASC, Albright addressed some aspects of the SSP. Two of the several points he stressed concerned sustained support for SSP:

"Without sustained support for nuclear weapons science, stockpile stewardship will eventually fail.

"We remain optimistic about the prospect of long-term success of "science-based" stockpile stewardship, provided that support is sustained. The skills deriving from a solid science base will enable stockpile stewards to maintain a safe, secure, and effective deterrent and deliver on challenging life extension programs."

These themes have persisted in Laboratory directors' testimonies since the inception of the SSP in the 1990s. Albright described successes in computational capabilities and noted that:

"The simulation codes have much higher fidelity than those originally used in the design of the weapon. Evaluation of a weapon 'as designed' is one issue; evaluating it when materials have aged and anomalies are present is much harder."

Albright also cited the progress made in the NIF and its applications to the SSP. For example:

"NIF has already made a pivotal contribution to stockpile stewardship with resolution of the 'energy balance' issue after a series of experiments performed last year. The issue was originally identified during the era of nuclear testing, and it has remained a significant anomaly for 40 years—an anomaly that in the past was an important reason for full nuclear testing. Over the last decade, experiments on a variety of experimental facilities contributed to improving the understanding of this anomaly and pointed to its likely source. LLNL researchers developed a sophisticated computational model that better simulated nuclear weapons performance and, in particular, the specific aspects of performance that could possibly explain the anomaly. The unique capabilities of NIF were required to validate simulation results. With resolution of the energy balance anomaly, LLNL and LANL will have more confidence in assessments of the current weapons, which continue to change with age, and will be able to make better-informed choices in upcoming LEPs."

William (Bill) Goldstein testimony, April 2014

In April, 2014, Laboratory Director William (Bill) Goldstein testified before the SASC.[H7] He said that the committee's continuing support of the SSP has helped enable the Laboratory to sustain confidence in the nuclear weapons stockpile without nuclear testing. He emphasized that the SSP needs to address an aging stockpile with new military requirements for future delivery systems. He also spoke about the need for stockpile assessments, LEPs, and a science, technology, and engineering base:

"Stockpile Assessments. While currently assessed to be safe, secure, and effective, stockpile warheads have aged well beyond their original design intent. Maintaining confidence in the stockpile requires a vigorous assessment program, subject to rigorous peer review, made up of both physical and enhanced surveillance, underpinned by NNSA's science, technology, engineering, and production capabilities. If Life Extension Programs (LEPs) are prolonged or postponed, assessment tools and capabilities must be enhanced to address a growing set of issues, and to help guard against technical surprises."

"Life Extension Programs. Because weapons in the stockpile continue to age beyond their intended service life, timely execution of planned LEPs is important. The LEP strategy supports the U.S. Strategic Command's '3+2' vision for the future stockpile (three future-delivered warheads and two future air-delivered weapons), endorsed by the Nuclear Weapons Council……."

"The Science, Technology, and Engineering (ST&E) Base. The ST&E capabilities at the NNSA laboratories are the foundation of the SSP. The people and their tools are needed for assessing and, where necessary, refurbishing our nuclear warheads. As the stockpile continues to age, and while LEPs and new production capabilities are delayed, our scientists and engineers face increased challenges in addressing the effects of aging on weapon safety, security, and effectiveness. We must continue to improve the ST&E capabilities that underpin the SSP."

Goldstein described accomplishments in annual stockpile assessments, LEPs, NIF contributions to SSP, increased computing capabilities, non-nuclear experiments, and advanced manufacturing technologies. He also spoke on recruitment of a successful workforce.

H1 B. Tarter, "Stockpile Stewardship and a Comprehensive Test Ban," testimony before the U.S. Senate Armed Services Committee, October 7, 1999.
H2 "Annual Certification Takes a Snapshot of Stockpile's Health," *Science and Technology Review*, July/August, 2001, p. 5–10.
H3 B. Tarter, *The American Lab: An Insider's History of the Lawrence Livermore National Laboratory*, Johns Hopkins University Press, Baltimore, MD, 2018.
H4 B. Tarter, "The National Nuclear Security Administration's Budget request for FY 2003," testimony before the Hearing of the Committee on Armed Services, Strategic Subcommittee, April 10, 2002.
H5 G.H. Miller, testimony at a Hearing of the Committee on Appropriations, Subcommittee on Energy and Water development, U.S. Senate, April 16, 2008.
H6 P.C. Albright, "National Nuclear Security Administration Management of Its National Security Laboratories," Hearing of the Subcommittee on Strategic Forces, Committee on Armed Services, U.S. Senate, April 18, 2012, LLNL. Albright gave virtually the same testimony the day before to the Subcommittee on Strategic Forces of the House Armed Services Committee.
H7 W. Goldstein, "Lawrence Livermore National Laboratory's Role and Contributions to the Nuclear Security Enterprise," Hearing of the Subcommittee on Strategic Forces, Committee on Armed Services, U.S. Senate, April 9, 2014.

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