Department of Energy
National Nuclear Security Administration
Office of the General Counsel
P. O. Box 5400
Albuquerque, NM 87185

FEB 2 3 2017

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

Mr. John Greenewald
The Black Vault
[redacted]

Dear Mr. Greenewald:

This letter is the final response to your two June 19, 2009 Freedom of Information Act (FOIA) requests for a copy of the Annual Weapons Program Report for 2008 and a copy of the Sandia Weapon Review – Special DNA Issue: Nuclear Weapon Characteristic Handbook, SAND90-1238.

With regard to your request for a copy of the Annual Weapons Report for 2008, we addressed this portion of your request in our response to you dated December 3, 2009.

We contacted the Sandia Field Office (SFO), which has oversight responsibility for Sandia National Laboratories (SNL), about your request for a copy of the Sandia Weapon Review – Special DNA Issue: Nuclear Weapon Characteristic Handbook, SAND90-1238. SFO, as well as SNL, searched and located the classified document.

Pursuant to Title 10, Code of Federal Regulations, section 1004.6 (10 CFR § 1004.6), the Office of Classification, Office of Environment, Health, Safety and Security, in the Department of Energy (DOE) has completed its review of the document. This document, located in the files of Sandia National Laboratories, contains information properly classified Restricted Data (RD) and/or properly safeguarded as Official Use Only (OUO); therefore, it is provided to you with deletions pursuant to 5 USC § 552(b)(3) (Exemption 3 of the FOIA).

Title 5, United States Code, section 552(b)(3) (5 USC § 552(b)(3)) (Exemption 3), exempts from disclosure information specifically exempted from disclosure by statute (other than section 552(b) of this title), provided that such statute (A) requires that the matters be withheld from the public in such a manner as to leave no discretion on the issue, or (B) establishes particular criteria for withholding or refers to particular types of matters to be withheld. The Atomic Energy Act (AEA) of 1954, as amended, 42 USC § 2011 et seq., is an Exemption 3 statute. Sections 141-146 of this Act (42 USC §§ 2161-2166) prohibit the disclosure of information concerning atomic energy defense programs that is classified as either RD or Formerly Restricted Data pursuant to the AEA, as amended. The portions deleted from the subject document pursuant to Exemption 3 contain information about weapon design that has been classified as RD. Disclosure of the exempt data could jeopardize the common defense and the security of the nation.

To the extent permitted by law, the DOE, pursuant to 10 CFR § 1004.1, will make available records it is authorized to withhold under the Freedom of Information Act (FOIA) whenever it determines that such disclosure is in the public interest. With respect to the information withheld from disclosure pursuant to Exemption 3, the DOE has no further discretion under the FOIA or DOE regulations to release information currently and properly classified and/or safeguarded as OUO pursuant to the AEA, as amended, and/or FOIA.

Additional information is being withheld pursuant to 5 USC § 552(b)(7)(f) (Exemption 7 of the FOIA). Pursuant to Exemption 7(F), the portions of the document being withheld contain specific information about nuclear weapon and/or nuclear weapon component information. Exemption 7(F) of the FOIA protects law enforcement information that could reasonably be expected to endanger the life or physical safety of any individual. The ordinary meaning of law enforcement includes not just the investigation and prosecution of offenses already committed but also proactive steps designed to maintain security.

The disclosure of information pertaining to nuclear weapon and/or nuclear weapon component information could be of interest and potential value to adversaries harboring a desire to develop and/or defeat a nuclear weapon system. Disclosure could enable anyone, including terrorists, to more easily plan operations that would target these systems. Without question, uncontrolled release or access to this information by an unauthorized person could endanger the life or physical safety of agency employees as well as the general public.

The Department of Defense (DOD) also reviewed the document and made further deletions pursuant to 5 USC § 552(b)(1), (Exemption 1 of the FOIA), 5 USC § 552(b)(2), (Exemption 2 of the FOIA), 5 USC § 552(b)(3), (Exemption 3 of the FOIA).

Title 5, United States Code, Section 552(b)(1), (Exemption 1), provides that an agency may exempt from disclosure matters that are (A) specifically authorized under criteria established by an Executive order to be kept secret in the interest of national defense or foreign policy and (B) are in fact properly classified pursuant to such Executive order. The portions deleted from the subject document pursuant to Exemption 1 contain information about United States Government programs for safeguarding nuclear materials/facilities and are classified under Section 1.4 (f) of Executive Order 13526 (EO 13526). It has been determined that release of the information could reasonably be expected to cause damage to the national security.

Title 5, United States Code, section 552(b)(2) (5 USC § 552(b)(2)) (Exemption 2), provides that an agency may exempt from disclosure information related solely to the internal personnel rules and practices of an agency. The courts have interpreted this Exemption to encompass two distinct categories of information: (a) internal matters of a relatively trivial nature and (b) more substantial internal matters, the disclosure of which would risk circumvention of a legal requirement. The portions deleted from the subject document pursuant to Exemption 2 contain information which would give a recipient some unfair advantage in dealing with the Government or result in harm or disturbance to the internal workings of a Government entity. Such information has been safeguarded as OUO under the Freedom of Information Act (FOIA) and is therefore exempt from disclosure.

Pursuant to 10 CFR § 1004.6(d), Dr. Andrew P. Weston-Dawkes, Director, Department of Energy Office of Classification, Office of Environment, Health, Safety and Security, is the official responsible for the denial of the DOE classified and/or safeguarded information pursuant to Exemption 3 of the FOIA.

Paul Jacobsmeyer, Chief, Department of Defense (DOD), is the official responsible for the denial of the information determined by the DOD to be classified under Exemptions 1 and 3 of the FOIA and for information withheld pursuant to Exemption 2 of the FOIA.

Pursuant to 10 CFR § 1004.7(b)(2), I am the individual responsible for the withholding of the information mentioned above pursuant to Exemption 7 of the FOIA.

You may appeal the withholding of Exemption 1, 2, 3, and 7 information pursuant to 10 CFR § 1004.8. Such an appeal must be made in writing within 90 calendar days after receipt of this letter, addressed to the Director, Office of Hearings and Appeals, HG-1, U.S. Department of Energy, 1000 Independence Avenue SW, L'Enfant building, Washington, DC 20585. Your appeal must contain a concise statement of the grounds for the appeal and a description of the relief sought. Please submit a copy of this letter with the appeal. Please clearly mark both the envelope and the letter "Freedom of Information Appeal." You may also submit your appeal by e-mail to OHA.filings@hq.doe.gov, including the phrase "Freedom of Information Appeal" in the subject line. Thereafter, judicial review will be available to you in the District of Columbia or in the district where (1) you reside, (2) you have your principal place of business, or (3) the Department's records are situated. There are no charges to you for processing your FOIA request.

If you have questions, please contact Karen Laney at karen.laney@nnsa.doe.gov, or write to the address above, and reference Control Number FOIA 09-00234-J in your correspondence.

Sincerely,

Jane Summerson
Authorizing and Denying Official

Enclosure

cc w/o enclosure:
J. Bitsie, SFO

REDACTED VERSION - 09-00234-J-1

SECRET

DRC 17945

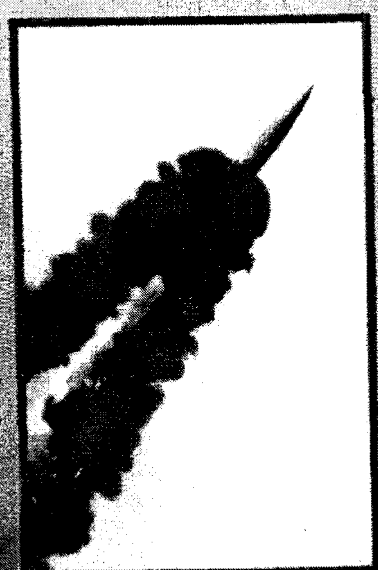
SANDIA WEAPON REVIEW

Sandia National Laboratories — Albuquerque, NM, and Livermore, CA

Defense Nuclear Agency — Washington, D.C. and Albuquerque, NM

DNA [illegible] TH-90

September 1990



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[illegible] by CG-W-5, January 1984

~~N[illegible] Weapon [illegible] Sigma 1~~
~~C[illegible] Information~~

special DNA issue: Nuclear Weapon Characteristics Handbook (U)

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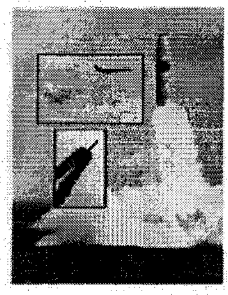

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Cover Photos: Sandia has weaponized nuclear explosives for all branches of the US military. *Front:* The Navy's Trident I missile carries W76/Mk4 Reentry Bodies; the Air Force B-1B delivers a B83 gravity bomb; and the Army's Lance missile carries a W70 warhead.

DOE (b)(3), DOD (b)(3)

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Nuclear Weapon Characteristics Handbook
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FCDNA Publications Branch/FCPSP

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This report is a supplement to HQDNA-AR-48M Nuclear Weapon Characteristics Report. Information included herein current as of 1 August 1990.

Nuclear Weapon Data Sigma 1
Critical Nuclear Weapon Design Information
DoD Directive 5210.2 Applies

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Sandia Weapon Review

Special DNA issue:
Nuclear Weapon Characteristics Handbook (U)

September 1990

Sandia National Laboratories

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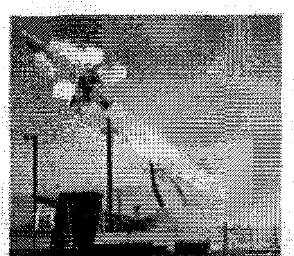

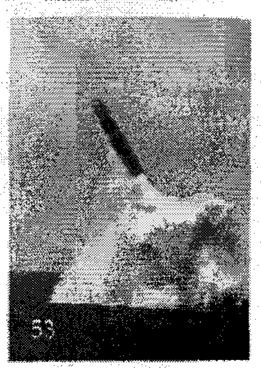

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Defense Nuclear Agency
Washington, D.C. 20305-1000

Gerald G. Watson
Major General, USA
Director

The Defense Nuclear Agency (DNA) is meeting the challenges of the 21st century today by aggressively pursuing research in nuclear weapons effects while monitoring and evaluating the United States stockpile. These efforts support the US policy of peace through deterrence. Adopted after World War II, this policy is designed to deter aggression, nuclear or conventional, against the US and its allies.

DNA traces its history to the Manhattan Project, formed in 1942 to oversee the development of the atomic bomb. Over the years, DNA has focused on researching the military effects of nuclear weapons and applying that knowledge to military systems, plans, and policy. While the basic mission is unchanged, the technical thrust of DNA's mission evolves to keep pace with, or anticipate, modern nuclear weapon designs, more robust military weapon systems, changing tactics, operational requirements, strategy and defense policy.

DNA activities focus on nuclear weapon effects research and testing. Underground nuclear weapon testing enables DNA to study nuclear radiation effects. Nuclear survivability testing provides an alternate means to obtain data using conventional high explosives and laboratory facilities to simulate weapon effects. Scientific computing provides a theoretical research capability using supercomputers. Theoretical studies in shock physics and material response resulted in the creation of some of the most sophisticated computational codes in existence. Nuclear survivability and security initiatives involve research and development programs designed to assure survivability of both strategic and nonstrategic nuclear forces. Other program aspects include research to develop physical security equipment to enhance the security of strategic and tactical nuclear forces. Command, control, communications, and intelligence systems are also enhanced through theoretical and experimental testing and analysis. DNA's biomedical effects research focuses on understanding the physiological effects of ionizing radiation.

Stockpile management is both a peacetime and a wartime mission for DNA. The Agency monitors the quantity, quality, safety, reliability, and worldwide location of nuclear weapons in the US stockpile. Additionally, DNA manages nuclear weapons accounting, reporting, logistics, publications, and inspection programs. DoD/DOE emergency response procedures are reviewed during nuclear weapon accident and improvised nuclear device response exercises sponsored by DNA. DNA also operates the Joint Nuclear Accident Coordinating Center, a central point where information on radiological assistance capabilities is maintained and exchanged.

Strategic Defense Initiative (SDI)-sponsored research is a comprehensive program aimed at demonstrating key technologies necessary for ballistic missile defense. DNA supports SDI system architects and weapons designers by providing lethality criteria for kinetic and directed energy weapons and characterizing the environment in which they must operate. Our arms control research and development efforts center on developing the technology necessary to verify a treaty through on-site inspection.

DNA is committed to ensuring the safety, security, and survivability of the US nuclear weapons stockpile. As the number of nuclear weapons is reduced under arms control agreements, DNA's work becomes even more crucial. It is my belief that DNA will serve as the DoD hub for research, development, and stockpile management activities well into the next century.

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Sandia National Laboratories

Albuquerque, New Mexico 87185
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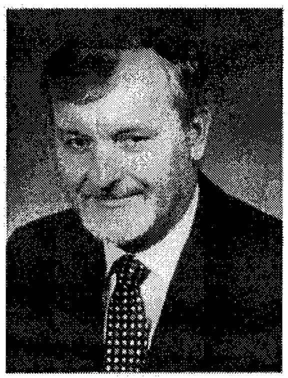
A. Narath
President



For more than forty years, deterrence has been the cornerstone of US defense policy, consisting of a stockpile of nuclear weapons and the missiles, aircraft, and artillery to deliver them. Sandia National Laboratories' special mission, as part of the Department of Energy, is to ensure that nuclear warheads meet the highest standards of operational capability, reliability, safety, and control.

With this review, we discuss Sandia's role in weaponizing nuclear explosives, the historical development of the stockpile and our monitoring and evaluation activities. We include a discussion of the important safety and use control aspects of nuclear warhead engineering. Our net assessment concludes that today's stockpile is effective and reliable but that important work remains to be done to make it as safe and secure as evolving technologies permit.

In its history, the stockpile has been shaped by strategic doctrine that has evolved from massive retaliation to flexible response as the international situation warranted. Until recent years, arms control and strategic defense have not been major components of strategic design because of technical limitations. Today it is clear that deterrence, as represented by the stockpile, will be bolstered by new aspects of national security policy that are now technically or politically viable.

It is fair to assume that the stockpile will not grow; indeed, it is quite possible that new arms reduction agreements may reduce the number and types of weapons deployed. However, the responsibilities associated with maintaining a competent nuclear weapon arsenal will continue to be formidable. Its deterrent value must be sustained. Safety is of paramount importance: a single accident involving a nuclear explosion or dispersal of nuclear material would be a catastrophe, and could badly damage or terminate public support for a nuclear deterrent. In addition, we will continue to pursue improvements in command and control: the President must have flexible, exclusive, and unencumbered command of our nuclear forces.

Ensuring quality effort and product is a major initiative for the laboratories. Quality is conformance to requirements . . . in the case of nuclear weapons, ensuring quality means meeting requirements of performance, schedule, and cost. We are striving to improve our designs and the manufacturing procedures for the nuclear weapons complex so that we do meet these goals, and we will increase our efforts to streamline some of these processes.

One aspect of nuclear weapon quality that is of particular concern is reliability. Assessing nuclear weapon reliability is an evolving process. Our assessments are updated through periodic laboratory and flight testing of samples of each weapon in the stockpile — a process allowing us to see the effects of new technologies and more demanding requirements. We recognize that smaller and safer weapons, and those with greater military capabilities, may be less reliable if we are not vigilant throughout each weapon's lifetime — through development, production, deployment, and retirement. I am personally committed to continuous improvement of quality to ensure that reliability is high and is in balance with safety and control.

The stockpile of the first forty years of the nuclear age was designed during a cold war. During the next forty years it must be designed to foster stability, nonproliferation, and peace. I believe our policy makers may begin to think of the stockpile not in terms of deterring war, but in terms of maintaining peace. Modern weapons must be militarily appropriate, safe, secure, and survivable. A "peacetime stockpile" must offer an appropriate level of deterrence and fit with arms control, verification, strategic defense, and conventional force strategy as part of an integrated national security posture.

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DOE (b)(3), DOD (b)(1), (b)(3)

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DOE (b)(3), DOD (b)(1), (b)(3)

Weaponizing Nuclear Explosives

Title Unclassified, Article Unclassified

The DoD and the DOE jointly develop nuclear weapons in a series of structured steps ranging from concept assessment and engineering to manufacture and, finally, retirement.

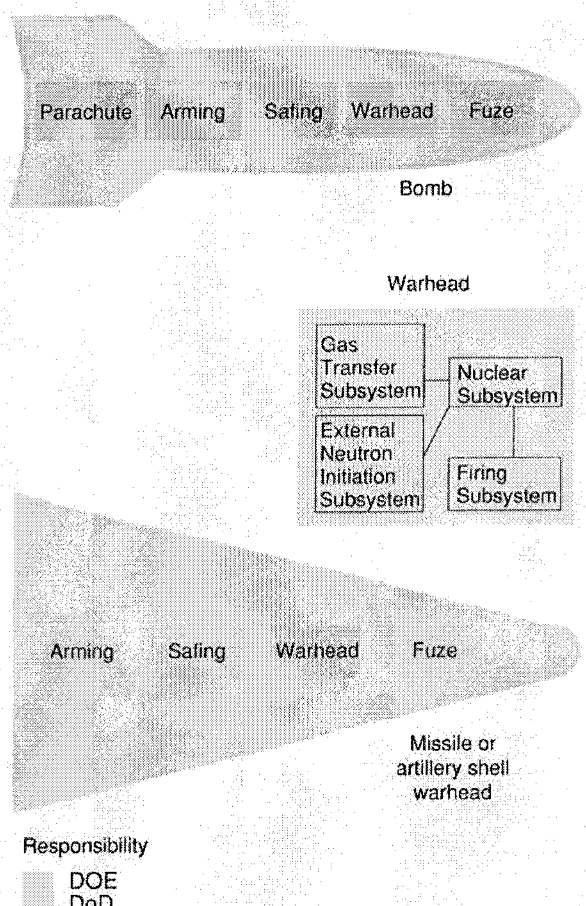
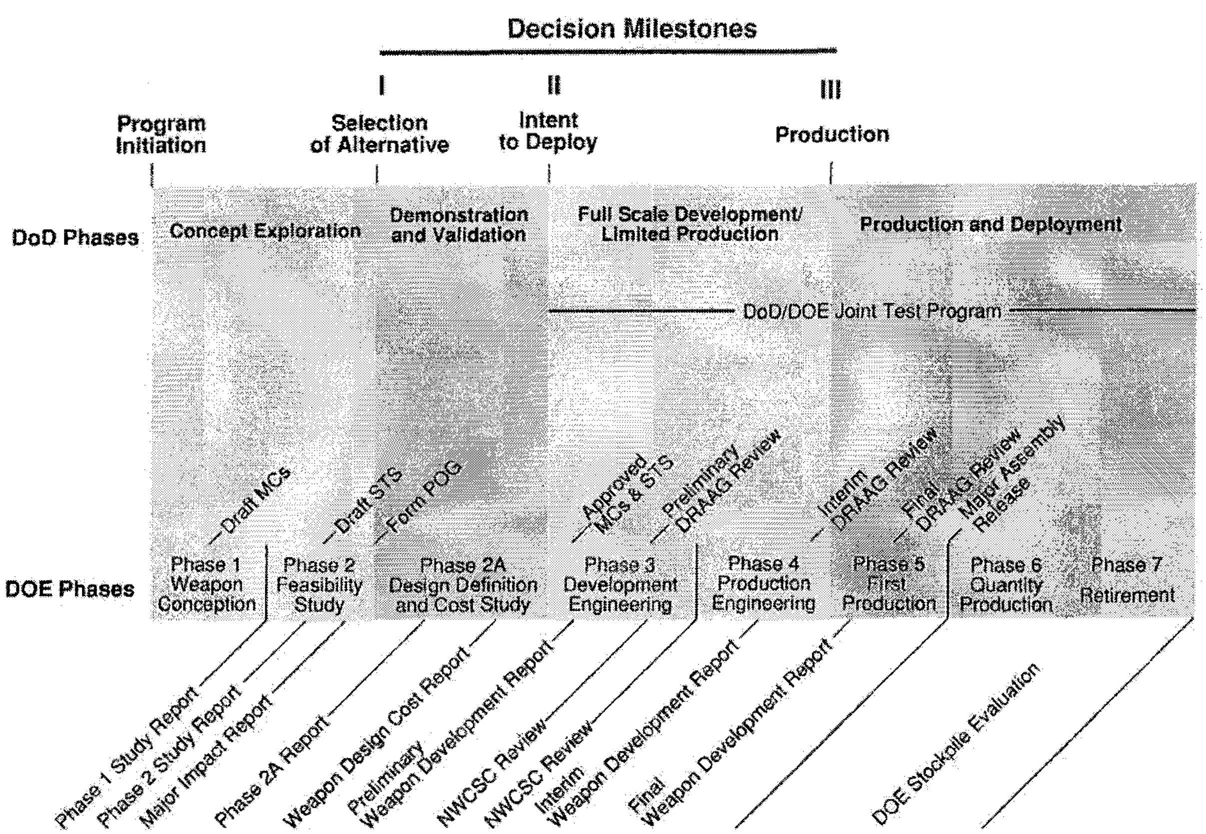


Figure 1. DoD and DOE share design and development responsibilities according to the Atomic Energy Act of 1954 and memoranda of understanding. DOE is responsible for all warheads, whether used on bombs or missiles, as well as for entire bomb systems. DoD shares with DOE the design responsibilities for nuclear weapons delivered by missiles.

In the nuclear weapons program, Sandia National Laboratories is charged with three basic responsibilities: maintain the integrity of the stockpile; design and develop new weapons for the stockpile; and maintain a technology base to (1) support the first two responsibilities, (2) provide options for future nuclear weapon requirements, (3) avoid technological surprise by our adversaries, and (4) provide support for arms control proposals and verification issues. We have totally or partially weaponized every weapon in the stockpile. For each weapon, we interface with one of the DOE nuclear design laboratories and the service user as shown in Figure 1.

The DOE laboratories generally work with the military services in assessing the potential for meeting new mission needs with existing weapons or new weapons concepts. These "pre-Phase 1" activities provide insight for focusing laboratory advanced development work and lend realism to the military mission need statement. DOE and DoD phases are compared in Figure 2.

Figure 2. Ideally, nuclear weapon and weapon system development proceed through coordinated DoD and DOE phases. In practice, programs rarely are meshed quite this well; however, joint approvals and reporting requirements ensure that both weapon and weapon system proceed toward production in a controlled manner.



Phase 1 (Concept Definition) studies may be performed by any DoD component or the DOE laboratories, or may be conducted jointly. In addition to the study of potential weapons applications, Phase 1 studies may be conducted to investigate broader mission area needs or applications of nuclear-related technology. These studies usually involve preliminary effectiveness analyses, delivery system and warhead trade-offs, and development of a preliminary draft of the Military Characteristics (MCs), which state the warhead performance requirements. The report written by the Phase 1 study group provides information needed by the DoD to determine whether to proceed into Phase 2 and helps the DOE laboratories shape their activities.

Phase 2 (Feasibility Study) is a crucial step in determining how best to meet national security needs. This joint DoD-DOE study determines the technical feasibility of meeting the need and identifies those aspects of nuclear design, development, testing, production processes, and resource availability likely to be determining factors in developing and producing a nuclear weapon for a particular weapon system. A Phase 2 study is initiated only after a military department request is approved by the Nuclear Weapons Council (NWC). One of the most important tasks for the joint DoD-DOE study group is to conduct trade-off studies and to ensure that total weapon system cost and performance are considered in establishing the military requirements and design objectives.

Candidate warheads are proposed by design teams from Lawrence Livermore/Sandia and Los Alamos/Sandia. The advantages and disadvantages of each candidate are analyzed, and economic and nuclear material savings that would occur from changes in requirements are identified. Determining feasibility frequently requires preliminary warhead designs and testing, including underground nuclear tests.

The Phase 2 study usually takes about one year and culminates with a report to the NWC. This report contains the study group findings and updated draft warhead MCs, and should be available for high-level DoD and DOE deliberations. The DOE also develops comparative warhead costs so that the NWC is able to consider cost/benefit issues.

In harmony with the DoD weapon system demonstration and validation work, the DoD and DOE conduct a joint Phase 2A (Design Definition and Cost Study) to identify a baseline design that best balances resources and requirements. The DOE normally selects a single design team to work with the cognizant military department and its contractors. The study is conducted by a Project Officers' Group (POG), which oversees the trade-off studies and refines the warhead's MCs. Tentative development and production schedules are established and a DoD-DOE division of responsibilities for development and production is drafted.

The POG is charged with producing a report to support Defense Acquisition Board deliberations. The DOE provides a Weapon Design and Cost Report, which describes the baseline design and decision cost estimates and reports the results of trade-off analyses involving requirements, costs, and nuclear material cost and availability. The DOE laboratory team conducts design activities in sufficient depth to support the trade-off studies and cost analyses. Prototyping and testing are conducted as necessary.

Phase 3 (Development Engineering), which normally occurs concurrently with DoD full-scale development, begins after the Secretary of Energy accepts a formal request for this work from the Secretary of Defense. The POG, with oversight by the NWC Standing Committee, continues to coordinate DoD-DOE activities.

Early in Phase 3, Sandia, on behalf of the POG, prepares a Preliminary Weapon Development report that provides design objectives, a weapon description, test plans, requirements for ancillary equipment, and a program schedule. This report is submitted for review to the DoD Design Review and Acceptance Group (DRAAG), which will ultimately assess design compliance with the MCs and recommend on acceptance to the DoD.

During Phase 3, the DOE laboratories conduct intensive design, prototype development, and testing activities, including joint testing with the DoD weapon system. Warhead interfaces are determined and studies conducted to ensure that the design will meet the stringent safety requirements specified in the MCs. The DOE establishes a baseline cost for warhead production.

The NWC reviews each program annually during Phase 3 and 4. It considers the impact of the MCs and the Stockpile-to-Target Sequence (STS), which describes the logistical and operational evolutions and the resulting physical environments the weapon may encounter, on the design and engineering effort and on the resources needed to meet the design requirements and goals. Specific DoD requirements or DOE design/production decisions that will increase costs are given particular attention.

Formal establishment of **Phase 4 (Production Engineering)** authorizes the DOE production complex authority to begin procuring and fabricating materials and components for a portion of the production schedule as specified by DOE. The DOE laboratory design team supplies the production complex with complete drawings, process instructions, and engineering releases during this phase, and continues with the joint DoD-DOE testing initiated in Phase 3. DoD-DOE interfaces and activities on trainers, spares, special equipment, manuals, and post-development testing are also established during this phase.

Phase 5 (First Production) is a period in which the DOE evaluates the production processes and the resulting product to determine if all quality requirements are met. During this period, the laboratory design team prepares and submits a Final Weapon Development Report to the DoD DRAAG. If the DRAAG determines that the design meets the approved MCs and STSs to the extent that no further DOE development effort is required, it recommends to the NWC that the design be accepted as a standard stockpile item. During Phase 5 the military department 's Nuclear Weapon System Safety Group conducts a pre-operational safety study to determine the adequacy of the weapon system's safety features and operational procedures. This group prepares Safety Rules for approval by the Secretary of Defense and makes recommendations for any needed improvements in nuclear safety.

Phase 5 culminates with the issuance of a Major Assembly Release, which is prepared by the DOE design laboratories, stating that the weapon is satisfactory for release to the DoD for specified capabilities and uses.

Phase 6 (Quantity Production and Stockpile) begins after all Phase 5 checks have been successfully completed, including production and deployment approval by the Secretary of Defense. Phase 6 continues through a weapon's production and stockpile life. The DOE maintains full-scale production at the rates necessary to meet directed schedules.

Stockpile evaluation is a major Phase 6 activity. It ensures, through stockpile sampling and laboratory and flight testing, that stockpiled weapons continue to meet quality requirements. Should deficiencies be found and corrective action needed, the DOE laboratories prepare production change proposals with specific solutions. From time to time, technical advances require that portions of the stockpile be modernized. These design actions are also handled by the DOE laboratories.

Phase 7 (Retirement) begins with the first physical withdrawal of the weapon from stockpile. Weapons are returned to be disassembled at the DOE's Pantex Plant. Inspections provide additional information that can guide R&D for future designs. Sandia participates in safety studies related to retirement and weapon disassembly.

Certain ancillary equipment (e.g., Permissive Action Link (PAL) controllers) may be needed by DoD on schedules different from major system development. This development work by DOE laboratory designers is conducted under ad hoc DoD-DOE arrangements. By the same token, DoD frequently uses existing nuclear weapons on new aircraft or platforms. And while little or no warhead redesign may be required, a great deal of compatibility testing may be needed to establish the operational capability.

The Weapons Program Status chart in the appendix shows the progression of weapons through the structured phases, including weapons currently in stockpile and those in development.

The bulk of this material has been excerpted from *DOE Nuclear Weapon RD&T: Objectives, Roles, and Responsibilities*, SAND89-1243, March 1989, by Glen R. Otey.

For more information, call
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SNL/Glen Otey *(505) 844-7006*
HQDNA/SMOP *(703) 325-1004*
FCDNA/FCPRW *(505) 844-2810*
FCDNA/FCPSM *(505) 844-0401*

Stockpile Milestones ◦ Related Events

	Stockpile Milestones	Related Events
	Trinity/Hiroshima/Nagasaki	WWII ends, AEC formed
1940s	B36 bomber deployed	SAC formed
	US bombers based in United Kingdom	NATO formed
	Rapid stockpile buildup	USSR explodes fission device
	US explodes fusion device	USSR explodes fusion device
	DOE (b)(3), DOD (b)(1)	
1950s	Wooden bomb concept	Rapid, flexible delivery requested
	Laydown bomb concept	USSR deploys surface-to-air missiles
	Sealed pits, gas boosting	Nuclear material shortage
	ICBM deployed (ATLAS)	USSR launches Sputnik, deploys IRBM (SS-4)
	SLBM deployed (Polaris)	USSR deploys ICBM (SS-6)
	Permissive Action Links (PAL)	NATO Quick Reaction Alert (QRA)
1960s	MRVed SLBM deployed (Polaris A-3)	USSR deploys MRVed missile
	First underground test (Nougat)	Limited test ban treaty
	DOE (b)(3)	
	Exclusion region safety concept	AEC/DoD safety study
	Insensitive high explosive	Palomares accident (1966)
	MIRVed ICBM (MM III) and MIRVed SLBM (Poseidon) deployed	USSR deploys MIRVed ICBM
	Sprint, Spartan to reserve	SALT I treaty
1970s	SRAM deployed on aircraft	Standoff weapon needed
	Active protection systems	QRA weapons in foreign countries
	Stockpile improvement program	ERDA/DoD safety review
	Trident I SLBM deployed	USSR deploys MIRVed SLBM (SS-18)
	Limitation on launchers, bombers	SALT II treaty
	DOE (b)(3), DOD (b)(1)	
1980s	Peacekeeper ICBM and Trident II SLBM deployed	USSR deploys mobile ICBM (SS-25)
	GLCM, Pershing II to reserve	NATO INF treaty

How the Stockpile Developed

Title Unclassified, Article Secret Restricted Data

After World War II, increased geopolitical tensions and evolving technologies shaped today's stockpile.

The awesome effects of atomic bombs dropped on Hiroshima and Nagasaki and their role in ending World War II with Japan led the US to envision maintaining only a small inventory of essentially hand-built bombs. This vision presumed that the US would maintain its monopoly on atomic weapons for some time, and did not anticipate that the Soviet Union and China would try aggressively to expand their spheres of influence.

Political events and resources affected military requirements for a nuclear deterrent.

The drawing of the Iron Curtain across Eastern Europe, the Berlin crisis in 1948, the detonation of the first Soviet atomic bomb in 1949, and the Communist overrun of mainland China, also in 1949, caused the US to increase greatly its stockpile of atomic weapons. The Mark 4 bomb, introduced in 1948, was the first atomic weapon designed to be mass produced and safely stored in an assembled state (with the fissile core removed).

With the advent of the Korean Conflict in 1950, the US was involved in a ground war in Asia, and our focus shifted to tactical nuclear weapons. The Mark 7 bomb and the Mark 9 280-mm Artillery Fired Atomic Projectile were the first of these weapons. In the early 1950s we started developing nuclear warheads for short-range missiles such as the Honest John and Corporal (Figure 1).

Until the early 1960s the size of the US nuclear stockpile was essentially limited by the availability of

Figure 1. An important milestone in the development of the nuclear stockpile occurred in the early 1950s. At that time we started development of warheads for short-range, tactical missiles like the W7 Honest John shown here.

plutonium and highly enriched uranium. [redacted] DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1)

DOE (b)(3), DOD (b)(1) From 1954 until the end of the decade, large multimegaton bombs dominated the strategic stockpile.

Technological events — at home and abroad — had great impact on the US nuclear stockpile.

The USSR's Sputnik ushered in the era of ballistic missiles, and USSR surface-to-air missiles became a threat to high-flying US nuclear delivery aircraft. Los Alamos and Lawrence Livermore National Laboratories perfected sealed-pit weapons, with complete, pre-assembled nuclear explosives, which therefore were ready for instant deployment. Sealed-pit designs allowed more weapons to be built for a given amount of nuclear material. Reduced weapon size resulted because gas boosting was tied to the sealed-pit technology. Surface-to-air missiles raised real doubts about the continued use of aircraft as nuclear delivery systems unless bombs could be designed for low-altitude (laydown) delivery so that the aircraft could fly and deliver weapons beneath radar coverage. In 1955, the joint AEC/DoD Tableleg Committee was formed to study the feasibility of a tactical laydown weapon. This work and our parachute development led to the B43, the first bomb designed for laydown delivery. The B43 had a nose spike to stick into the target on impact to attenuate the ground impact shock (Figure 2). All bombs placed in the stockpile since 1961 have had a laydown capability, although the spike was not used again.

Ballistic missiles led to new classes of nuclear weapon systems — intermediate-range, intercontinental, and submarine-launched.

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[redacted] DOE (b)(3) DOD (b)(1), (b)(3)

DOE (b)(3) This program contributed significantly to the W68/Mk3 Poseidon system, where 14 independently targetable reentry bodies could be carried on a single submarine-launched ballistic missile. This concept of integration was subsequently used for the W76/Mk4 and W88/Mk5 Trident systems.

Figure 2. By the early 1960s we had developed tactical laydown bombs. The first deployed, the B43, was parachute retarded so the delivery aircraft could escape after low-altitude delivery. A nose spike caused the bomb to stick to the target to attenuate the ground impact shock and prevent bomb ricochet.

Component developments increased stockpile capability, economy, and safety.

In the early 1950s, an important development was the inflight insertion mechanism that inserted the fissile capsule ball into the pit when the mechanism was electrically actuated from the cockpit or within the missile. This device allowed the nuclear assembly to remain in a safe position until late in the stockpile-to-target-sequence. Another development was the external neutron generator that replaced the internal neutron source. More precise timing of the neutron pulse allowed less fissile material to be used.

Environmental Sensing Devices (ESDs) were incorporated in weapons after the introduction of sealed pit systems. The ESD interrupts the warhead arming and firing circuit. It closes (and allows final arming and firing) only after sensing some deployment-unique environment. Several weapons were retrofitted beginning in the late 1950s with ESDs. In 1962, President Kennedy directed that Permissive Action Links (PALs) be incorporated in all NATO-deployed weapons to protect against unauthorized use. Today many nuclear weapons incorporate PALs or coded launch-control systems. Some Navy weapons are the exception. Modern PALs provide a significant level of protection from unauthorized use of a nuclear weapon.

In 1968 more stringent design criteria were adopted to achieve higher levels of nuclear safety.

A new concept for weapon electrical system safety was developed and engineered at Sandia to meet these new criteria. Using unique-signal-operated strong link switches, this concept has been incorporated into every new weapon entering the stockpile since 1976 and has been retrofitted into several existing weapons.

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The US nuclear stockpile is reliable and continues to meet the national security requirements.

The oldest weapon, the W33, is 34 years old; the average age of weapons in the stockpile today is nearly 14 years [redacted] DOE (b)(3), DOD (b)(1), (b)(3)

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Monitoring the Stockpile

Title Unclassified, Article Secret Restricted Data

The DOE and DoD work together to ensure the continued effectiveness of the nuclear deterrent.

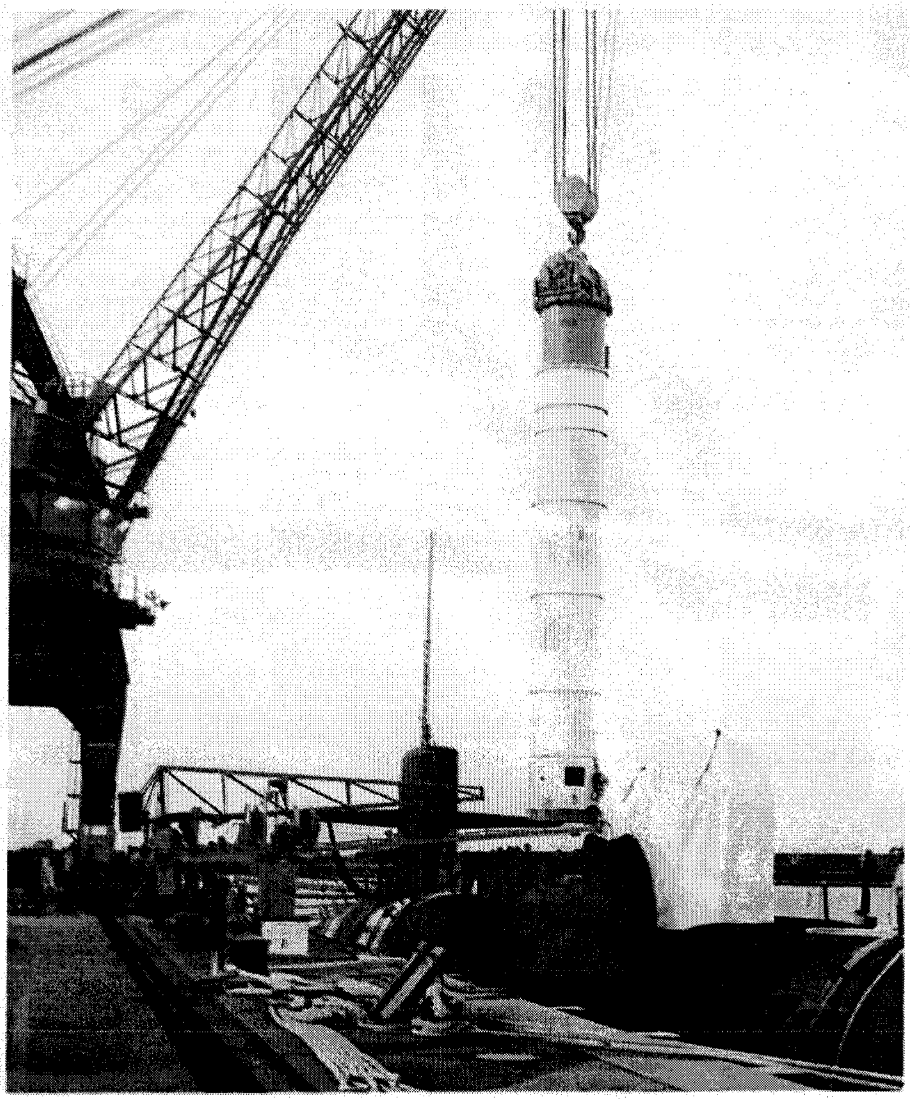

Figure 1. For as long as they are in the active stockpile, weapons are sampled periodically and returned to DOE facilities for extensive evaluation. Here, a development exercise shows a Trident II missile being removed from the USS Tennessee.

Sandia is responsible for the integrity of the hardware we develop for weaponizing nuclear explosives. This responsibility does not end when our engineering development is complete. In fact, we and the Defense Nuclear Agency (Figure 1) are responsible and actively involved in stockpile issues until the weapon is retired from the stockpile. Separate, parallel Sandia organizations that report to Sandia's president design the system and components and evaluate the stockpile. This corporate separation of the design and evaluation functions provides an independent assessment of the stockpile, that is, the checks and balances. We implement a series of integrated programs that ensure our involvement is effective. These programs are briefly described in this article.

While a weapon is in development and production, we carry out reliability and quality assurance programs. After the weapon enters the stockpile, we continue our responsibility for stockpile evaluation and military liaison. Collectively, these programs ensure that we make sound and timely technical decisions that may be needed to maintain stockpile integrity.

Reliability assurance is an analytic program that supports design tradeoffs that must balance safety, deployment, and functional issues. Results of development and stockpile evaluation tests are used to assess the hardware performance. Quality assurance activities ensure that production processes and controls are in place and effective.

Stockpile evaluation testing is our best possible simulation of weapon performance in actual use. Randomly selected weapons are tested periodically for as long as they are in the active stockpile. Test results support decisions for weapon upgrades should they be needed. Through our military liaison activities, we ensure that military users are thoroughly familiar with weapon-related operations during storage, shipment, deployment, and in case of an accident.

The following sections describe reliability assessment and quality assurance, stockpile evaluation, and military liaison in more detail.

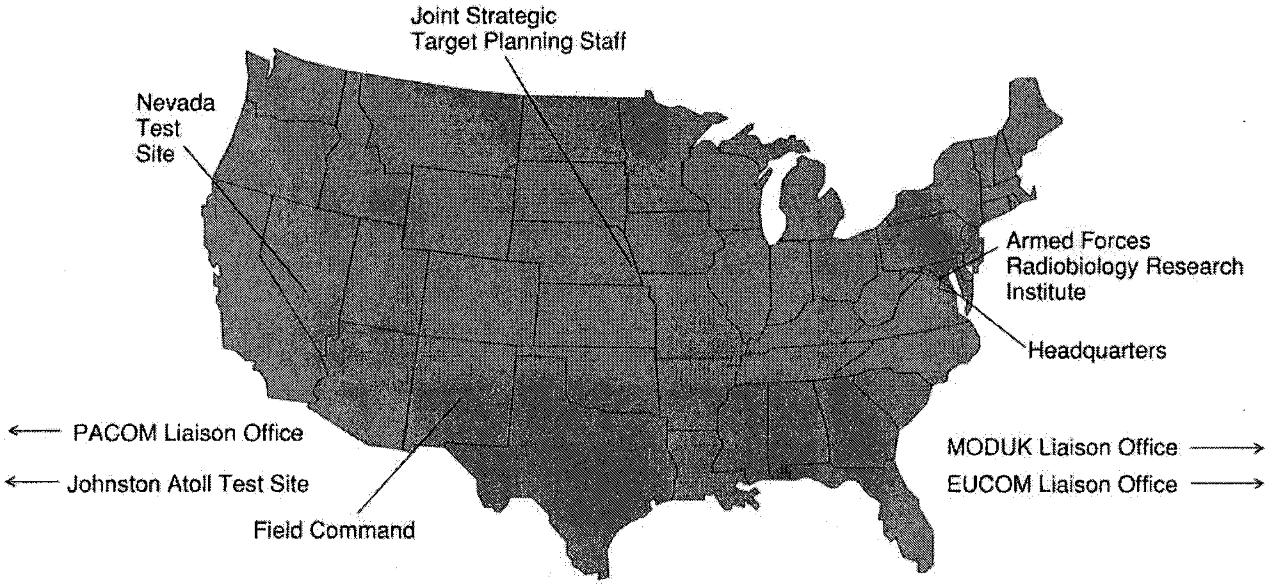

Figure 1. Defense Nuclear Agency Activities

Reliability Assessment and Quality Assurance

Our quality and reliability assurance programs augment engineering development.

The weapon design laboratories have been assigned the quality and reliability assurance responsibility for providing and maintaining an effective nuclear weapon stockpile for national defense. Quality is defined as conformance to all requirements, and reliability is the successful and effective performance of a weapon. Our quality and reliability assurance efforts begin during development of a weapon and end only after the weapon is retired from the stockpile. This effort is unique because we must ensure and assess the quality and reliability of a weapon that cannot be fully tested and may never be used (if deterrence is successful), but must function reliably if needed.

Thus, nuclear weapons require extraordinary measures to ensure with high confidence that they can be safely handled, efficiently controlled, and remain operational in storage. The issues we address are many, varied, and complex. We must ensure that weapon reliability goals are recognized in the design process, achieved in production, and maintained throughout stockpile life. The principal responsibility for achieving high reliability lies with our design organizations, who provide basic assurance for quality and reliability in the design process through project management, analysis, testing, and peer review. The keys to achieving high stockpile reliability include a robust design; attention to production processes and materials compatibility; comprehensive development testing; wide-range production monitoring (Figure 2); adequate stockpile surveillance; and, when needed, corrective action.

Weapons cannot enter the stockpile without their manufacture having been monitored through actions of the design laboratories' and production contractors' quality processes. The technological advances employed in weapons have been matched by improvements in the ways we monitor weapon quality. In the modern

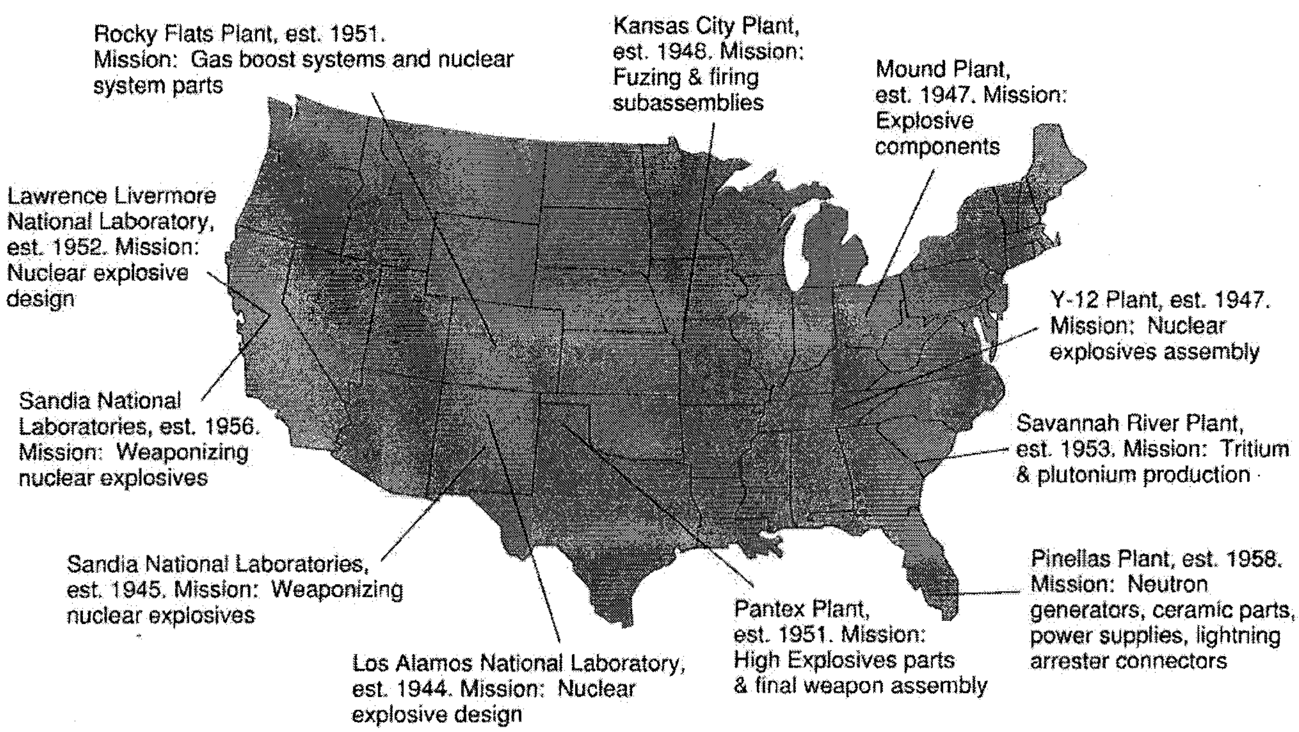

Figure 2. The DOE Integrated Contractor Complex

quality methodology, the disciplines of statistics, human factors, and reliability engineering are some of the means employed to enhance the quality of the design and manufacturing effort by providing continual, independent assessment of the design, the manufacturing processes, and weapon hardware performance.

In 1947, a multifaceted program was started to ensure the high reliability of stockpiled nuclear weapons. Quality assurance methods at that time included inspection, audit, sample evaluation, and product qualification through first article inspection.

By the late 1950s, a new design concept was introduced that featured sealed-pit nuclear packages, environmentally sealed warhead sections, and one-shot devices. The new design reduced the need for field maintenance and, as a consequence, precluded field testing of important components and subsystems. To compensate for the lack of field-generated data, a stockpile sampling program was developed to provide the necessary assurance information. Joint flight tests with the DoD were started in the early 1960s to complement the DOE stockpile sampling program. The test results are used to monitor the stockpile condition and to update reliability assessments of the weapons.

Complementary test programs provide data for continuing reliability assessment of stockpiled weapons. Our objective is to conduct a variety of tests in sufficient number to ensure that any significant problem will be detected in time to allow corrections before the stockpile is seriously degraded. All failures and test anomalies are thoroughly analyzed to determine cause, frequency, expected extent, and finally, impact on the current reliability assessment. Reliability assessments are regularly updated to include the most recent applicable data (Box A).

As nuclear weapons became more complex (Figure 3), the quality procedures grew to meet the challenge. Weapon evaluation became more sophisticated, while the first article inspection expanded into a review of all manufacturing processes

Box A: Reliability Analysis Methods

Assessing weapon reliability requires analysis of system designs, formulating mathematical assumptions and models, and testing systems and components. The assessed reliabilities reflect our best estimate of the stockpile, and we assume they will be stable over the life of the stockpile unless otherwise stated.

Analysis defines the response of the weapon system and its components under extreme environmental conditions. A variety of system and component tests at environmental extremes and flight tests confirm the theoretical design. Conservative design techniques and added margin allow for unanticipated responses.

DOD (b)(2)

DOD (b)(2)

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along with the design and production documents. The procedure that began as first article inspection is now moving to the very beginning of the design process to provide quality support and review for all of the design and development activities. Participation by quality personnel in the design process also brings an early focus on design margins, development testing, production processes, and subcomponent availability. These activities supplement the quality control procedures of the production agencies and vendors.

Today's quality functions have been broadened to include quality assurance for software used in microprocessor-controlled subsystems. Providing assistance and guidance in the formulation of organizational quality plans in weapon programs is another new direction. Reports of the quality performance of weapons and the agencies who design and manufacture them bring quality matters to the attention of the Sandia's top management.

These programs of preventive measures to achieve weapon quality before stockpile entry are the foundation of reliability and cost effectiveness in providing the nuclear deterrent. Our quality and reliability assurance programs are designed initially to prevent problems from occurring and finally to detect, assess, and solve stockpile problems early, before stockpile effectiveness is seriously degraded. The fact that the assessed reliability of our nuclear weapons remains high, even for the oldest designs (see *Reliability of Stockpile Weapons* in the appendix), is evidence of Sandia's contribution to maintaining an effective nuclear deterrent force.

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Figure 3. Modern nuclear weapons such as this B61 Mod 3 are complex, consisting of many parts that interact in subtle ways. Therefore, our quality assurance and reliability assessment programs must be adaptable to a broad spectrum of processes and hardware ranging from simple but critical mechanical pieceparts to complex electronic assemblies.

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Stockpile Evaluation

Periodic testing of stockpiled weapons ensures their credibility.

Stockpile Evaluation comprises those activities that preserve the deterrent strength of the weapons already in the arsenal — today's deterrent strength — by maintaining these weapons during their long periods of dormant storage.

Stockpile evaluation needs are dictated by the demands made of these weapons. Weapons must remain unequivocally safe to handle during storage, yet operate reliably in all specified operational environments at a moment's notice. Weapons can degrade with age, handling, and exposure to environments, so we must provide for restoration of stockpile capability if significant degradation takes place.

The design laboratories and DOE continually evaluate weapons throughout their stockpile lives.

Sandia's stockpile evaluation group coordinates evaluation requirements of Los Alamos and Lawrence Livermore national laboratories in preparing and implementing stockpile evaluation plans for each weapon program.

These plans, formulated during development phases of weapon programs, specify all testing, short of underground nuclear tests, of DOE material from weapons accepted for stockpile use by the DoD. (Underground tests of stockpiled weapons are conducted on an infrequent basis by either Los Alamos or Lawrence Livermore national laboratory.) Stockpile evaluation plans provide for testing as long as a weapon remains in stockpile.

The program has two parts: one tests new weapons before they enter the stockpile (new materials tests); the other tests fielded weapons (stockpile tests). In the new material test program, DOE-accepted weapons from each month's production are randomly selected and tested. This testing ensures that weapons entering the stockpile will perform as designed and that production has been consistent. Realistic system tests of material from completed weapons can detect subtle defects that have escaped the extensive production-component test programs, and that would otherwise find their way into stockpile.

Fielded weapons are continually tested for defects. They are randomly selected, annually or biennially, from the entire inventory of fielded weapons, regardless of where they may be deployed. The weapons are returned to DOE's Pantex assembly plant in Amarillo, TX, and are prepared for and subjected to the same kinds of realistic, system-level tests employed in the new material test program. In this way, performance of fielded weapons can be carefully compared to the performance of new weapons, providing sensitive measures of any degradation that might have occurred.

Each test is extensive for both the new and fielded weapons. Upon receipt of a weapon at Pantex, safety and command and control features are examined and tested with electrical and radiographic techniques. In most of the weapons, internal gas atmospheres are sampled and examined through mass spectroscopy to detect chemical reactions such as hydrogen evolution, that might be detrimental to weapon performance. A few weapon functions are tested prior to disassembly so that the command disablement features can be evaluated without perturbation. Some of these *in situ* tests verify function of certain arming features, but they are performed only after suitable safeguards are taken to ensure that safety is not compromised.

After 100% examinations, the weapons undergo minimum disassembly to remove the nuclear explosive. Careful inspection is made at each stage of disassembly to disclose visible changes such as material degradation. Torques and other assembly features are also examined and the measurements recorded.

The nuclear explosive is separated from the fuzing and firing systems, and subjected to examinations or tests specified by Los Alamos or Lawrence Livermore national laboratory. Most nuclear systems are nondestructively examined, after which they are returned to the production line to be rebuilt into weapons.

The arming, fuzing, and firing hardware is predominantly Sandia's responsibility. It is configured for system level testing, either in the laboratory or in the field.

In the laboratory, special testers evaluate the function of the weapon under simulated use conditions.

Laboratory tests assess the function of mechanical and pyrotechnic devices, parachutes, and the arming, fuzing, and firing systems. Following preconditioning of the test units at the most extreme temperatures in which reliable operation is required, the testers provide additional environmental inputs, such as acceleration, necessary to activate sensing devices (Figure 1). The testers also provide electrical signals in the same sequence and timing that the weapon would experience in actual use. Monitor points throughout the system provide real-time measurements of the behavior of the system as it operates.

Each test is scored as a success if all the functions necessary to produce a nuclear explosion are accomplished: function select, gas boosting, neutron flux, and detonator performance. A failure to achieve any of these end events is scored as a test failure.

In many weapons there are several use options available. For example, a gravity bomb may be used in airburst, laydown, or contact burst options, either parachute-retarded or freefall. Such options usually involve unique circuitry or hardware. In the laboratory it is often possible to evaluate a weapon in a "primary" option, and then evaluate the unique hardware associated with other options by replacing or simulating spent components and testing the system again in a new option. (Each option is tested as the primary option in at least one test.) Each option is scored, and a weapon failing any option is deemed a failure.

Each test results in a large amount of data, both attributes (go/no-go) and variables (voltage levels, elapsed times, etc.). These data are accumulated and maintained in a

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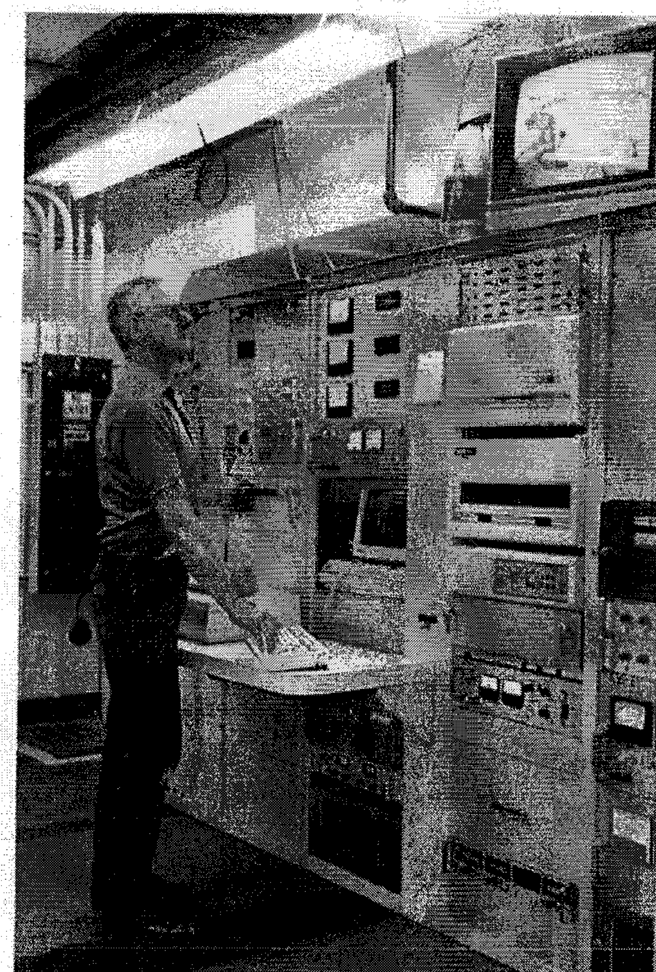

Figure 1. Weapons are tested at DOE's Pantex Plant in Amarillo, TX. Sandia-designed test systems provide physical and electrical stimuli to a weapon and record its response. In this case, a centrifuge provides acceleration environments a warhead would experience during missile flight (above). The test is controlled and response measured at the test system console (below).

large, computerized database, together with information describing the tests, the serial numbers of the weapons and their components, and narrative descriptions of defects observed. Statistical analyses of the data are routinely performed, and may include data from tests conducted as many as thirty years ago.

In flight testing, realistic weapon configurations are launched on missiles, dropped from aircraft, or fired from howitzers.

Some weapon hardware, such as the parachute systems we develop for gravity bombs, can only be evaluated by full-scale flight tests. The deployment and parachute dynamics cannot be evaluated in the laboratory. There is no need to simulate environmental conditions or interfaces with DoD in joint flight tests because the actual conditions are present.

In preparing for flight testing, the arming, fuzing, and firing components are built into joint test assemblies that match the real weapon in every aspect possible except one: they do not contain nuclear explosives. The cavity that housed the nuclear system accommodates instrumentation and either active telemetry or recorders. Mass properties (weight, moments of inertia, and center of gravity) and dynamic properties (spring constants and vibrational modes) are matched with those of the original weapon. Thus, save for markings and other identification features, and perhaps an external antenna system for radiating telemetry, the assembly is nearly indistinguishable from the real weapon.

After positive verification by gamma spectroscopy and other techniques that the assembly is a nonnuclear device, it is sent to the military organization that will conduct the flight test. The military organization assembles the joint test assembly into the weapon system (e.g., a warhead test assembly is mounted onto a missile) and conducts the test under conditions allowed by the range safety procedures (Figure 2). Realism is further enhanced when operational troops, using operational procedures, simulate an actual mission.

Extensive data are collected from each test and used for scoring, evaluating the signals at the interface between the DOE and DoD hardware (to isolate agency responsibility for failures and defects), and providing diagnostic information to help determine causes of failures and defects. These data are accumulated in the same computerized base as the laboratory test data.

Beyond the development and implementation of the test programs, a major Sandia responsibility is the timely and thorough investigation of all potential stockpile problems, most of which are revealed by stockpile evaluation tests. In addition, anomalous behavior of weapon material might be observed in other activities. For example, inspections by the military, conversion activities, weapon retirements, shelf-life programs, or production lot-sample testing can produce a symptom of a present or impending stockpile problem. We are notified of all such anomalies and are responsible for conducting, with the full support of the entire weapon community, investigations of each of them. The investigations address the causes of the anomalies, their present and future impact on stockpile reliability or safety, and possible corrective actions. A panel of Sandia supervisors reviews conclusions of all investigations to ensure completeness and objectivity.

Our responsibilities include the publication of program results. The principal publication is the quarterly DOE Weapons Reliability Report, which provides reliability assessments for each weapon in the stockpile. Investigations that disclose reliability or safety concerns are described in this report, together with the status of corrective actions.

Cycle reports address results of tests conducted in a testing period

Figure 2. DOE and DoD jointly test new and fielded weapons in the most realistic use conditions possible. Sandia-developed instrumentation (installed in the volume from which the nuclear system has been removed) measures weapon operation in the use environments. Here, an instrumented gravity bomb is tested at our Tonopah Test Range near Tonopah, NV.

for a given weapon program, and the results of all investigations conducted during the period. An Historical Summary and a Flight Test Summary are published annually to summarize all testing since the late 1950s, defects and failures observed, and corrective actions taken.

We improved the stockpile evaluation program by using the knowledge we gained from early tests.

Initially, as many as 900 weapons a year were destructively tested to evaluate the stockpile, marking the task as extremely expensive. These early tests allowed us to accumulate a database to evaluate not only the weapon stockpiles, but also the test programs themselves. Significant improvements and economies have been achieved in the test programs over the years.

Today, 300 to 400 weapons are tested each year (Figure 3). But the program still represents a large expenditure — the DOE funding alone is over $200 million a year.

The success of the test programs is measured in terms of their ability to detect and correct stockpile deficiencies quickly. Against this criterion, we found early programs lacking, despite the large numbers of weapons tested. There were a couple of reasons for this paradox. First, all tests were nearly identical, and they were conducted under rather benign conditions. This allowed subtle deficiencies to remain hidden until the problems became serious. For example, the introduction of testing at temperature extremes uncovered a variety of stockpile problems that were virtually undetectable in tests at ambient temperatures. The need for diversified tests to evaluate weapon performance under all expected use conditions and delivery options, and with all applicable carriers or launch platforms, is now well understood.

Another reason was that some early programs also suffered from unnecessary compromises in the tests or test configurations. Often a necessary condition for failure of the weapons was eliminated from the test or test configuration, or compromises left doubt about the validity of

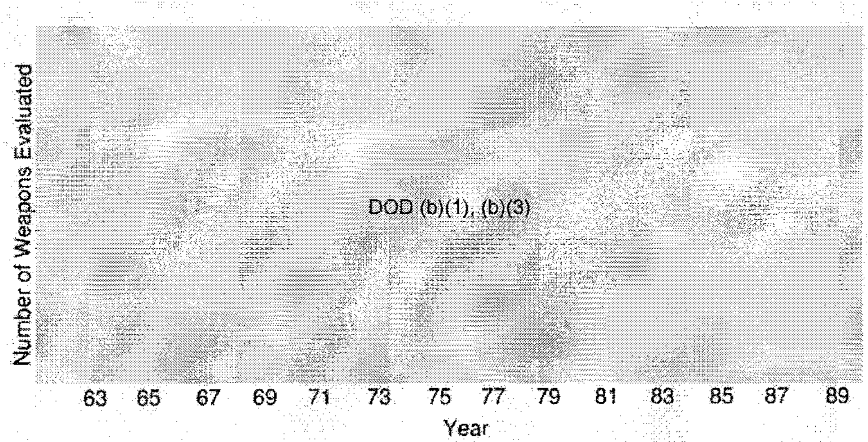

Figure 3. Significant improvements in the stockpile evaluation program have led to reduced test quantities and costs.

a failure indication. Lack of realism, of course, is an ever-present danger, since safety and data requirements cannot always be satisfied without some compromise. The willingness to diversify tests sometimes helps, however, as not all tests and test units need be subject to the same compromises.

The early shortcomings have been largely overcome in today's testing, and the results from these steadily improving test programs clearly show their importance in maintaining the nuclear arsenal.

Through the stockpile evaluation program, we have identified significant anomalies and developed timely and appropriate corrective actions.

Since the present evaluation program began in 1959, over 500 corrective actions have been taken on parts of the stockpile. These actions, which vary according to the seriousness of the findings, include process changes during manufacture; special monitoring to detect potential problems; military operational actions; restrictions on use; and in some cases, retrofit of stockpiled weapons.

Corrective actions have maintained the reliability of the stockpile in all required use conditions. In addition, less serious but consequential defects have been corrected, thus avoiding future, possibly more serious problems.

That the test programs and subsequent corrective actions are doing what we want them to is evident from another view of the results. The diversified, realistic tests that now characterize stockpile testing continually and consistently display a weapon failure rate of only about one percent. This demonstrates that through the process of discovering and fixing problems, we are helping to maintain high performance standards. This result provides credibility for our nuclear arsenal. The weapons in the US nuclear stockpile will perform reliably if they are ever needed.

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Military Liaison

Sandia is the DOE laboratories' operational and training interface with the military services.

The DOE is mandated with sustaining each weapon throughout its stockpiled life with a package of services and support. Part of this vital package is provided by Sandia National Laboratories.

We interact with the military representative, Field Command Defense Nuclear Agency, in a broad set of activities.

We plan the support of weapons for the stockpile jointly with weapon design engineers, the military users, and DOE staff. Ongoing support of the stockpile covers weapons designed by Sandia and Los Alamos or Lawrence Livermore national laboratories and centers on evaluating weapon design from the user's point of view.

Weapon look-alikes. We define requirements and review designs for trainers — weapon look-alikes that do not contain the nuclear explosive, but have mechanical and electrical systems that closely resemble the real weapon. We provide engineering assistance and technical manuals for trainers.

Some trainers demonstrate the relationships among subsystems or components. For example, they may emphasize the materials making up the nuclear explosive. Or they may illustrate weaponization of the nuclear explosive by showing Sandia's subsystems for arming, fuzing, and firing; command and control; and use control.

Concepts for disposal of explosive ordnance. We follow up with recommended procedures, interpret and support guidelines, and provide training for safely and efficiently handling a variety of probable scenarios.

Areas addressed include procedures to handle a damaged weapon; to collect classified material from the scene of an accident; and to detect, access, identify, field evaluate, render safe, neutralize, and recover hazardous materials.

Recommendations on spare parts for nuclear weapons. We host provisioning conferences where we recommend quantities and types of spare parts needed to support the maintenance and repair of individual weapons throughout their stockpile life. Base spares are items purchased by DOE and used to support the weapons themselves. Military spares are items purchased by the military services to support ancillary equipment and training.

Technical Publications. About 250 different manuals provide the military with step-by-step procedures to operate, assemble, disassemble, maintain, store, alter, retrofit, test, inspect, handle, and transport any weapon with its associated handling, disablement, and test equipment. This breadth underscores the DoD's dual role as custodian and operator of the stockpile.

Most of our manuals apply to specific weapons, while some are generic and cover safety or storage across all weapons.

Source data are also prepared for the military services' own use. This material may be incorporated into or adapted to technical publications having to do with topics such as loading or unloading weapons from their delivery systems — specific aircraft, submarines, mobile launchers, or reentry vehicles.

This entire task involves stringent management of a joint DOE-DoD publication system that includes built-in technical and editorial checks and balances. Our technical publications are continually being updated and improved as required by a variety of formal inputs.

We also prepare technical information on other projects: safe secure

DOD (b)(3)

trailers and railcars for transporting weapons; a nuclear emergency search team; and an emergency response handbook.

Videotapes to supplement technical manuals. Our videotape training program is focused on the military customer, geared directly to the troops, and is supported by our technical writers and field engineers from script writing through production (Figure 1).

The videotape training program uses military personnel and professional videographers in the field or in our modern training aids laboratory. Training entails portrayal of authorized operational concepts, weapon maintenance, test and handling equipment maintenance, special repair procedures, and retrofit procedures. Subscribers are supplied with updates as they are produced.

In-house review of procedures. The laboratory task group includes weapon design engineers, DOE personnel, and representatives from other Sandia organizations.

The group, led by a military liaison field engineer, evaluates the adequacy of both the manuals and the weapon design for field use. Considered are nuclear safety, human safety and health, environmental factors, human factors, weapon reliability, and measurement standards.

Joint DOE-DoD evaluation of procedures. The purpose of the joint task group is to validate the procedures as written in our technical manuals while still in a laboratory setting that permits development of alternate procedures or parts.

The evaluation is chaired by a representative of the Field Command Defense Nuclear Agency, and coordinated by the military liaison staff. A Sandia-trained military team carries out the procedures as written. Up to 50 people may be involved at once, each reviewing the procedures based on his or her expertise (Figure 2). We extend the joint evaluations to field operations wherever and whenever possible to take into account working conditions that may be found at military sites. The field setting for this joint task group activity allows closer approximation of the everyday reality of keeping the stockpile viable and healthy. We review weapons and associated hardware several years after their entry into the stockpile. An established format is used to recommend changes to the design, hardware, and procedures of weapons that have been operationally capable for three to four years. Operational capability is reviewed to maintain reliability and safety and to improve field operations.

DOE (b)(7)f

Figure 2. Sandia and military personnel work together to evaluate written procedures for the W87 in a simulated military environment. We provide two facilitators: the technical writer and the field engineer.

Training for special military teams. We train some troops directly; for example, members of teams that exchange limited-life components such as tritium bottles, dispose of explosive ordnance, and retrofit weapons. Hands-on experience within sight of an expert field engineer is complemented by multimedia presentations.

However, we primarily train military instructors and senior personnel — and, at times, equip them with audiovisual training aids for their classes (Figure 3).

By separate agreements between the DOE and each of the military services, we provide refresher courses that are not available at military schools.

Other training consists mainly of instruction in special repair procedures or training assistance in the field. We also conduct briefings and refreshers for staff officers, military inspection teams, and DOE personnel.

Unsatisfactory Reports. These reports cover questions, problems, and summaries of potential discrepancies that are sent by stockpile custodians and maintenance personnel through the military chain of command to the Field Command Defense Nuclear Agency and then on to Sandia. Photographs of graphically

DOD (b)(2)

may accompany the reports.

When Unsatisfactory Reports refer to DOE hardware, we coordinate the response as needed with Los Alamos or Lawrence Livermore National Laboratory, DOE, and Sandia weapon engineering organizations. A written response is then sent to the originating military unit through the Field Command Defense Nuclear Agency. Our goal is to answer urgent reports that may affect the military alert status of weapon units within

DOD (b)(2)

Figure 3. Military personnel come to Sandia for firsthand experience guided by a Sandia expert. Coding and recoding of Permissive Action Links, shown here, is an important example of this specialized training.

We also maintain a database on these reports for access by organizations within the nuclear weapons design laboratories. The database is useful for analyzing trends and pinpointing potential problem areas for additional action.

On-call, worldwide technical assistance. We conduct evaluations in the field to diagnose and resolve stockpile problems requiring hands-on tests. These onsite engineering activities enhance maintenance, safety, reliability, and functional readiness of the stockpile, even after years of storage and handling. Providing field assistance also improves our relationship with the user troops by encouraging questions and feedback on the performance of the weapon throughout its stockpile life.

Evaluations of stockpile improvements and repairs. We write change proposals, coordinate evaluation of alteration or retrofit procedures, and participate in design reviews of operations involving maintenance or exchange of limited-life components.

We have an active role in describing proposed improvements in the design or safety of older weapons. The writing of these change proposals can be prompted by events such as a cluster of Unsatisfactory Reports, failure of a stockpile sample during testing, or a design improvement recommended by our design engineers and approved by the DOE — the Defense Nuclear Agency coordinates approval by the DoD.

We conduct these evaluations to provide comprehensive proof-of-concept demonstrations that the operations can be properly completed. Thus, any problems can be diagnosed and corrections incorporated before procedures are implemented on a real weapon in the field.

When a retrofit to a stockpiled weapon is required in the field, we accompany the military or DOE team to make sure that all appropriate training has been accomplished and that the parts kits, tools, and procedures are ready and in place.

Sandia's military liaison role has expanded over the years.

Since its origin in 1947, the military liaison function has been performed primarily by field engineers who are not only knowledgeable but also available to make special trips on call to troubled areas. This role was first defined 42 years ago to provide a specialized team of laboratory observers to the Field Command Defense Nuclear Agency's precursor, the Armed Forces Special Weapons Project. Today this role has expanded to include extensive technical liaison with the military user and particularly with the troops in the field.

Our field engineer and technical writer — each both a generalist and specialist — are part of the Sandia structure in the feedback loop for each weapon. In addition to their other responsibilities, they are a part of a team that is on constant standby to monitor and fine-tune the adequacy and performance of stockpiled weapons under field conditions.

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Safety and Use Control

Title Unclassified, Article Secret Restricted Data

Sandia has played a major role in a continuing effort to review and recommend changes to the stockpile of nuclear weapons and provide solutions to improve nuclear safety and use control.

As technology progresses and studies and tests reveal new insights, threats, and priorities, advanced concepts are formulated and developed for nuclear safety assurance and control.

In this article, we discuss the emergence of modern requirements and the state-of-the-art for nuclear safety and control. Three sections following report on how well the stockpile meets quantitative safety design goals, the state of use control features in today's environment, and the program to prioritize improvement of our stockpile.

The Stockpile Nuclear Safety chart in the appendix gives an overview of the nuclear safety features incorporated into each weapon system currently in stockpile. A description of modern electrical safety features and of insensitive high explosives (IHE) is included in this chapter. Special terms are defined in Box A.

Box A: Special Terms

Nuclear weapon — the nuclear warhead including the arming and fuzing system and aerodynamic case.

Nuclear weapon system — the nuclear weapon and the DoD delivery system, procedures, and personnel.

Normal environments — storage and operational environments in which the weapon is required to survive without degradation in operational reliability.

Abnormal environments — accident environments in which the weapon is not expected to retain full operational capability.

Ensuring Nuclear Weapon Safety

Making nuclear weapons safe is a continuing challenge as standards are raised, missions and designs become more diverse, and the stockpile ages.

Between 1945 and 1951, nuclear weapons descended from the Fat Man and Little Boy design used a removable capsule of fissile material that could be inserted or removed manually from an otherwise fully assembled weapon. Without the capsule, the weapon was absolutely nuclear safe. The capsule could be inserted while on the way to the target, removed before landing if the mission was aborted, and stored separately from the chemical explosives to prevent radioactive material dispersal should the high explosive detonate accidentally.

In 1952, nuclear weapons design changed to include missile warheads and bombs for external aircraft carriage. To avoid insertion of the capsule before launch, the In-Flight Insertion device was developed to hold the capsule outside the high explosive sphere. Enroute to the target, the capsule would be inserted by an electric motor. The capsule could be extracted prior to landing if the weapon were not used. However, once the capsule was installed in the In-Flight Insertion device, it could be inserted by inadvertent or accident-caused operation of the electric motor, thus voiding the safety feature.

In 1957, sealed-pit nuclear weapons entered the stockpile. In these weapons, the fissile material was permanently sealed inside the high explosive assembly. [redacted] DOE (b)(3)

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Table 1. Milestones — Nuclear Weapon Safety

1946-1951	Manually inserted nuclear capsules
1952-1967	Mechanically inserted nuclear capsules
1957-present	Pre-assembled nuclear explosives (sealed pit designs)
1957-present	SAC Ground Alert (aircraft-delivered weapons)
1958-present	ICBM and Fleet Ballistic Missile Alert
1959-1986	Tactical Alert in Europe
1958-1968	Around-the-Clock Airborne Alert
1961	B-52 accident, Goldsboro, NC
1964	B-58 accident, Bunker Hill AFB, IN
1966	B-52 accident, Palomares, Spain
1968	B-52 accident, Thule, Greenland
1968	Nuclear detonation safety requirements expressed in probabilistic terms
1968-present	Sandia abnormal environment weapon response studies
1972	Sandia develops enhanced electrical safety concepts
1973	Sandia commits enhanced electrical safety design for B61-5
1977-1978	DOE Stockpile Improvement Study
1977	B61-5 enters stockpile with enhanced nuclear detonation safety systems
1979	B61-4 enters stockpile with insensitive high explosive
1980	Grand Forks B52 accident
1980	W53 Titan II accident, Damascus, AR
1987	DOE 1987 Stockpile Study

[redacted] DOE (b)(3), DOD (b)(1), (b)(3)

events related to nuclear weapon safety are listed in Table 1.

Beginning with the earliest designs, the electrical system has also incorporated numerous concepts to enhance nuclear safety and to prevent warhead detonation in an accident.

A strike-enable plug was developed to interrupt the arming circuit until the plug was inserted. Weapons were developed with removable power supplies. In other designs, the power supply was located outside the warhead so that no power capable of arming and firing the detonators was within the warhead itself.

Motor-driven safing switches, called "ready-safe" switches, were added to interrupt the circuits between the voltage power supplies and the capacitors that held the energy to fire the warhead detonators. The switch contacts were closed when the pilot operated a control knob in the cockpit.

Thermal fuses were developed to open critical circuits when the fuse was exposed to high temperatures (~320°F) in an accidental fire.

Environmental Sensing Devices and Handling Sensing Devices were added to respond to unique environments associated with the weapon having been irrevocably committed to use — for example, acceleration force for some time during missile launch, or deceleration for some time during deployment of

Figure 1. Accidents involving nuclear weapons during the 1960s led to operational and technical safety-related corrective

DOD (b)(1)

a bomb parachute. Having sensed the proper environment, the Environmental Sensing Devices would operate switches that completed the arming circuits.

Both types of devices were the first forms of use control DOE (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3) The sensing devices addressed this concern by providing an open circuit that could not be closed without a significant environment.

Increased exposure of nuclear weapons to hazardous operations led to accidents and new safety concerns.

In 1956, the Strategic Air Command began standing ground alert and around-the-clock airborne alert operations began in 1958; large deployments of nuclear weapons were made to Europe.

To date, the US has had 32 accidents where nuclear weapons were involved; 31 occurred before 1969. These accidents demonstrated that early electrical safing features were vulnerable to accident environments and further, their response to these environments was unpredictable. A few important examples illustrate this new concern.

- **Goldsboro, NC, 1961** — A B-52 flying alert with two B39-2 bombs suffered a ruptured wing fuel tank and broke up in flight over Goldsboro. Before the accident, the

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retardation. The high explosive in neither bomb detonated.

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Figure 3. Over Palomares, Spain, a B-52 bomber collided with its KC-135 refueling tanker. Four nuclear bombs fell from the aircraft, three impacted on land and one fell into the sea. Shown here is the recovery from an ocean depth of 2550 ft.

- **Bunker Hill AFB, IN, 1964 —** DOE (b)(3), DOD (b)(1), (b)(3)

- **Palomares, Spain, 1966; and Thule, Greenland, 1968 —** DOE (b)(3), DOD (b)(1)

At Palomares, the B-52 collided with its KC-135 tanker at about 30,000-ft altitude and both planes crashed. The four bombs separated from the aircraft at high altitude as the aircraft broke up.

Three bombs impacted on land. Two of these impacts resulted in detonation of the high explosive with extensive scattering of DOD (b)(1), (b)(3) DOD (b)(1), (b)(3) Detonation of the high explosive occurred because of the high impact velocity — DOD (b)(1) DOD (b)(1) DOD (b)(1) when the B-52 broke up. The fourth bomb impacted at sea DOD (b)(1) DOD (b)(1)

At Thule, Greenland, an airborne B-52 caught fire. The aircraft crashed on the ice cap and the high explosive in all four bombs detonated. There was no nuclear yield, but there was significant radioactive contamination. Shortly thereafter, airborne alert operations were discontinued.

[redacted] DOD (b)(1), (b)(3)

• **Damascus, AR, 1980** — The US has suffered only one nuclear weapon accident since 1969. This involved a W53 warhead on a Titan II intercontinental ballistic missile in its silo near Damascus (Figure 4). The missile's liquid fuel tank ruptured when a wrench was dropped on it by a worker. This ignited the fuel and the subsequent explosion destroyed the silo. The warhead

[redacted] DOD (b)(1)

In addition to these major accidents, electrical faults caused by equipment malfunction or human error have actuated safing switches. Thirty-seven such incidents were reported between 1961 and 1989. DOE (b)(7)f

In 1968 quantitative criteria were developed to guide the design and protection of nuclear weapons and nuclear weapon systems.

An evolution of the original qualitative standards survives today and calls for positive measures — tangible design features or procedural actions whose existence is relied upon to ensure that the goal is met. The standards, contained in DoD Directive 3150.2, required that there be positive measures to:

1. Prevent nuclear weapons involved in accidents, or jettisoned from planes, from producing a nuclear yield.
2. Prevent deliberate prearming, arming, launching, firing, or releasing of nuclear weapons, except upon execution of emergency war orders or when directed by competent authority.
3. Prevent inadvertent prearming, arming, launching, firing, or releasing of nuclear weapons in all normal and credible abnormal environments.
4. Ensure adequate security of nuclear weapons, pursuant to DoD Directive 5210.41.

During late 1967 and early 1968, criteria were jointly formulated by DOE (then AEC) and DoD and documented in letters from the Chairman, Military Liaison Committee, to the Assistant General Manager for Military Application, AEC. These criteria, called the "modern" nuclear detonation safety design criteria, required that:

• In normal environments, the probability of premature detonation will be less than one-in-one-billion per weapon lifetime.
• In abnormal environments, the likelihood of premature detonation will be less than one-in-one-million per accident.

Stockpile-to-Target Sequence documents, which define the physical environments the nuclear weapon can experience from the stockpile to the target, were expanded to provide realistic definitions of accidents and abnormal environments. In addition, a modern one-point safety criterion was developed to state, "In the event of a detonation initiated at any one point in the high explosive system, the probability of achieving a nuclear yield greater than four pounds TNT equivalent shall not

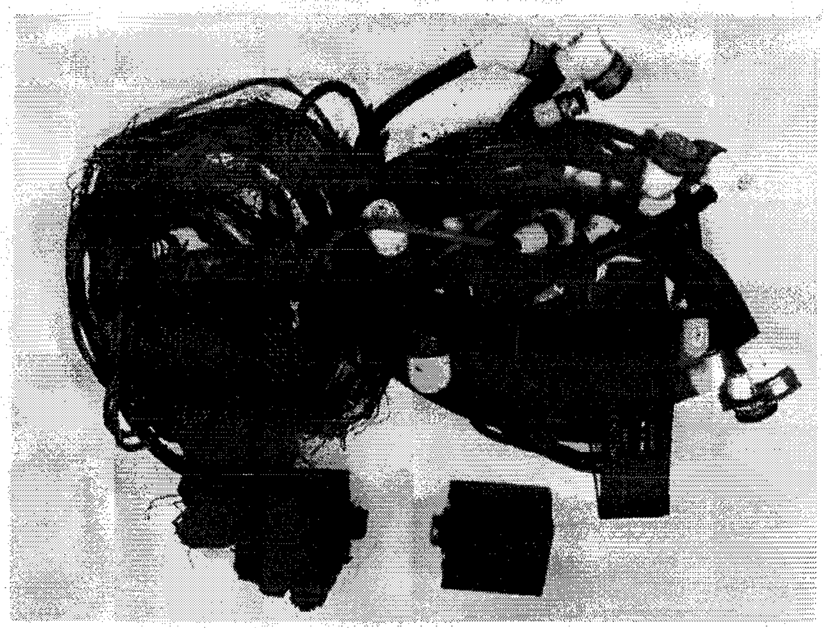

Figure 5. In 1968 we started a series of tests to assess weapon component response to accident environments. Fire destroyed the insulation from this cable assembly making its electrical response unpredictable and therefore potentially unsafe.

exceed one-in-one-million. One-point safety shall be inherent in the nuclear design; that is, it shall be obtained without the use of a nuclear safing device" (from a 1968 letter to Brigadier General Edward B. Giller, AEC, from Carl Walske, Chairman of the DoD Military Liaison Committee).

To determine if the 1968 stockpile could meet the quantitative requirements, we started an extensive investigation of how weapon materials responded to abnormal environments.

We already knew that safing switches could operate to the ARM position by faults other than those caused by an accident. It was possible that accidents could also cause an electrical signal to close the switches. We also found that the value of moving the major power supply out of the warhead was small if the warhead was mated to an alert-ready weapon system with a power source. If thermal fuses are subjected to temperatures above those at which they should open, the fuse material could reform and the fuse would carry current again.

Polymers used as insulators in printed circuit boards charred at high temperatures caused by fire or electrical short circuits. The charred material created low-resistance paths between conductors. These short circuits could result in unpredictable, potentially dangerous reconfigurations of the electrical system that could operate or bypass safety devices. It was shown that one wire in a weapon cable bundle, when subjected to high current, could melt the insulation. The melted insulation could form a short circuit, which could conduct current to adjacent critical wires (Figure 5). Some early weapon system designs routed power and safety-critical circuits in the same cable bundle.

Encapsulated printed-circuit boards were fractured by high temperatures. Extensive char damage resulted and metal particles were free to bridge conductors. Continued accumulation of knowledge showed how materials and systems react in severe environments such as fuel fires (Figure 6) and lightning (Figure 7).

Figure 6. Fuel fires can cause insulating materials in electronic components to become conductive. As a result, the response of the component cannot be predicted with confidence. In this test, the fuel fire directly contacts the bottom of the component assembly (center).

We concluded that it was not feasible to prevent electrical faults in a weapon exposed to abnormal environments and that simple electrical faults could operate existing safety subsystems.

In addition, we observed that our methods of analyzing weapon systems exposed to abnormal environments were inadequate to predict probability thresholds for a nuclear accident. In fact, the hardware response itself was not predictable in abnormal environment exposures. We established the following goals for systems to ensure nuclear detonation safety in abnormal environments to the levels required:

- Provide an assured, predictable, safe response of the weapon electrical system in a broad range of accident environments including fire, impact, crush, and unwanted electrical energy.
- Ensure that the predictable safe-response is maintained until the weapon receives, from the weapon system, an unambiguous indication of intended use.
- Minimize the number of weapon system components that are safety-critical in abnormal environments.

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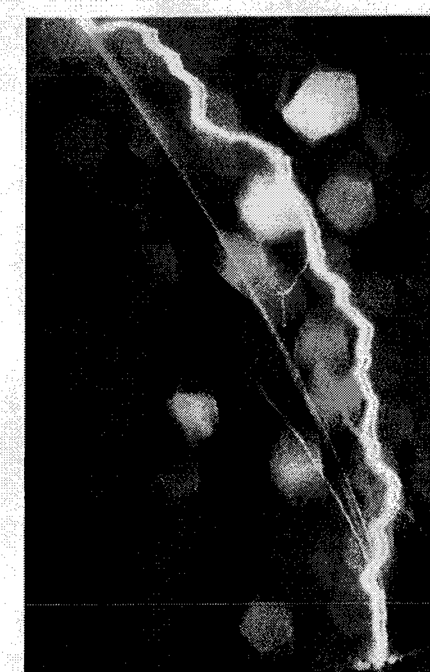

To ensure nuclear detonation safety in modern nuclear weapons, independent safety subsystems are incorporated to avoid dependence upon a single subsystem.

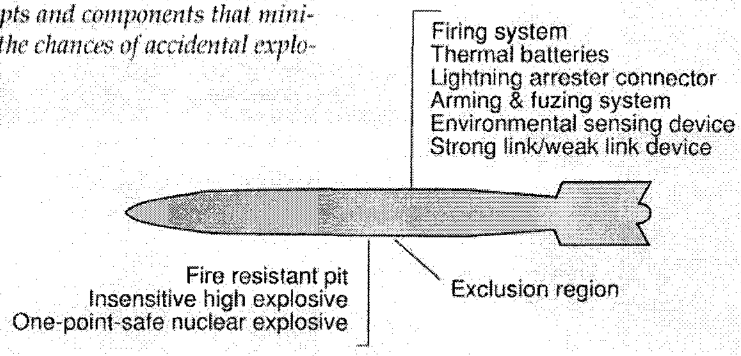

Figure 8. In weaponizing a nuclear explosive, we apply a variety of design concepts and components that minimize the chances of accidental explosions.

Each safety subsystem is designed to independently ensure isolation of threat-voltage sources from safety-critical components in the exclusion region (Figure 8). For abnormal environments, two independent safety subsystems are used to meet the one-in-one-million quantitative goal. Each system can be designed and tested to ensure an individual safety of greater than one-in-one-thousand (one-in-one-million together). For normal environments, a third subsystem is added to the chain to meet the one-in-one-billion requirement.

The first element of the new nuclear safety concept is a physical barrier that encloses components essential to causing a nuclear detonation — the firing set and nuclear system detonators — in an exclusion region isolated from all threat electrical energies. For normal weapon operation, electrical energy must be transferred across the barrier, but premature energy transfer must be precluded in both normal and abnormal environments.

Transfer of electrical energy through the exclusion region barrier is controlled by strong-link switches. These components are cased in high-strength steel. They use high-temperature-resistant inorganic insulation materials to ensure electrical isolation between input and output terminals in abnormal environments such as fire and crushing.

It is impractical to design strong-link switches and barriers to maintain assured electrical isolation at extreme levels of certain accident environments such as the very high temperatures in a fuel fire. For this reason, we use weak links. These are critical parts of the firing set and the nuclear system that are required to achieve nuclear yield. The weak links become irreversibly inoperable in the accident environment and thereby ensure safety. Examples of weak links are the high-voltage

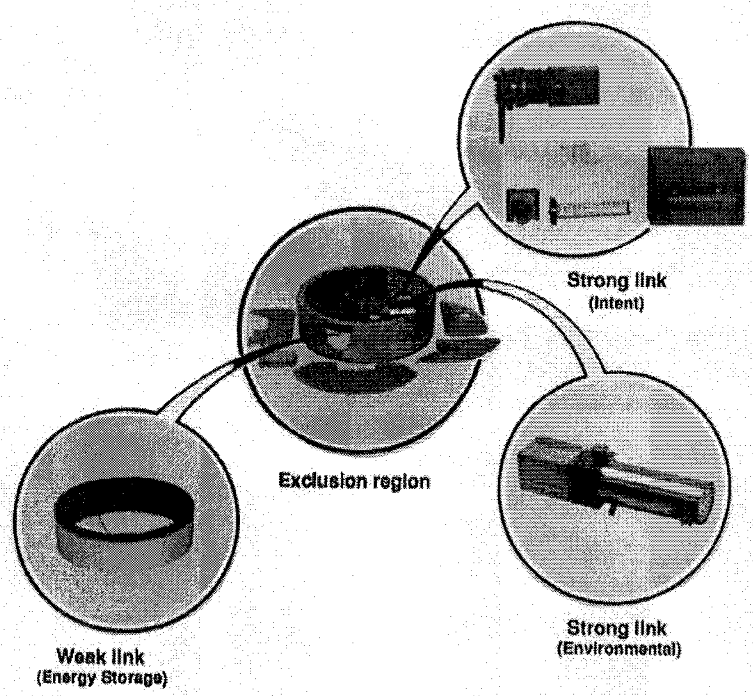

Figure 9. Modern nuclear safety concepts include strong-link switches that withstand extreme environments and operate only upon receipt of signals that cannot be applied by accident. Typically, one strong link operates as a result of human action; the other operates only if the weapon experiences a delivery environment such as bomb drop or missile launch. Weak links are designed to fail before the extreme environments cause the strong links to operate unpredictably. Typical weak links are the firing set energy-storage capacitor shown here and the the high explosive in the nuclear system. Strong and weak links are located together in an exclusion region (barrier) from which unwanted electrical energy is excluded.

capacitor in the firing set, whose energy fires the warhead detonators and the high explosive in the nuclear system.

Weak links, strong links, and exclusion region barriers are colocated and physically arranged so that in an accident, the weak links will become inoperable before the strong links or barriers cease to maintain electrical isolation (Figure 9).

The stimuli needed to actuate a strong-link switch may be electrical signals having a unique pattern or inertial inputs such as acceleration, and should require an unambiguous indication of human intent to use the weapon. The stimuli have unique characteristics that are highly unlikely to be duplicated in accident environments or as a result of hardware malfunction. Unique enabling stimuli and strong-link discriminators also provide an interface with the warhead that allows the delivery system to meet its safety requirements to prevent inadvertent enabling.

Additional safety in normal environments is also required. The arming and fuzing subsystem provides this protection by preventing application of power to the exclusion region boundary until it is required for proper weapon system operation. For example, power to charge the firing set capacitor is not applied until an appropriate point is reached in the delivery trajectory. No abnormal-environment nuclear detonation safety requirements are placed on any elements of the arming and firing subsystem located outside the exclusion region.

Modern safety features are being used in the stockpile as each technology matures.

Strong-Link Switches — The first modern strong links entered the stockpile in the B61-5 in 1977. This switch was made of high-strength steel with high-temperature resistant ceramics to isolate the switch contacts. A specific series of 47 long and short pulses of 28 volts is the only pulse sequence that can operate the switch. Any other pattern will cause the switch to lock in the SAFE/RESET position.

Another switch was also used in the B61-5 as the second strong link and is part of the trajectory-sensing safety subsystem. Its vastly different design and pattern of 24 electrical pulses ensure its independence and contribution to safety.

Environmental Sensing Strong-Link Devices — The strong-link technology was extended to use environmental stimuli to directly close the switch contacts. The stimulus is usually a combination of acceleration and time to indicate to the switch that the weapon is experiencing an intended-use environment, such as missile trajectory toward a target, and not a combination that could occur in an accident. An example is the fluid-metering accelerometer used in the Navy W76/Mk4.

Lightning Arrester Connector — Because strong-link switches can only hold off energy up to certain voltages, lightning arrester connectors were designed to break down at about 1000 volts (well below the assured holdoff of strong-link switches) and shunt lightning energy to the weapon case. Combined with strong links, the connectors ensure that lightning energy will not penetrate the exclusion region.

DOD (b)(1)

Magnetic Strong Links — This type of strong link uses a split transformer with the primary coils outside of the exclusion region and the secondary coils inside (Figure 10). The electrical arming energy is converted to magnetic energy and passed between the coils only when a strong-link wheel receives the proper unique signal and rotates a ferrite window into place. In the safe position, the misalignment of the metal strong-link wheel prevents magnetic coupling.

Detonator Safing — Lawrence Livermore National Laboratory developed the concept of detonator safing for the W84 and W87. This concept uses a discriminator/driver to operate a mechanical safing and arming device. The device has a high-strength steel wheel which, when actuated, rotates a high-explosive booster pellet into line with the detonators. In the SAFE position, the steel wheel mechanically blocks the exploding detonator from initiating the explosive train. When armed, the wheel rotates the booster pellet so that the detonator can initiate the insensitive high explosive.

Optical Systems — New concepts being developed include optical systems for charging a capacitor and for firing a detonator. These options could greatly enhance safety by eliminating electrical connections to the arming and firing system in the exclusion region. This would eliminate pathways for unwanted external-energy penetration and make arming and firing immune to electrical threats.

Insensitive High Explosives — In the mid 1970s, Los Alamos and Lawrence Livermore National Laboratories developed insensitive high explosives, which greatly decrease the probability of scattering radioactive material in abnormal environments such as impact, fire, crushing, or lightning. In 1979, the B61-4 was the first weapon to enter the stockpile with insensitive high explosive.

Fire-Resistant Pits — During the 1980s, nuclear weapons were introduced into the stockpile with nuclear material in the primary surrounded by a fire-resistant shell. This shell reduces the potential for dispersal of radioactive material even if the high explosive burns in an accident.

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Use Control

Higher levels of readiness, faster reaction times, and broader deployment of nuclear weapons required more physical security and stricter controls on custody.

Table 1. Milestones in Use Control

Year	Event	Use Control
1946	Atomic Energy Act	AEC custody
1954	Atomic Energy Act amended to allow programs of cooperation	
1957	Pre-assembled nuclear explosives (sealed pit) to stockpile	DoD custody
1959	NATO weapons on Quick Reaction Alert	
1960	Custody problems with NATO weapons	
1962	President directs improved methods	Mechanical Locks
1963		Category A*
1964		Category B
1972	Decision to use Permissive Action Link (PAL) in Pacific	Category B′
1973		Category C
1974		Category D
1976	Decision to use PAL for bombers	
1979		Category F
1980	Automated code handling requested	
1983	Automated PAL to field	Category G
1986	Automated code handling to field	
1990		Category D′

* see Table 2 for explanation of PAL category types

"Effective command and control of nuclear weapons will contribute to the maintenance of deterrence by assuring authorized use of nuclear weapons when directed; it will also contribute to the maintenance of stability and safety by assuring against unauthorized or inadvertent use of nuclear weapons." (NSDD 281, United States Nuclear Weapon Command And Control (C), August 21, 1987.)

This statement reaffirms existing policy that has guided the US for over 40 years. Use control is a broad term that includes the procedures, devices, and equipment that allow timely authorized use of nuclear weapons while precluding or delaying unauthorized use.

Some form of use control has always been applied to nuclear weapons (Table 1). At first, both safety and control were achieved by maintaining the critical nuclear components separate from the rest

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of the weapon system and in the custody of the Atomic Energy Commission (AEC). With the advent of bilateral programs of cooperation between the US and various NATO allies and the decision in 1960 to place some of the NATO weapons on Quick Reaction Alert, concerns surfaced over the ability to maintain physical control.

In August 1959, the DoD requested that Sandia initiate development of a remotely operated electromechanical lock to replace the 3-digit combination lock used for increased handling safety on Atomic Demolition Munitions. The locks had been used instead of environmental sensing devices (ESDs) because some prescribed action was necessary to prevent inadvertent or accidental arming that wasn't required with the sensing devices. During the summer of 1960, we began to discuss with the AEC how remotely operated locks could be used as a command and control aid. By that November, 4-digit, demonstration prototypes were available.

In February 1961, the Joint Congressional Committee on Atomic Energy (JCAE) delivered to President Kennedy a report based upon onsite visits suggesting that custodial arrangements for QRA weapons might not be in compliance with the Atomic Energy Act. As a result of a number of subsequent studies by the DoD, Joint Chiefs of Staff, JCAE, and the AEC, President Kennedy issued National Security Action Memorandum 160 on June 6, 1962, directing that all weapons deployed to Europe be equipped with Permissive Action Links (PALs).

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During the late 1960s, the Strategic Air Command (SAC) also began to supplement procedural controls with coded locks. We provided technical consultation for development of equipment such as the Titan Coded Switch, and we developed the Bomber Coded Switch System to provide mechanical launch/release control. In 1983, SAC began operational use of PAL-equipped bombs in the FB-lll and B-52.

Increased awareness of the terrorist threat, and the potential impacts of radioactive contamination that would occur if the explosive penalties of Emergency Destruct (ED) had to be used, led to development of Command Disablement (CD). When initiated, CD renders the weapon unusable by disabling critical components without the danger of radioactive contamination. This capability entered the stockpile in 1973 in the W70 Lance and continues to be a requirement for all new tactical and some strategic systems.

Although CD is integral to the weapon system and more available than ED, there are tactical situations in which little or no time is available to decide and order either procedure. We anticipated this and began development of Active Protection Systems (APS), which would automatically invoke the disablement penalty upon detection of an invasive attack. DOE (b)(3), DOD (b)(1), (b)(3)

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The DOE is required by joint agreement with the DoD to develop and produce necessary ancillary equipment. Consequently, much of the PAL, CD, and APS control equipment is also designed by Sandia. Our involvement does not stop there. Under shared DoD/DOE responsibility to ensure safety, security and control, we are involved in a wide range of activities to ensure that the code management, nuclear release system, and interfaces and equipment work reliably, safely, and securely. Thus, while our use control involvement started with the development of a coded lock for a weapon, it has been greatly enlarged in scope (Figure 1).

Use control must both thwart potential adversaries from obtaining meaningful yield from a weapon and allow rapid use when authorized by the President.

To accomplish use control objectives, modern designs include both a PAL and a weapon denial system. The weapon denial system consists of two parts: the disablement system (APS and/or CD) and passive delays provided by the PAL. Current PALs can contain up to six different 6-digit release codes. Any of these release codes can be used to unlock the weapon for authorized use. The PAL senses the number of consecutive unsuccessful code attempts and, after reaching a specified number, permanently locks the weapon, preventing an adversary from guessing the correct release code. When locked, the PAL prevents the functioning of critical arming or firing circuits that are buried deep within the weapon system.

In the event physical security measures are breached, the weapon denial system provides an additional layer of protection. When initiated, the CD system causes the rapid destruction of critical components in the weapon. Although the destruction is of sufficient severity to require major rebuild of the weapon, it is accomplished in a manner that does not pose either a health or environmental threat. Accidental or inadvertent initiation of the CD system is prevented by a 3-digit code that must be inserted before a unique pattern is generated and sent to the disablement logic.

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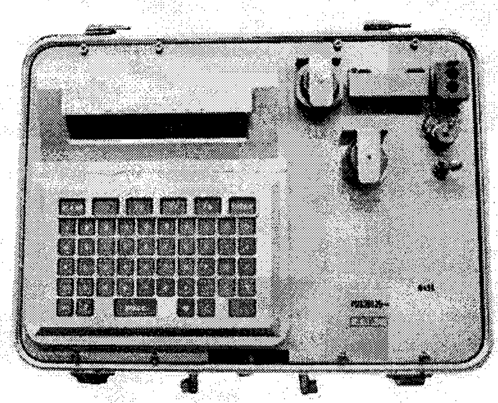

Recode controller

Figure 1. Sandia is involved with the using Services in virtually all aspects of nuclear weapon command and control. In addition to weapon resident hardware, we provide code management hardware and concepts and disablement systems.

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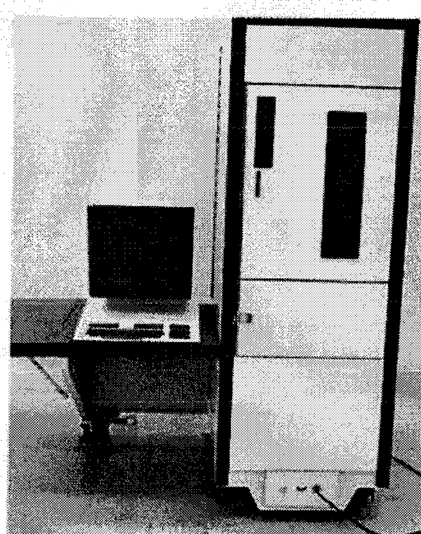
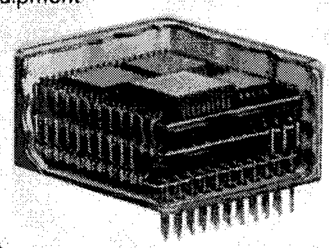
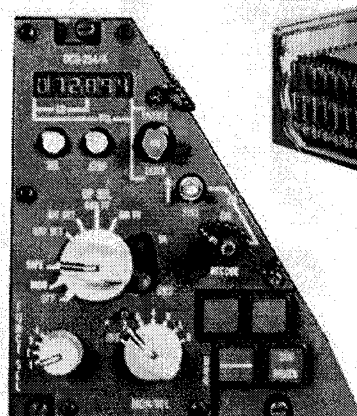
Ancillary equipment



Headquarters processor



Permissive action link



Aircraft monitor and control

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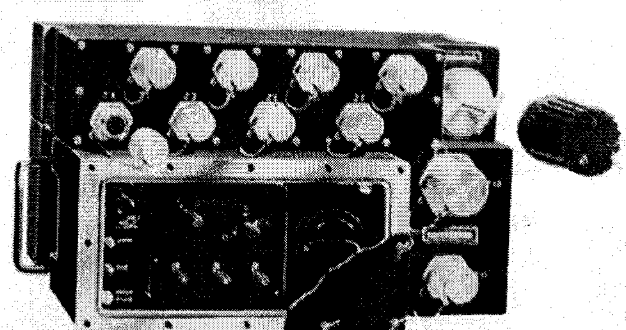

Disablement controller

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If an adversary obtains possession of a weapon, the last line of defense is provided by the classified PAL hardware. Not only is the adversary faced with the task of locating and bypassing the specific devices controlled by the PAL, his job is further impeded by the lack of special disassembly tools and other passive use-control features in the design. By presenting both an unknown and complex task to the adversary, these passive features are intended to provide additional delay, allowing security forces to regain control of the weapon.

Since 1962 Sandia has developed and fielded eight distinct PAL devices and several DoD launch/release control devices.

With the exception of several Army-developed combination locks used on AFAPs, use control of all land-based tactical and strategic aircraft-carried nuclear weapons is accomplished with coded locks that Sandia has developed.

The evolution of the stockpile can be divided into three eras, each of which can be traced to changes in national policy and external events. First, the rapid incorporation of PAL into the stockpile was the result of NSAM 160. The PALs were single-combination mechanical locks and electromechanical devices that supplied the necessary political and military control required for a nuclear policy of Mutual Assured Destruction.

The increased likelihood of nuclear terrorism and needs created by the shift in national policy to Flexible

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While this trend has continued through the introduction of new systems and the stockpile improvement program, the ability to fully support a Flexible Response doctrine has been hampered by the longevity of our older systems. This is especially true in the tactical arena where retirement or retrofit of the older single-code weapons has not occurred.

The inability to completely modernize the stockpile creates other challenges for Sandia. The military services have in their operational inventory a total of over 20,000 pieces of use control equipment that Sandia designed and DOE produced. This equipment represents nearly seventy separate designs, many of which have exceeded their design service life. Consequently, we are actively involved in providing maintenance and, in some cases, life extension retrofits.

The aging stockpile also complicates the design of new use control equipment. Operational, training, and logistical needs of the military services require that new control equipment must be compatible with the complete spectrum of existing devices, both new and old. This requirement not only increases cost, but, in some cases, limits improvements in flexibility and security.

In an era of reduced numbers of weapons and constrained operational budgets, greater emphasis is being placed on survivability and manpower utilization. Evolving national policy dictates a need for greater control over the escalation and termination of nuclear hostilities. These factors, coupled with an ever increasing terrorist threat, has started the third era (encrypted PAL) in the evolution of use control.

Like the weapon systems that they are associated with, use control systems are becoming more automated and less dependent on personnel. One method of achieving this has been to integrate the use control interfaces into the weapon systems themselves. This requires different control and security techniques. We have developed a multiple-code PAL that allows all peacetime operations to be encrypted. The first use of this PAL will be on the 155 mm, W82 AFAP scheduled to enter the stockpile in the 1990s. Subsequent systems will also incorporate this new PAL.

By using encryption, peacetime operations can be done securely by operational personnel and in deployment situations not previously possible. Currently, all aircraft systems must be taken off alert and recoded directly. Encryption allows a whole aircraft to be securely recoded from a single point while remaining on alert.

DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3)

We are developing new control equipment to support encrypted PAL operations that will be in use by the mid 1990s. In addition to supporting encrypted operations, it also includes the MIL STD 1553 digital interface to communicate directly with the new weapon systems and aircraft entering the inventory. Use of this control equipment will not only improve security, but will enhance operations by enabling operational unit personnel to perform all code operations, both in peacetime and wartime.

By actively participating with the military services, our research and development activities provide the use control needed to support an evolving nuclear stockpile. Our efforts support national policy to ensure that nuclear weapons can be used if, and only if, authorized by the President.

For more information, call
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Stockpile Improvement Program

We have addressed safety and use control concerns and improved reliability on selected stockpile weapons through retrofits.

In early 1968, the DoD transmitted enhanced nuclear detonation quantitative design criteria to the AEC. These design criteria caused the nuclear weapon laboratories to reconsider how weapons were designed and to examine the potential response of existing weapon hardware to severe abnormal environments. Initial studies suggested that the design of existing weapons was consistent with the one-in-one-billion probability of a nuclear detonation per weapon stockpile lifetime during exposure to normal environments.

In 1968, existing weapons used organic plastics as dielectrics; direct current motors or relay coils as prime movers for safety devices; junction boxes to interconnect safing, arming, and fuzing subsystems; and multiconductor cables to carry both the input and output of safety devices. Tests and analyses showed that (1) organic plastics become conductive during and after exposure to high temperatures, (2) stray direct current voltages could prematurely operate safety devices, and (3) charring and crushing of junction boxes and cables could bypass safety devices. These findings suggested that a sound technical basis did not exist to support an assessment of a one-in-one-million assured safety in abnormal environments.

These conclusions stimulated the development of new safety concepts that used unique-signal-driven strong-link safety switches coupled with dielectric barriers of inorganic materials to isolate critical circuits from potential power sources.

Colocation of these strong links with weak links (an element whose proper operation is required to achieve a nuclear detonation) minimizes the environments in which a strong link must maintain electrical integrity. The strong link is then only needed to ensure isolation until the failure of a weak link. Appropriate human intent or trajectory environment stimuli were identified that would ensure generation of the unique signal only at the proper time. Commitment of these new concepts to scheduled weapon development first occurred in 1973.

In 1974, after an intense study of all aircraft-delivered weapons and the new quantitative safety standards, Sandia formally notified the AEC of serious safety shortcomings.

We noted that:

DOE (b)(3), DOD (b)(1), (b)(3)

"...a plan to correct this situation (should) be developed within the AEC and...we (should) seek early concurrence in this plan with the DOD...this corrective action is required because these older weapons are being utilized in operations during which the currently specified abnormal environments are apt to occur....

"Until this or similar action is taken...the risk inherent in conducting QRA alert operations with these weapons (should) be called to the attention of the Secretary of Defense and the AEC (should) recommend that alert operations with these weapons be restricted to those missions that are absolutely required for national security reasons."

After we communicated our concerns to the Department of Defense, technical safety reviews were performed on all stockpiled weapons and their delivery systems.

DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3) Resources were not available to correct all stockpile weapons at once, so Sandia undertook a study to rank weapons according to priority for hardware upgrades and to identify procedural and operational changes that could reduce risks. This study culminated in the DOE Stockpile Modernization Study that was forwarded to the DoD in September 1978. All stockpiled weapons were ranked for corrective action into three groups according to the following criteria:

- exposure to safety, security, and command/control problems and the susceptibility of the weapon to those problems,
- military-use-related deficiency(ies), and
- national defense policy considerations.

Weapon characteristics that could affect nuclear detonation safety, radioactive material scatter, unauthorized use, and military use related deficiencies were considered. Weapons were put into these priority groups to reflect different urgencies for corrective action.

[redacted] DOE (b)(3), DOD (b)(1), (b)(3) [redacted] Weapons in the second priority group required corrective action at some time during the next decade. The third group consisted of those weapons lacking enhanced safety features, but judged to have significantly less potential exposure to abnormal environments. We recognized that these weapons might be retired from the stockpile without being upgraded. A few weapons were not considered because they would soon be retired.

The DoD accepted the DOE Stockpile Improvement Program recommendations, provided that the upgrading of existing weapons would not interfere with new weapon production.

The response authorized the development of hardware upgrades for B28FIs and B61-0,1,2, and 5 weapons and further joint studies on other weapons. The results of these studies led to one additional upgrade, the W31/Nike Hercules. The B53 (Figure 1), removed from alert operations in 1983 when the last B-52D aircraft was retired, was to be placed in the inactive reserve by the end of FY86. In early FY87, the Air Force decided to return the B53 to active status. It was to be used in alert operations on B-52H aircraft to cover targets then assigned to the W53/Titan, scheduled for retirement by the end of FY87.

[redacted] DOE (b)(3), DOD (b)(1), (b)(3) [redacted]

Figure 1. The B53, scheduled to be placed in inactive reserve, was instead needed for alert operations by the Air Force. A DOE-proposed safety upgrade was authorized in early 1987. The first modification kit was shipped in early 1988 and all B53s were retrofitted by the end of that year. The end views shown here compare the original (middle) and new (bottom) configurations.

Table 1. 1990 Status of Weapons in the 1978 Study

Weapon	*Status*
	PRIORITY 1 GROUP
B28FI	Retrofitted to B28-0,1 or retired in 1989.
W25 Genie	Retired in 1984.
	DOE (b)(3), DOD (b)(1), (b)(3)
B53	All have been retrofitted.
	PRIORITY 2 GROUP
B43	All Air Force weapons have been retired. Some are still deployed by the Navy, but will be retired by 1991.
B61-1	Retired for retrofit into B61-7s, scheduled for completion in FY90.
W69 SRAM	Taken off alert in 1990. To be replaced by the W89 SRAM II in the late 1990s.
B61-0	To be factory retrofitted to the B61-6 and B61-9 starting in 1991 and completed in 1993.
B61-2, 5	To be factory retrofitted to the B61-8 starting in 1993 and completed in 1998.
W50 Pershing IA	To be retired following the Intermediate-range Nuclear Forces treaty reductions in 1991.
W44 ASROC	Retired in 1989.
W53 Titan	Retired in 1987.
W33 AFAP	No change. Scheduled retirement is beyond 2000.
W48 AFAP	No change. Scheduled retirement is beyond 2000.
W31 Honest John	Retired in 1989.
	DOE (b)(3), DOD (b)(1), (b)(3)
B54 SADM	Retired in 1989.
B57 Depth Bomb	No changes. Scheduled for replacement by the B90, beginning in 1993, completed in 1999.
W70-1,2 Lance	No change. Complete retirement scheduled for 1998.
W70-3 Lance	No changes. Complete retirement scheduled for 1999.
	PRIORITY 3 GROUP
W56 Minuteman II	No changes. No scheduled retirement.
W62 Minuteman III	No changes. No scheduled retirement.
W58 Polaris	Retired in 1982.
W45 Terrier	Retired in 1988.
W55 SUBROC	Retired in 1990.
W68 Poseidon	Complete retirement scheduled for 1995.
	SET ASIDE; IMMINENT RETIREMENT
B28 RE	Retired in 1986.
W30 TADM	Retired in 1979.
W45 MADM	Retired in 1984.
W66 Sprint	Retired in 1985.
W70-0 Lance	Retired in 1982.
W71 Spartan	To be retired in 1991.
W72 Walleye	Retired in 1979.

The DOE proposed an accelerated safety upgrade program for the B53 to be accomplished before resumption of alert operations. This program was authorized in February 1987, the first kit was shipped in January 1988, and all B53s were retrofitted by the end of that year.

Table 1 shows the status of weapons listed in the 1978 study. The field retrofits on the B28FI and B53 weapons incorporated a single unique-signal-driven intent strong link, stainless steel barriers, and a lightning arrester connector. Use of a single strong link rather than two independent safety subsystems, which are currently used on new weapons, provides a level of assured safety in abnormal environments of one-in-one-thousand instead of the one-in-one-million stated in the modern design criteria. With this design approach, we were able to make a significant improvement in safety and meet a critical defense need. Additionally, the B28FI retrofit included a Category D PAL, rejuvenation of the main energy storage capacitors, and circuit changes in the free-fall fuzing system. The last two changes improved the bomb reliability by eliminating two age-related failure modes.

[redacted] DOD (b)(1), (b)(3)

Figure 2. An important part of the Stockpile Improvement Program is the modernization of the B61-1 now nearing completion. This is a factory retrofit that incorporates electronic components and insensitive high explosives to enhance nuclear-detonation safety. Category D PAL and a nonviolent command-disablement system provide use control. Sandia-developed components are shown here. The new weapon is the B61-7.

Because of the compressed schedule on the B53 program and the limited number of conductors passing through the sealed bomb case, only the laydown delivery option was retained on the modified weapon and a use control upgrade was not attempted.

The field retrofit on the W31/Nike Hercules included the addition of two independent safety subsystems, with their attendant strong links, and a lightning arrester connector. Therefore, this upgrade provides assured safety in abnormal environments at the level of one-in-one-million probability of a nuclear detonation. This modification also included a Category D PAL and a reliability improvement achieved by rejuvenating the main capacitors.

All of the B61 Stockpile Improvement Programs will be conducted as factory retrofits. All B61-1s have now been removed from stockpile for the retrofit to B61-7s scheduled for late 1990 (Figure 2). The retrofits provide improved nuclear safety with a new firing set with two independently enabled strong link switches. The first strong link is enabled prior to release by a unique prearming signal generated from the aircraft; the second strong link is enabled by sensing a unique post-release environment. [redacted] DOE (b)(3), DOD (b)(1), (b)(3)

Similar retrofits will be performed on the older B61s. [redacted] DOE (b)(3), DOD (b)(1), (b)(3)

[redacted] DOE (b)(3), DOD (b)(1), (b)(3) The B61-2s and 5s will be converted to Navy B61-8s with enhanced nuclear-detonation safety, insensitive high explosive, a Category D PAL, a command-disablement system, and an ACORN boost-gas transfer system similar to the B61-6. Completion of these upgrades, along with the B61-3, 4, and 10 and B90 new production programs, will

DOE (b)(3), DOD (b)(1), (b)(3)

allow retirement of all B43 and B57 weapons from stockpile.

In March 1988, the DOE published its 1987 Stockpile Modernization study with emphasis on safety and use control.

DOE (b)(3), DOD (b)(1), (b)(3)

Since the study, all B28FIs have been retired, all B61-1s have been either retrofitted or returned to Pantex for retrofit, all B53s have been retrofitted to B53-1s, and the SRAM A/W69 has been taken off alert. DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3)

The present program for replacing the SRAM A will not be completed until 1998. This adds five years of potential vulnerability to the manned bomber alert posture, assuming that it might be necessary for SRAM A to go back on alert in the interim. Priority replacement of SRAM As on alert could reduce this time.

DOE (b)(3), DOD (b)(1), (b)(3)

However, the B53-1 is an all-uranium weapon. This reduces the hazards of scattering, but the consequences could still be serious.

The W56 and W62 also stand alert on Minuteman missiles but are in silos. Therefore, the exposure to potential accidents during alert is less than for the aircraft alert system.

Several weapons would be ranked lower in priority if they were not air-transported or if they were transported in shock- and fire-resistant shipping containers. After continuous exposure during alert, air transport of weapons represents the next highest nuclear safety risk.

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The Net Assessment

Title Unclassified; Article Secret Formerly Restricted Data

Today's stockpile is effective and reliable, but important work remains to improve its safety and security.

The US nuclear weapon stockpile has evolved in response to major political, economic, and technological forces. Political forces have shaped the evolution of nuclear war-fighting doctrine from massive retaliation to flexible response. Economic considerations have influenced the mix of nuclear and conventional forces. Technological developments have given rise to new military applications for nuclear explosives.

Sandia's responsibilities to the stockpile have remained relatively unchanged through this evolution: provide technical options for nuclear deterrence, ensure the integrity and competence of the stockpile, and aid the nation's policy makers in new concepts for improving the stockpile. To meet these responsibilities, we continually assess the current stockpile's reliability, safety, control, and strategic utility.

No deterrent can serve its purpose unless it is credible. As described earlier in this issue, we conduct a continuous evaluation of US

DOE (b)(3), DOD (b)(1), (b)(3)

Ensuring the safety of nuclear weapons is both a moral and a technical obligation. Technological advances over the last 40 years have made it possible to establish more quantitative and stringent safety criteria. Unfortunately, our nuclear arsenal contains many older weapons, whose designs do not reflect all of these advances.

DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3) Less than one-quarter contain high explosives that are insensitive to shock and high temperatures.

DOE (b)(3), DOD (b)(1), (b)(3)

Control over the use of nuclear weapons is as crucial as nuclear safety. Command and control systems must preclude weapon use by terrorists or other persons without command authority, but still permit unencumbered use when authorized. Permissive Action Links, which were introduced into the stockpile in the 1960s, are coded devices built into nuclear weapons that prevent their unauthorized use. Today, one-third of weapons deployed overseas do not have these devices. We are concerned about their vulnerability to unauthorized use.

This is not to say that no progress has been made in weapon safety and use control. It's just that our progress has not been as great as it should have been.

In 1977, a Sandia study of older, deployed nuclear weapons started joint DoD/DOE stockpile improvements through retrofits, retirements, and new weapon designs. DoD altered operational procedures to remove certain weapons from operational status, to restrict their transport, or to improve their storage conditions. In 1987, we reexamined the stockpile and found that, despite significant improvements, the accomplishments did not meet the goals set ten years earlier.

Finally, in a net assessment of the stockpile, the issue of strategic utility must be considered: does the stockpile fulfill its mission? This is, quite properly, a question to be answered by elected policy makers and the executive institutions charged with maintaining national security. However, our work with the stockpile allows us insights into its value and its possible future directions.

In our view, the nuclear weapon stockpile has fulfilled its mission as a deterrent through the Cold War era: for over forty years, global conflict has been avoided. Today, however, encouraging international developments are resulting in relaxation of East-West tensions, and funding of the weapons program may be more constrained than ever before. In view of these changes, policy makers must consider how our nuclear defense should be shaped for a post-Cold War era.

We believe that the future stockpile, one whose primary purpose may be to maintain peace rather than deter war, may undergo fundamental changes in response to political and economic forces.

This "peacetime stockpile" should be appropriately sized to the threat, and should reflect the highest standards for safety and use control. To maintain the effectiveness of a nuclear deterrent, continual evaluation will be necessary.

Today's stockpile is effective and reliable, but important work remains to make it as safe and secure as it could and should be. We must upgrade and change our ensemble of nuclear weapons to respond to a changing world. What cannot change, however, is our vigilance toward stewardship of this deterrent.

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Appendix: Today's Stockpile

DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3)

This appendix briefly describes the weapons in the US nuclear stockpile at the start of Fiscal Year 1991. The charts summarize the status of the stockpile. The first chart shows the development and production status of the present stockpile and the new weapons about to enter it. The second chart shows the required and assessed reliability, and the third chart shows the safety status. The fourth chart gives the number of each type of weapon in the stockpile, and the fifth chart gives their average age. Figure 1 describes our plan to improve the safety and use control of the stockpile in coming years.

A brief description of each weapon type follows the charts. For each weapon type, a cutaway drawing shows the nuclear explosive and the Sandia-designed components. If a nuclear warhead is delivered by a missile, the cutaway shows only the part of the missile called the warhead section, the reentry vehicle, or the reentry body. Gravity bombs and artillery shells are shown as complete systems. These drawings illustrate our shared responsibility for missile warheads and Artillery Fired Atomic Projectiles and Sandia's total responsibility for weaponizing gravity bombs.

A second illustration for each weapon shows the warhead in its storage configuration, in field deployment, or under test. If there is more than one model (Mod) of a weapon (e.g., the B61), all Mods are discussed but only representative ones are shown.

A narrative section describes the available yields, delivery options, and the aircraft and missiles that deliver the weapon or the guns that fire them. Existing safety and use-control features are noted, and where applicable, in-process and planned improvements are described. Also noted are the limited-life component exchange interval, the reliability requirements, and the assessed reliability. Average age is restated for convenient reference.

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Weapons Program Status

Title Unclassified, Chart Confidential FRD

DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3)

[redacted]

DOE (b)(3), DOD (b)(1), (b)(3)

[redacted]

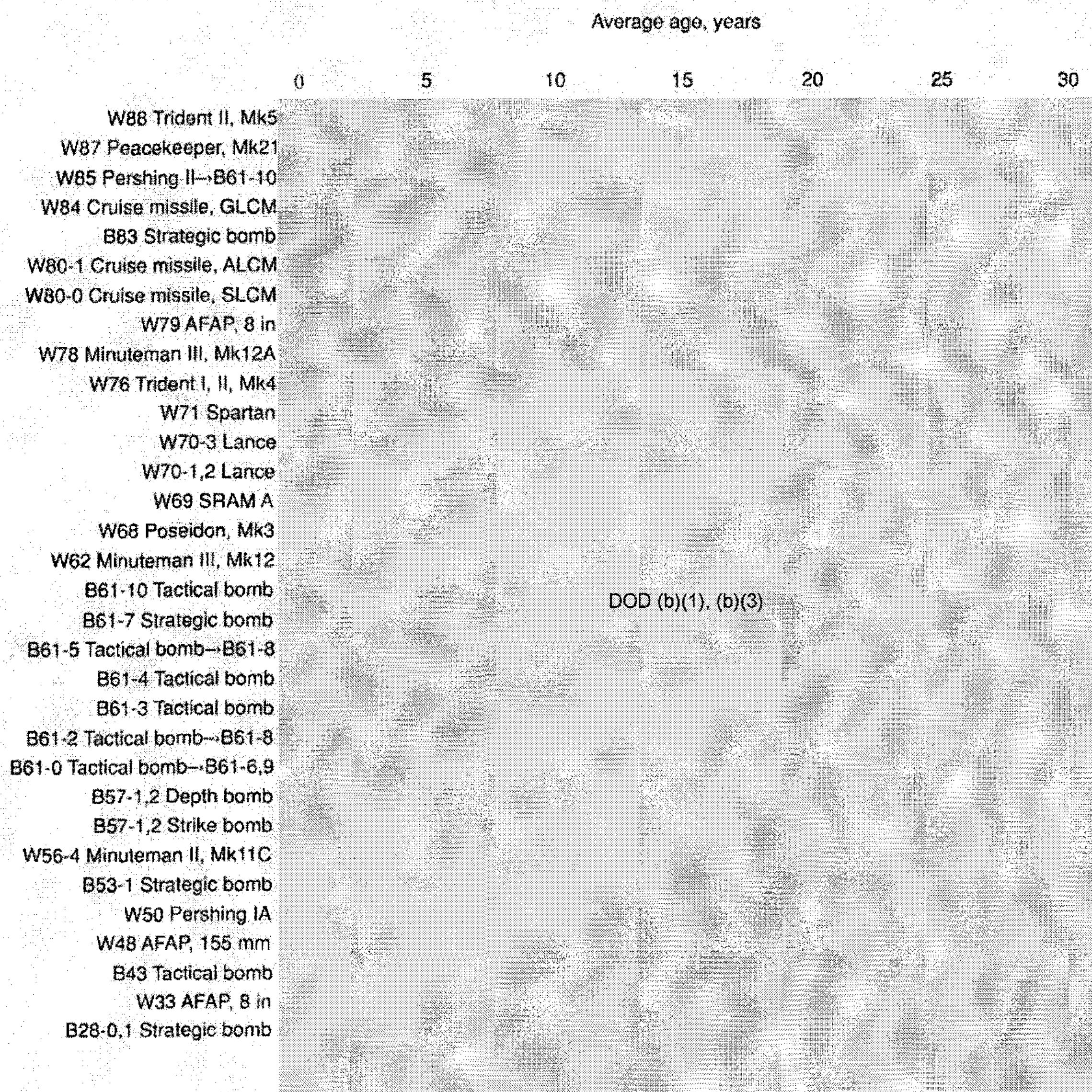
DOE (b)(3), DOD (b)(1), (b)(3)

[redacted]

DOE (b)(3), DOD (b)(1), (b)(3)

Stockpile Weapons Average Age

Title Unclassified, Chart Confidential FRD



Average age for retrofits is based on the overall system, but not the retrofitted component or nuclear system

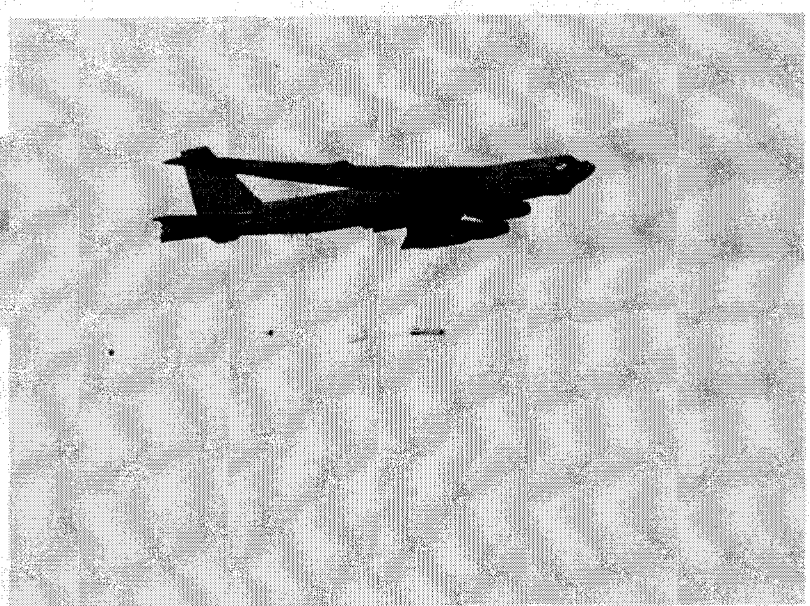
DOE (b)(3)

B28

The B28 is a two-stage thermonuclear strategic bomb carried by the B-52G/H.

DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3)



Only the B28-0,1 mods remain in the stockpile, all others having been either retrofitted to B28-0,1s or retired. The retrofits were made to provide nuclear safety and better command and control. The high-voltage thermal batteries were replaced with a transverter power supply. A strong-link switch replaced the high-voltage READY/SAFE switch to isolate this transverter from its external power source. A lightning arrester connector and filter were added for additional abnormal environment protection.

A Category D PAL was added for better command and control. To provide for in-flight PAL control and to supply the intent unique signal to drive the strong-link switch, a new aircraft monitor and control (AMAC) was installed in the B52s. There is no command disablement.

DOD (b)(2)

DOD (b)(2)

high explosives are still used. The B28-0,1 does, however, meet modern one-point detonation safety requirements.

The original IOC for the B28 was 1958, and for the B28-0,1 retrofit was 1983. It is scheduled to be taken off alert in 1990, and to be retired in 1993.

DOE (b)(3), DOD (b)(3)

DOE (b)(3), DOD (b)(3)

The design laboratories are Sandia and Los Alamos.

Average Age 29 yrs

W33

W33 is the Army's M422 8-inch Artillery Fired Atomic Projectile. It is fired from towed or self-propelled howitzers such as the US M110A2 and compatible NATO howitzers. IOC was 1956. Maximum range is 18 DOE (b)(3), DOD (b)(1), (b)(3) DOE (b)(3), DOD (b)(1), (b)(3) is the only gun-type (as opposed to implosion) weapon remaining in the US stockpile. DOE responsibility for this weapon is limited to the oralloy and depleted uranium parts and the neutron generators.

The W33 has neither enhanced nuclear detonation

DOD (b)(2)

vided by a combination lock on the rear of the projectile to preclude unauthorized loading into the howitzer.

Safety rules restrict transporting this weapon in the assembled storage configuration. With nuclear components stored separately, the weapon meets safety requirements. A current product improvement program will modify the projectile rear-body section to relieve the transportation restriction on the assembled round. There is no command disablement system. A use-control upgrade plan has been developed but its implementation is on hold. There is presently no authorized plan for retirement, replacement, or retrofit.

DOE (b)(3), DOD (b)(1), (b)(3)

The design agency for the nuclear components is Los Alamos; Sandia is the design agency for the neutron generators.

Average Age 28 yrs

DOE (b)(7)f

B43

This is a thermonuclear bomb with delivery options of laydown, retarded airburst, and free-fall airburst.

DOE (b)(3), DOD (b)(1), (b)(3)

The bomb is carried by the Navy A-4, A-6, and A-7 aircraft. IOC was 1961.

Like the B28, the B43 design is based on a "building block" concept. A Basic Assembly contains all arming and firing components, the nuclear explosive, and an impact spike; a Shape Component (or tail) contains the fins and the parachute and its deployment mechanism; and the Nose either contains a radar fuze or is a simple aerodynamic shape.

The Mod 1s in stockpile do not have a PAL; the Mod 2s in stockpile have Category B PAL; there is no command disablement system. There is no Stockpile Improvement Program planned for the B43; they are being retired as B61-2s and -5s are transferred to the Navy from the Air Force. They should all be retired in 1991.

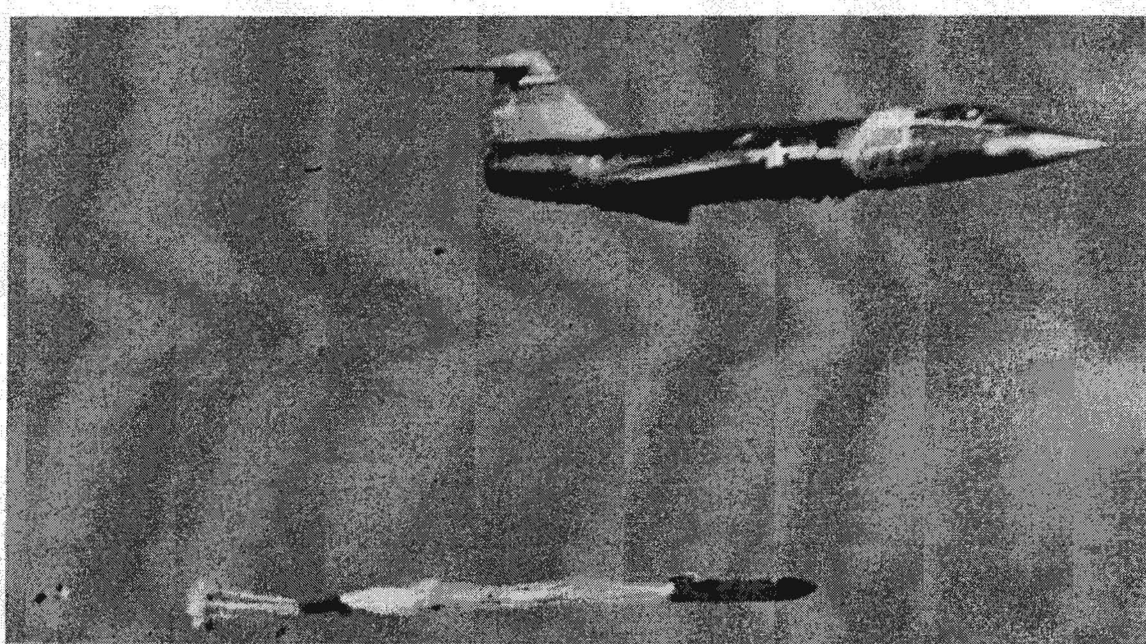
DOE (b)(3), DOD (b)(1), (b)(3)

The B43 has neither enhanced nuclear detonation safety features nor IHE. It does not meet the 1968 abnormal

DOD (b)(2)

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Los Alamos.



Average Age 27 yrs

DOE (b)(7)f

W48

This is an Army M454 155-mm (6-inch) Artillery Fired Atomic Projectile. It is fired from US self-propelled howitzers such as the M109A1/A3/A5, US towed howitzers such as the M114A2 and M198, and compatible NATO howitzers. IOC was 1963. The nuclear system is internally initiated; the DoD-supplied fuze provides surface or airburst options. Maximum range is 14.6 k DOE (b)(3), DOD (b)(1), (b)(3)

Use control is provided with a combination lock; there is no command disablement system. Helicopter movement requires a special Sandia-developed container. IHE is not used; this

DOD (b)(2)

During 1969-1970, the Sandia-designed firing set was replaced in the field to improve reliability at low temperature operation. There is no authorized plan for retirement, replacement, or retrofit.

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Lawrence Livermore.

Average Age 24 yrs

DOE (b)(3)

W50

The W50 is a two-stage thermonuclear weapon, gas-boosted and externally initiated, for the Army Surface Attack Guided Missile MGM-31A/B (Pershing 1A). One P1A missile is deployed per Tractor/Erector Launcher. IOC was 1963. Only the Mod 1 version with Category A PAL remains in the stockpile. Maximum range is 730 km DOE (b)(3), DOD (b)(1), (b)(3) DOE (b)(3), DOD (b)(1), (b)(3) IOC was 1963.

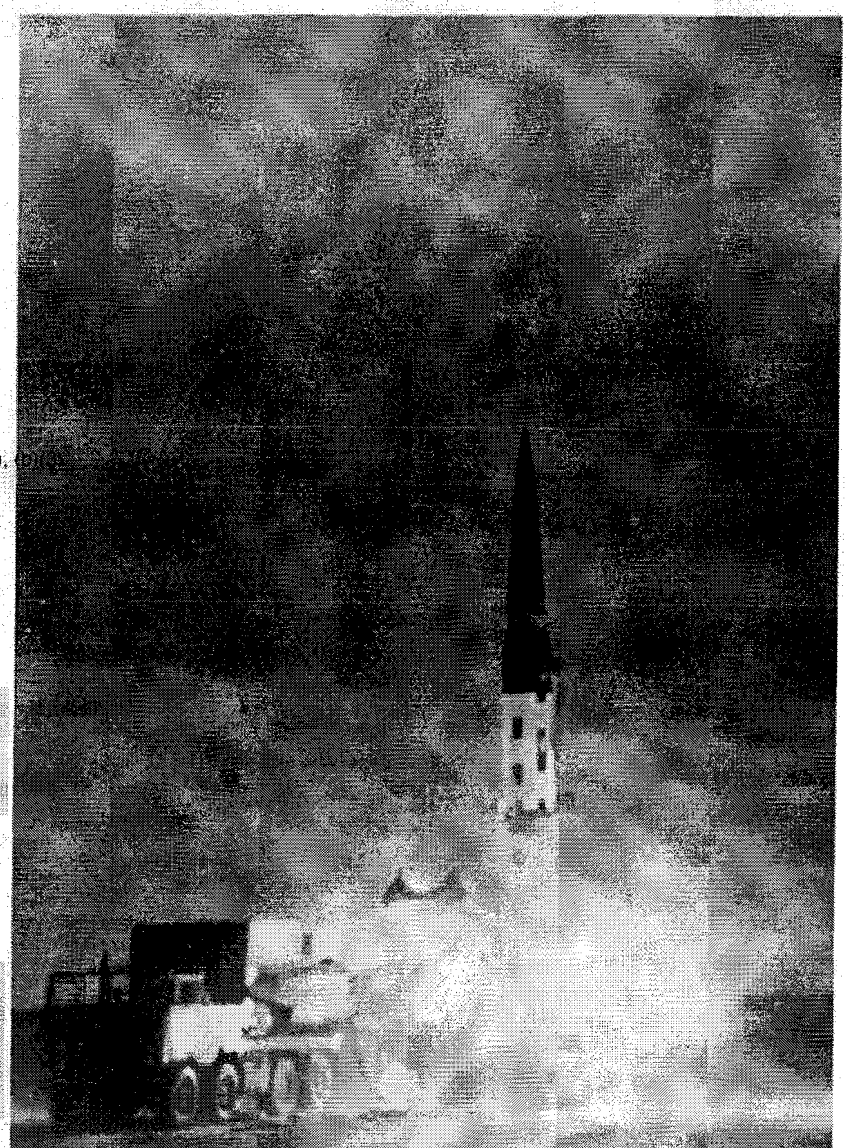
The W50 does not have enhanced nuclear safety features or IHE. It does not meet modern abnormal environment safety criteria; response is unpredictable in accident environments. Most of

DOD (b)(1), (b)(3)

Use control is provided by a Category A PAL. The W50 is now off alert and will be retired in 1991 as part of INF agreements.

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Los Alamos.



Average Age 25 yrs

DOE (b)(3)

B53

The B53-1 is a two-stage, thermonuclear, strategic gravity bomb. Original IOC was 1962. B53-1 IOC was 1988. Of the original full-fuzing options available, only the retarded laydown option was retained in the recent retrofit. It is internally carried by B-52G/H airc DOE (b)(3), DOD (b)(1), (b)(3)

In 1986, the B53 was placed

DOD (b)(1)

restated. A field retrofit was initiated as a Stockpile Improvement Program to upgrade some B53Y1-0s to become B53-1s. This modification was completed in 1988.

DOE (b)(3), DOD (b)(1), (b)(3)

A lightning arrester connector was also added.

The retrofit consisted of upgrading nuclear detonation safety features and making the B53 compatible with the B-52G/H AMAC. There is no PAL or command destruct system. IHE was not incorporated.

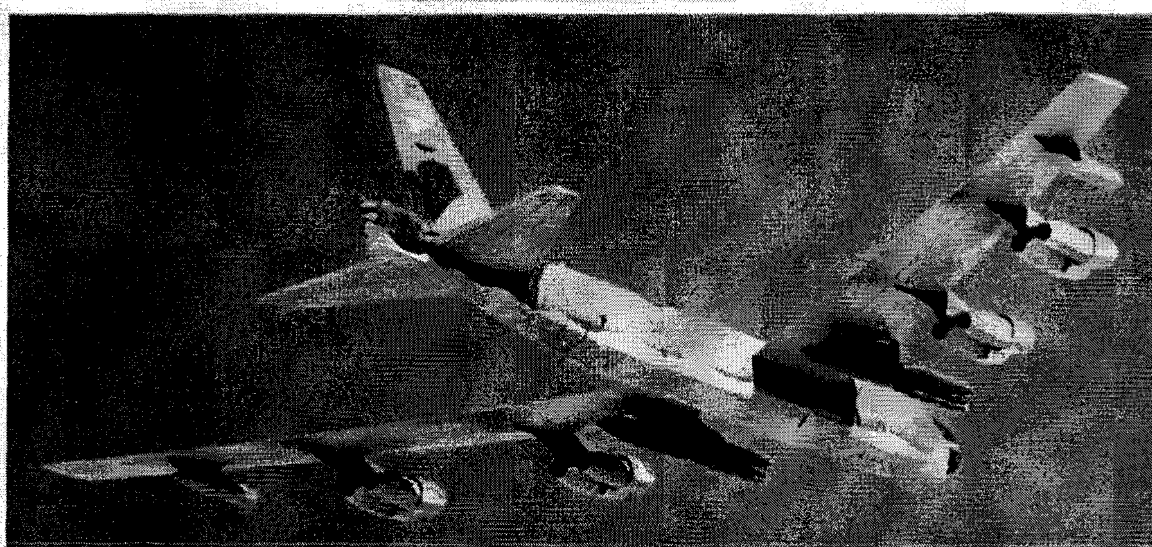
DOE (b)(3), DOD (b)(1), (b)(3)

The assessment is in the process of being revised based on the results of additional testing. Stockpile quantities will be reduced by one per year to support reliability assessment. Retirement will be completed in 1994.

DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Los Alamos.



Average Age 26 yrs

DOE (b)(3)

W56

The W56 is a thermonuclear warhead for the Minuteman II ICBM with a Mk11C RV. IOC was 1963. Only the Mod 4 remains in stockpile. The x-ray-hardened missile carries a single warhead to a maximum range of 10,200 DOE (b)(3), DOD (b)(1), (b)(3) The Minuteman II system stands alert. The Air Force plans to retain Minuteman until at least the year 2010.

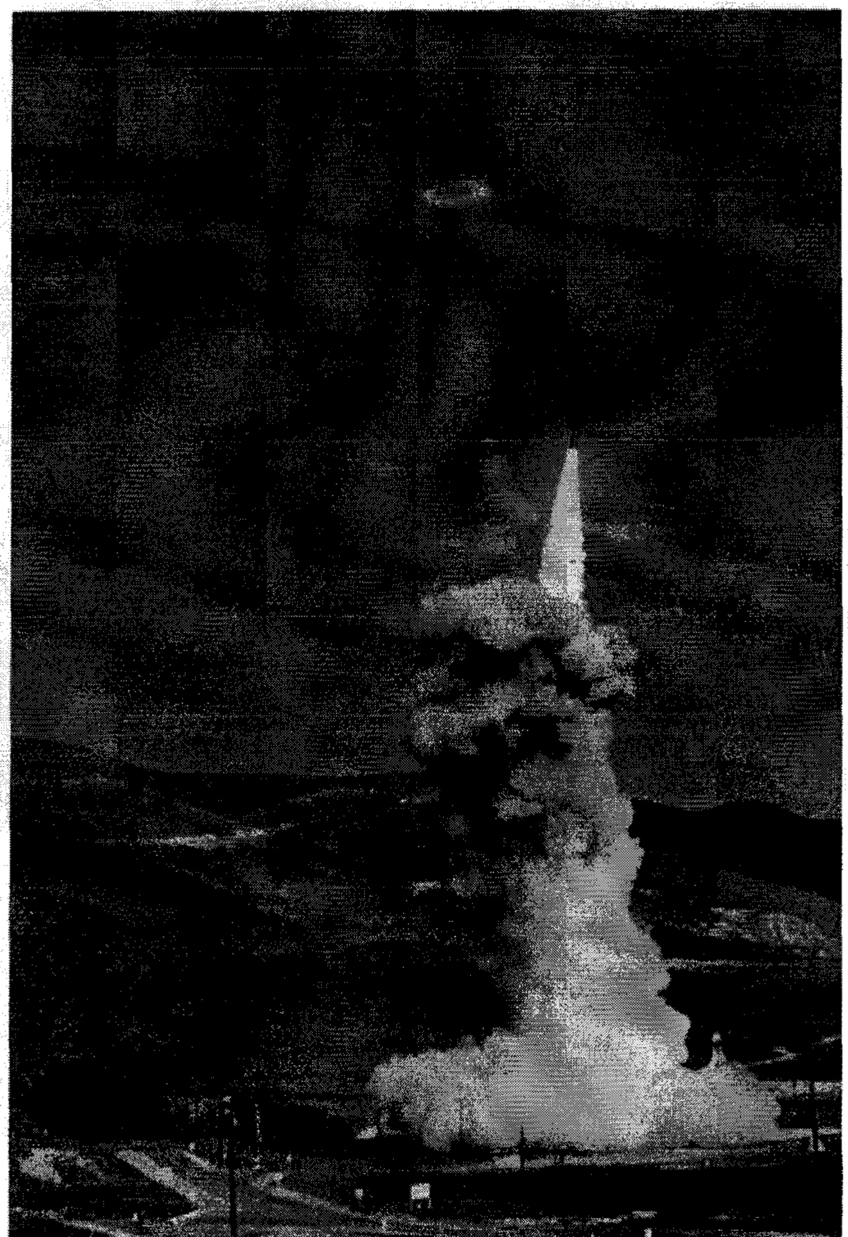
The W56 does not have a PAL or a command disablement system; use control is provided by launch control procedures at the missile site

DOE (b)(3), DOD (b)(2)

The assessment is in the process of being revised based on the results of additional testing.

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Lawrence Livermore.



Average Age 24 yrs

DOE (b)(3)

B57

The B57 is a single-stage, multipurpose bomb for use in antisubmarine and tactical bomb applications. IOC was 1963. Delivery options are retarded laydown, retarded depth-bomb, and retarded and free-fall airburst. The N57-0 nose is used for the depth bomb option; the N57-1 radar nose is used for all options; and the N57-2 is used for laydown.

DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3) Two versions are currently stockpiled: Mod 1 and Mod 2. Carriers are Navy A-4, A-6, A-7, F/A-18, P-3, S-3, SJH-3, and NP-3; Air Force carriers are F-4, F-16, F-111, FB-111; NATO carriers are F-4, F-16, F-104, Nimrod (HS-801), and Tornado MRCA.

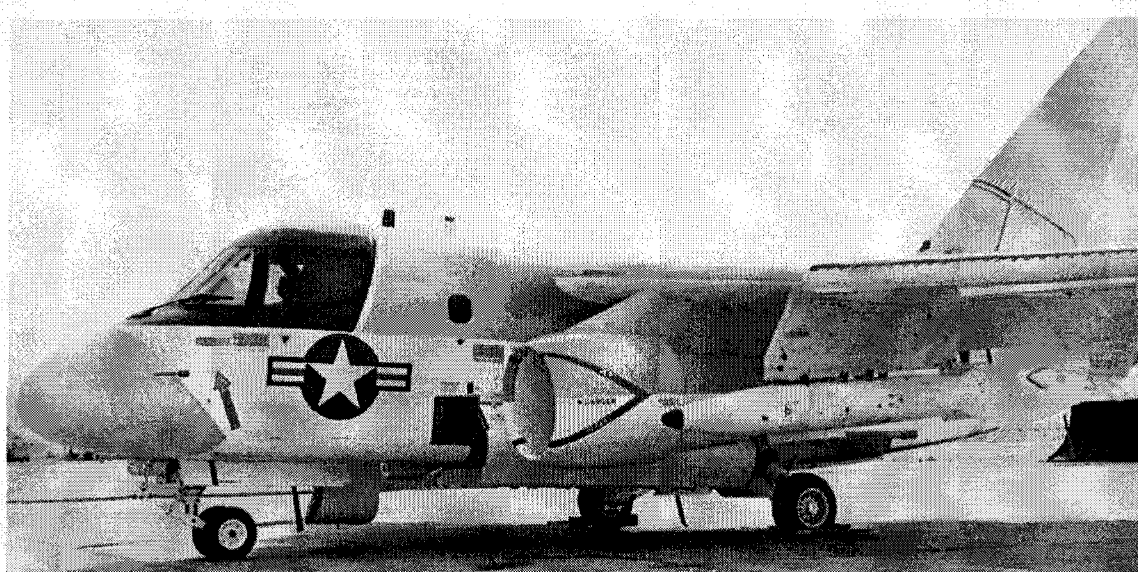
The Mod 1s do not incorporate enhanced nuclear detonation safety features or IHE. There is no PAL or command disablement system. The Mod 2s do not incorporate enhanced nuclear detonation safety features or IHE; use control is provided by a Category B PAL. The

DOD (b)(2)

As the Air Force receives B61-3s and B61-4s, their B57s will be retired or transferred to the Navy. The B90, now in Phase 3 development, will replace all Navy B57s starting in 1993. Present planning calls for retirement of the B57 by 1999.

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Los Alamos.



Average Age 25 yrs

DOE (b)(3)

B61

The B61 is a multi-purpose, selectable-yield thermonuclear bomb delivered by various aircraft: US Air Force F-4, F-16, F-111, FB-111, B-52G/H, and B-1B; US Navy A-4, A-6, A-7, F/A-18; and NATO F-16, F-104G/S, and Tornado MRCA. Mods 0, 2, 3, 4, 5, 7, and 10 are in the stockpile.

DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3)

IOC was 1968.

Safety and use control will be improved by retrofitting the Mod 0s to Mod 6s and Mod 9s. All Mod

DOD (b)(1), (b)(3)

The Mod 2s and Mod 5s will be retrofitted to Mod 8s. The Mod 3s and 4s and all the retrofittted B61s have enhanced nuclear detonation features, meet the 1968 safety criteria, and contain IHE. A Category F PAL and command disablement system provide use control.

DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Los Alamos.

Average Age 13 yrs

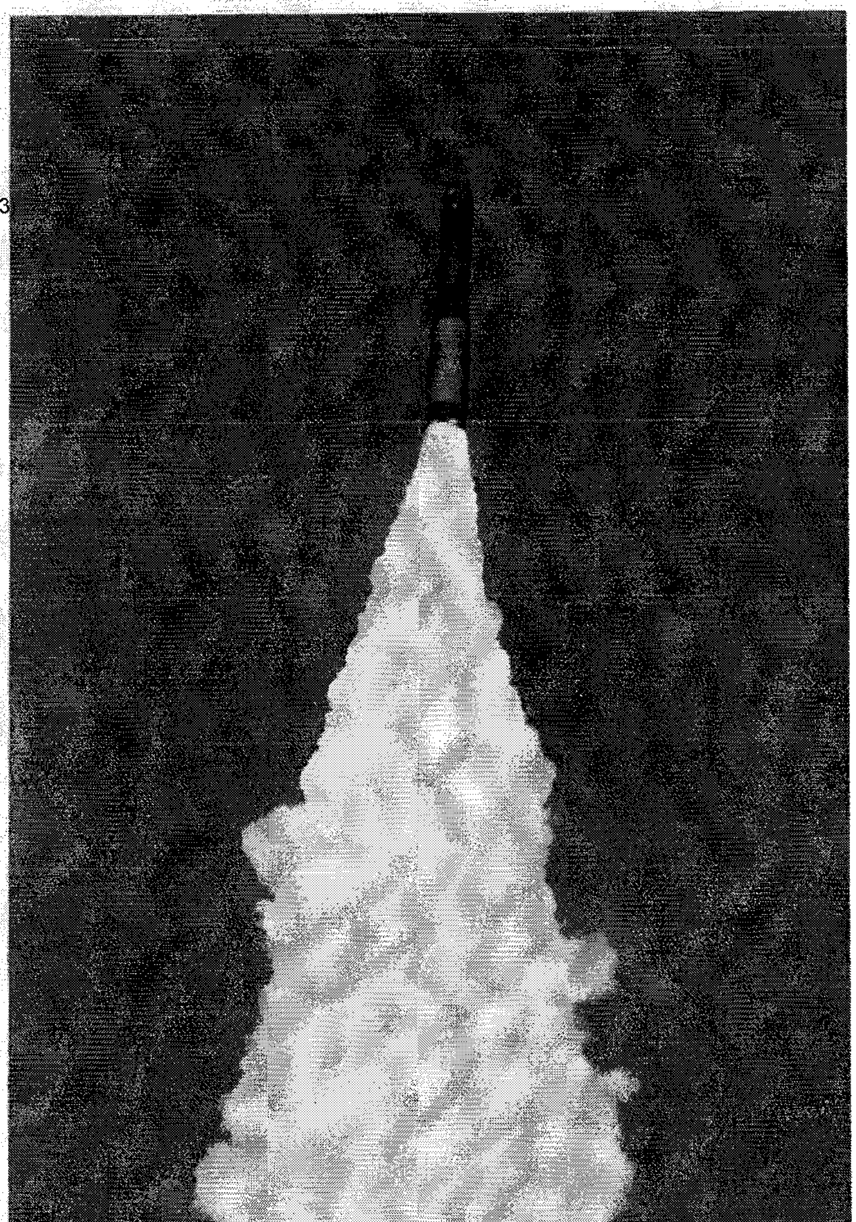
DOE (b)(3)

W62

The W62 is the warhead for the Air Force LGM-30G Minuteman III ICBM.

DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3)



The DOE responsibility consists of the nuclear system, firing set, explosive neutron generators, internal warhead support structure, and shielding. IOC was 1970.

The Minuteman III stands alert. The Air Force plans to retain Minuteman III until at least the year 2010. The W62 does not have a PAL or a command disablement system; use control is provided by launch control procedures at the Minuteman missile site.

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Lawrence Livermore.

Average Age 16 yrs

DOE (b)(3)

W68

DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3) The design laboratories are Sandia and Lawrence Livermore.

DOE (b)(3), DOD (b)(1), (b)(3) independently targetable RBs on the Poseidon C3 missile. Sixteen C3 missiles can be carried on Poseidon submarines. IOC was 1970. Four fuzing options are: low-altitude-radar backed up by the impact fuze; high-altitude-radar backed up by the electronic timer and the impact fuze; high-altitude-timer backed up by the impact fuze; and impact fuse only.

DOE (b)(3), DOD (b)(1), (b)(3) An integrated arming, fuzing, and firing system, identified as the Mk3 AF&F, was developed by Sandia for the Navy.

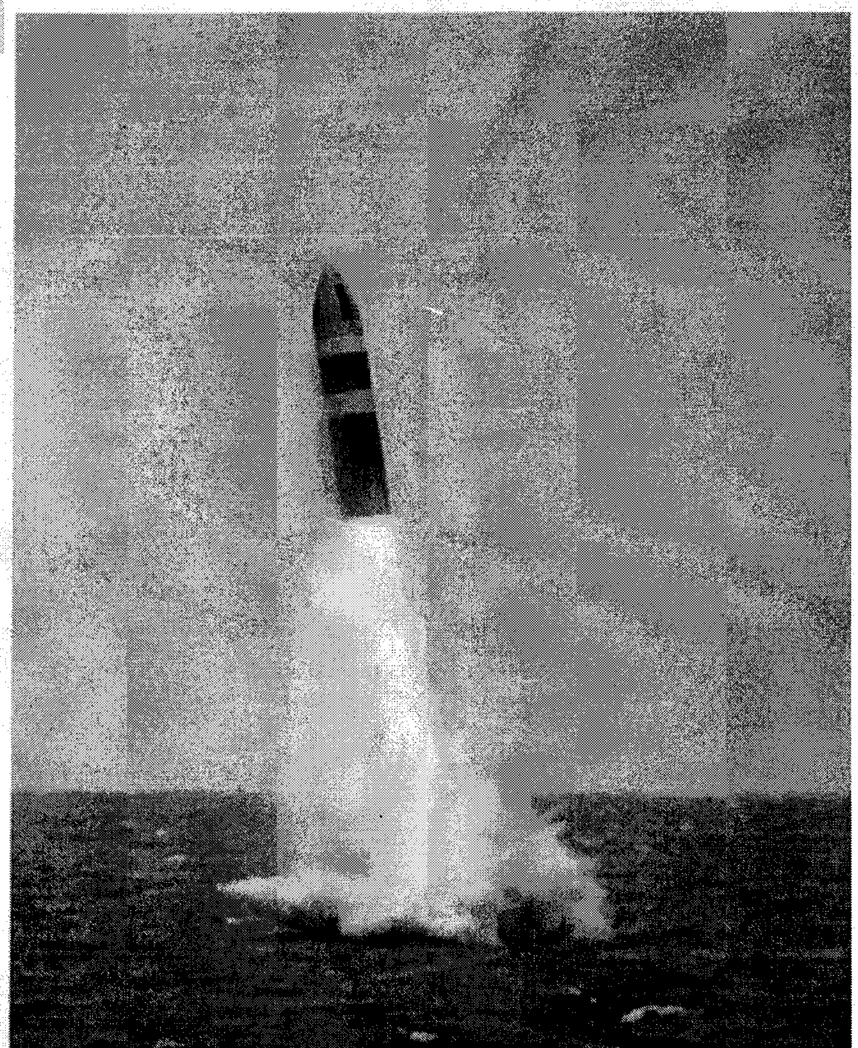
The W68 warhead is scheduled to be retired in 1995. It does not have a PAL or a command disablement system. It has neither enhanced nuclear detonation safety nor IHE.

DOD (b)(2)

DOD (b)(2) Use control is achieved by missile launch control procedures aboard the submarine.

DOE (b)(3), DOD (b)(1), (b)(3)

Average Age 17 yrs



DOE (b)(3)

W69

The W69 is a two-stage, thermonuclear warhead for the Air Force AGM-69A Short-Range Attack Missile (SRAM A). IOC was 1972.

DOE (b)(3), DOD (b)(1), (b)(3)

Carriers are the B-52G/H, FB-111A, and B-1B. As many as eight SRAMs can be carried in a rotary launcher in the aft weapons bay of the non-cruise-missile B-52G/Hs. The FB-111 carries 6 SRAMs. The SRAM is also carried internally by the B1-B.

Safety is provided by environment-sensing devices that preclude arming until after the missile is released from the aircraft and accelerated by its rocket motor. The W69 has neither enhanced nuclear detonation safety features nor IHE. It

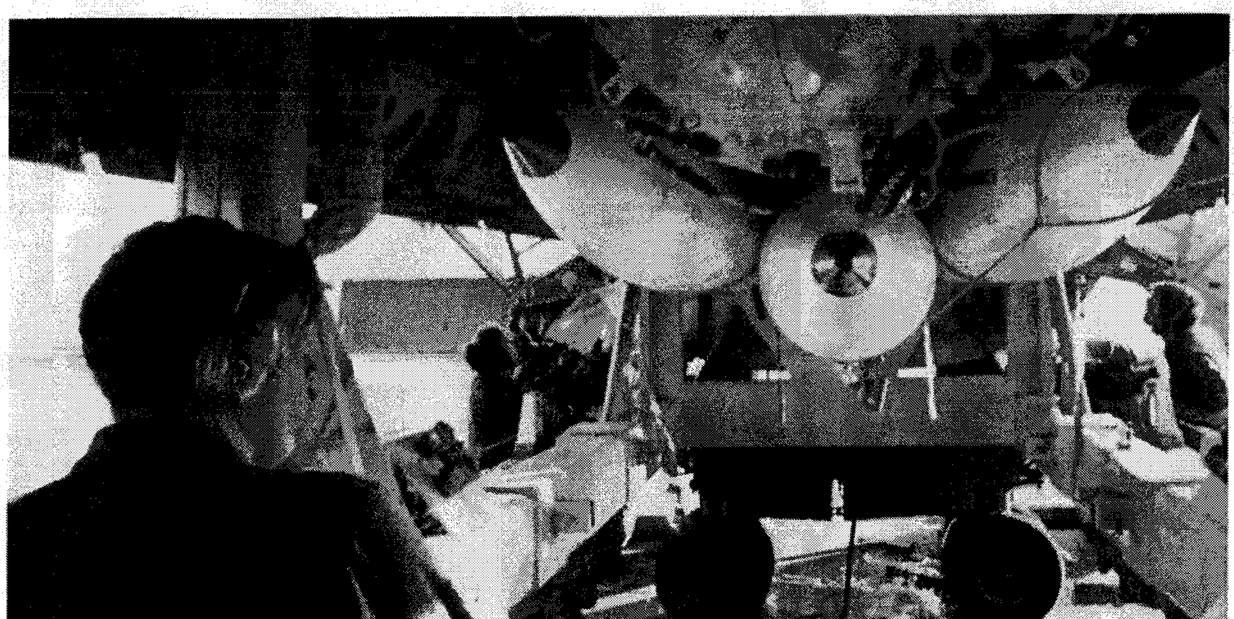
DOD (b)(1), (b)(3)

command disablement system.

Phase 3 for the W89 warhead for SRAM II began in 1988. This new warhead will provide enhanced nuclear detonation safety, IHE, Category D PAL, and a command disablement system. SRAM II will start replacing SRAM A in 1993. Present planning calls for retirement of the W69 by 1998.

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Los Alamos.



Average Age 16 yrs

DOE (b)(3)

W70

The W70 is a two-stage, thermonuclear, enhanced-radiation warhead for the Army Lance Surface Attack Guided Missile (MGM-52C). The Lance is launched from the US M752 self-propelled and M740 towed launchers, and from compatible NATO launchers. IOC was 1973 for Mods 1,2 and 1981 for Mod 3.

DOE (b)(3), DOD (b)(1), (b)(3)

Handling safety is provided by inertial switches. The warhead has neither enhanced nuclear detonation safety features nor IHE DOD (b)(2)

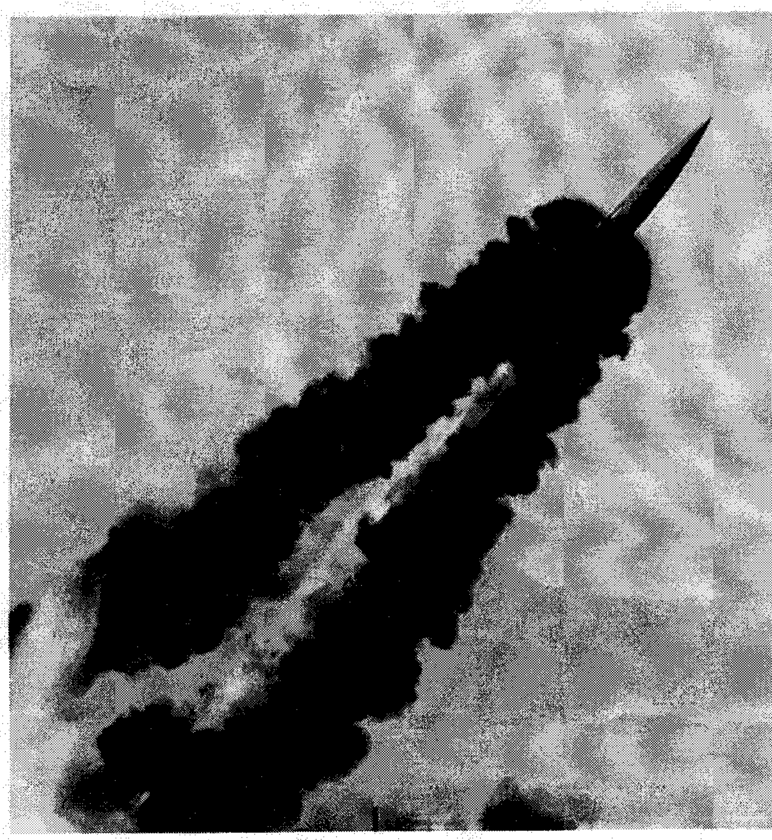
DOD (b)(2)

DOD (b)(2) Use control is provided by a Category D PAL and a command disablement system.

Development of the Follow-on to Lance, which was to have replaced Lance/W70 by 1999, has been cancelled. The rationale for this decision would also support placement of the Lance/W70 into the inactive reserve before 1999.

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Lawrence Livermore.



Average Age 13 yrs

DOE (b)(3)

W71

DOE (b)(3)

The Spartan was designed for long-range exoatmospheric intercept of incoming RVs. Together with the atmospheric-intercept Sprint missile, it formed the keystone of the Safeguard ABM system, which was deployed to defend Minuteman silos. IOC was October 1975.

The three-stage, solid-propellant Spartan was guided to the target by a Missile Site Radar (MSR) installation, which controlled aerodynamic steering during the first two stages and propulsion during the third. A single warhead was the payload for each missile.

DOE (b)(3), DOD (b)(1), (b)(3)

The W71 is one-point safe, but does not meet modern safety criteria for abnormal environments. It does not use IHE, a fire-resistant pit, strong-link switches, or an exclusion region.

For normal environments, it has two ESDs that interrupt all electrical circuits until the proper launch environment is sensed.

The W71 does not employ modern forms of use control. It has no command disablement system or PAL. DOE (b)(3)

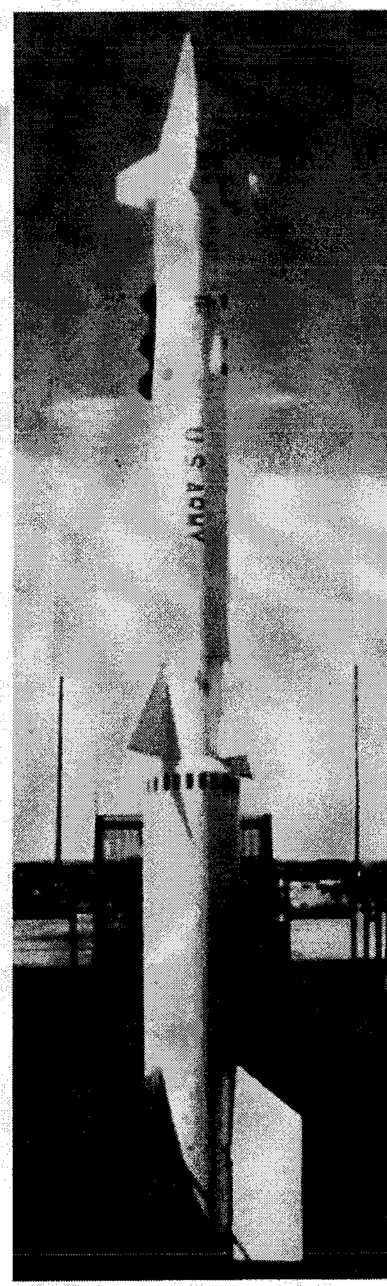
DOE (b)(3)

There are no viable delivery platforms at the present time. The MSR has been dismantled and the Perimeter Acquisition Radar turned over to the Air Force for the nation's early warning system.

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Lawrence Livermore.

Average Age 16 yrs



DOE (b)(3)

W76

The W76 is a two-

DOD (b)(1), (b)(3)

Navy Trident I (C4) and Trident II (D5) SLBMs.

DOE (b)(7)f

DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(7)f

DOD (b)(1), (b)(3)

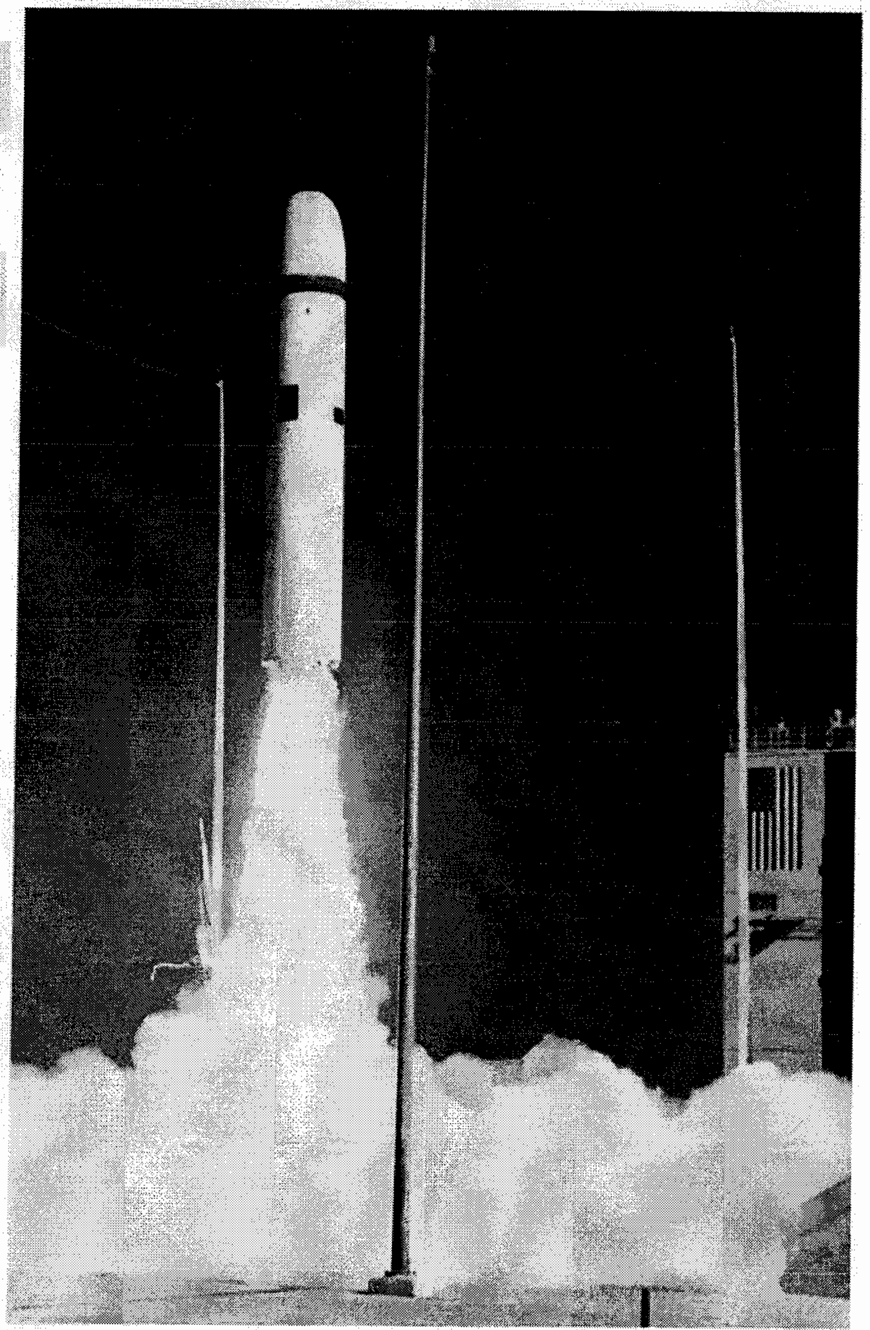
DOE (b)(7)f

Use control is achieved by launch-control procedures aboard the submarine. There is no authorized retirement plan.

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Los Alamos.

Average Age 7 yrs



DOE (b)(3)

W78

The W78 is a two-

DOD (b)(1), (b)(3)

for the Air Force Minuteman III ICBM (LGM-30G), which is

DOE (b)(3), DOD (b)(1), (b)(3)

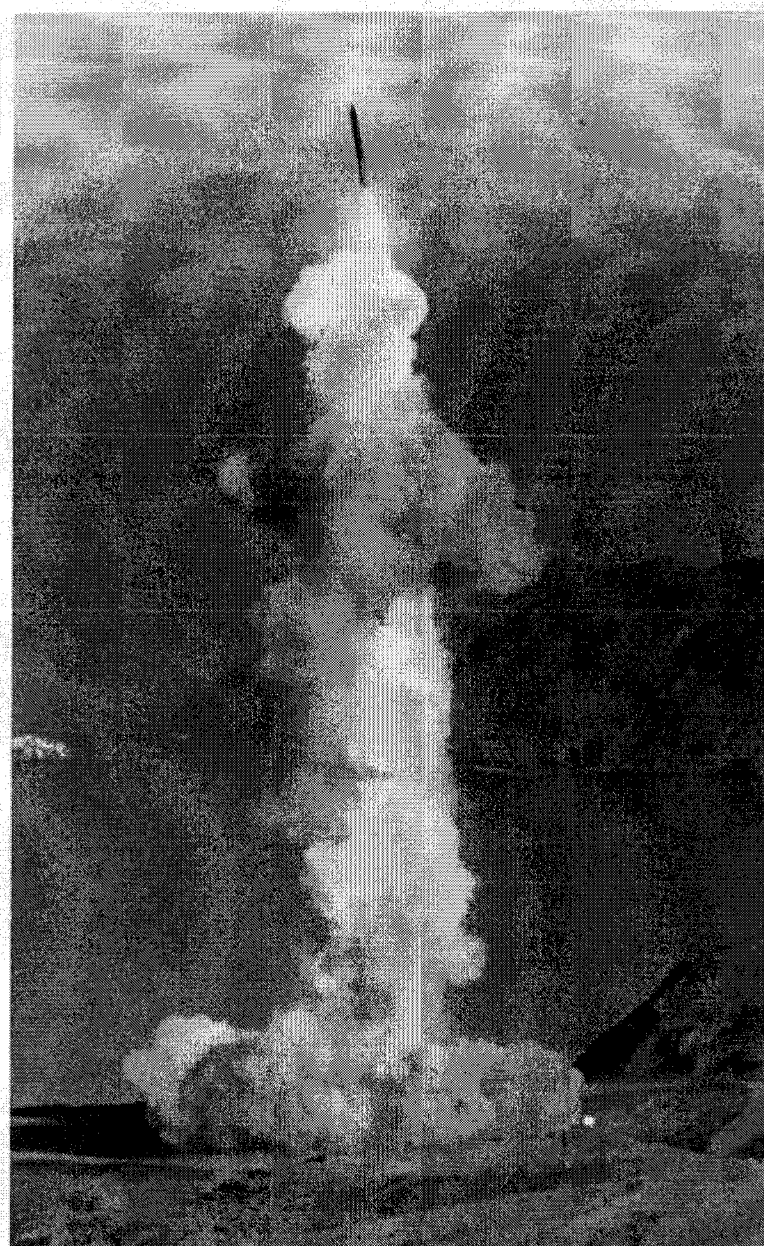
Up to three Mk12A reentry vehicles are deployed per missile; maximum range is 14,000 km. DOE responsibility for the reentry vehicle consists of the nuclear explosive system, the warhead electrical system, the gas-boost system, and the neutron generators.

Two independent safety features are included in the firing system: an accelerometer and a unique signal strong-link switch. The W78 does not have a PAL.

The warhead has enhanced nuclear detonation safety and meets the 1968 safety criteria, but does not contain IHE. Use control is provided by launch-control procedures at the Minuteman site. There is no authorized retirement plan.

DOE (b)(3), DOD (b)(1), (b)(3)

Sandia and Los Alamos.



Average Age 9 yrs

DOE (b)(7)f

W79

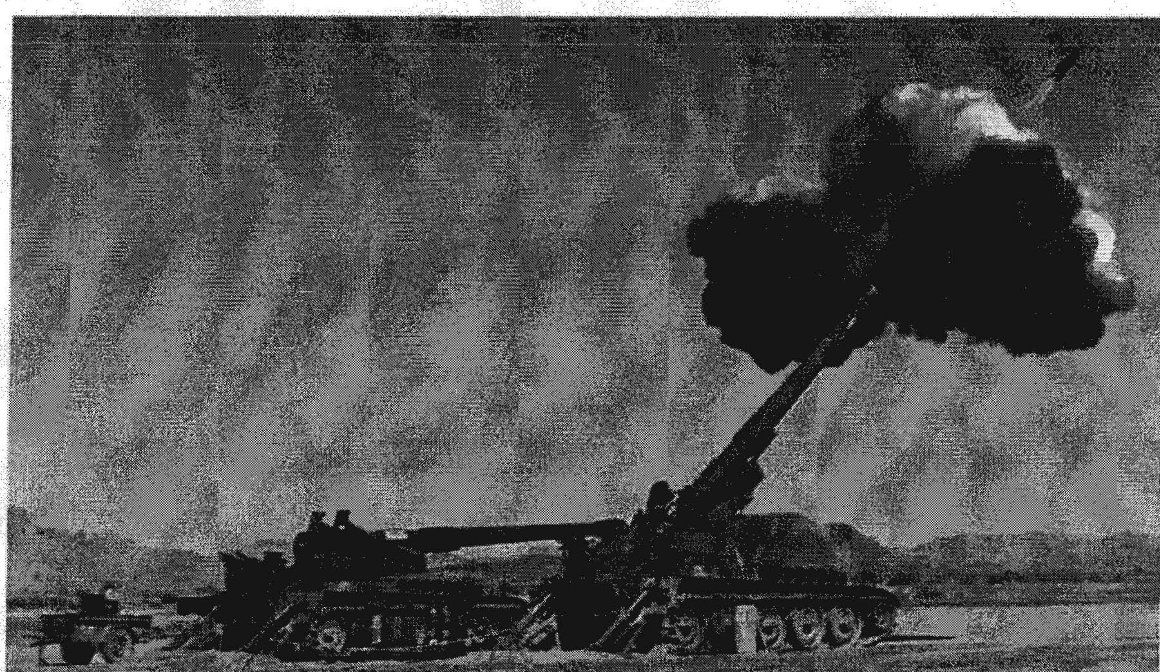
The W79 is used on the M753 long-range 8-inch Artillery Fired Atomic Projectile. The M753 has a maximum range of 24 km or 30 km with rocket assist. IOC was 1980. It is fired from the US M110A2 self-propelled howitzer and compatible NATO howitzers. The projectile is ballistically similar to the Army's M650 conventional shell. It consists of three parts: warhead, radar fuze, and rocket motor. The fuze and rocket motor are Army responsibilities; DOE is responsible for the war-

DOE (b)(3), DOD (b)(1), (b)(3)

The W79 has an enhanced nuclear detonation safety subsystem and meets the 1968 safety criteria, but does not contain IHE. It has a Category D PAL and a command disablement system. Susceptibility of this system to a nonnuclear HE detonation in a fire environment is of concern. The Army is tasked to incorporate protection in their overpack container for intratheater helicopter transport, but currently not for fixed-wing CONUS/OCONUS shipments. There is no authorized retirement plan.

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Lawrence Livermore.



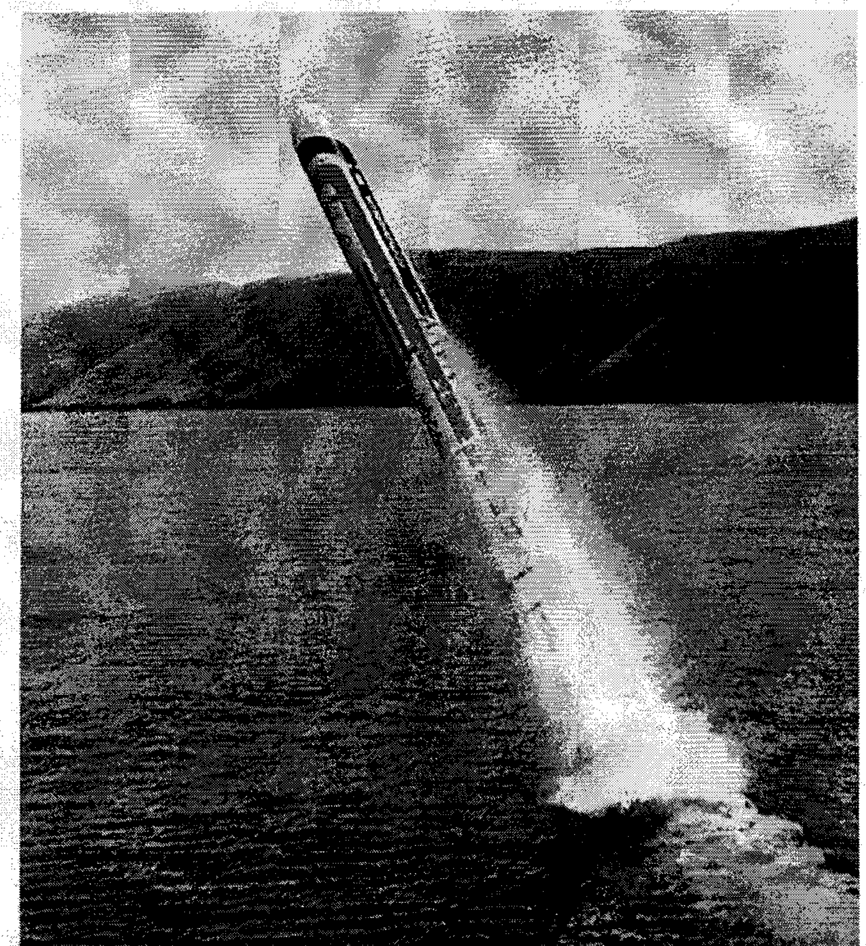
Average Age 6 yrs

DOE (b)(3)

W80

The W80-0 is a two-stage thermonuclear warhead used on the Navy Sea-Launched Cruise Missile, the BGM-109 Tomahawk Land Attack Missile. It is launched

DOD (b)(1), (b)(3)



The W80-1 is used on the Air Force AGM-86B Air-Launched Cruise Missile and the AGM-129 Advanced Cruise Missile. These missiles are launched from B-52G/H and B-1B aircraft. IOC was 1982.

Maximum range is 2700 km. The W80-0 has air-burst fuzing; the W80-1 has air-burst and contact fuzing options.

DOE (b)(3), DOD (b)(1), (b)(3)

The W80 has an enhanced nuclear detonation safety subsystem and IHE, and meets the 1968 safety criteria. Use control is a Category D PAL and a command disablement system. There is no authorized retirement plan.

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Los Alamos.

Average Age 5 yrs

DOE (b)(3)

B83

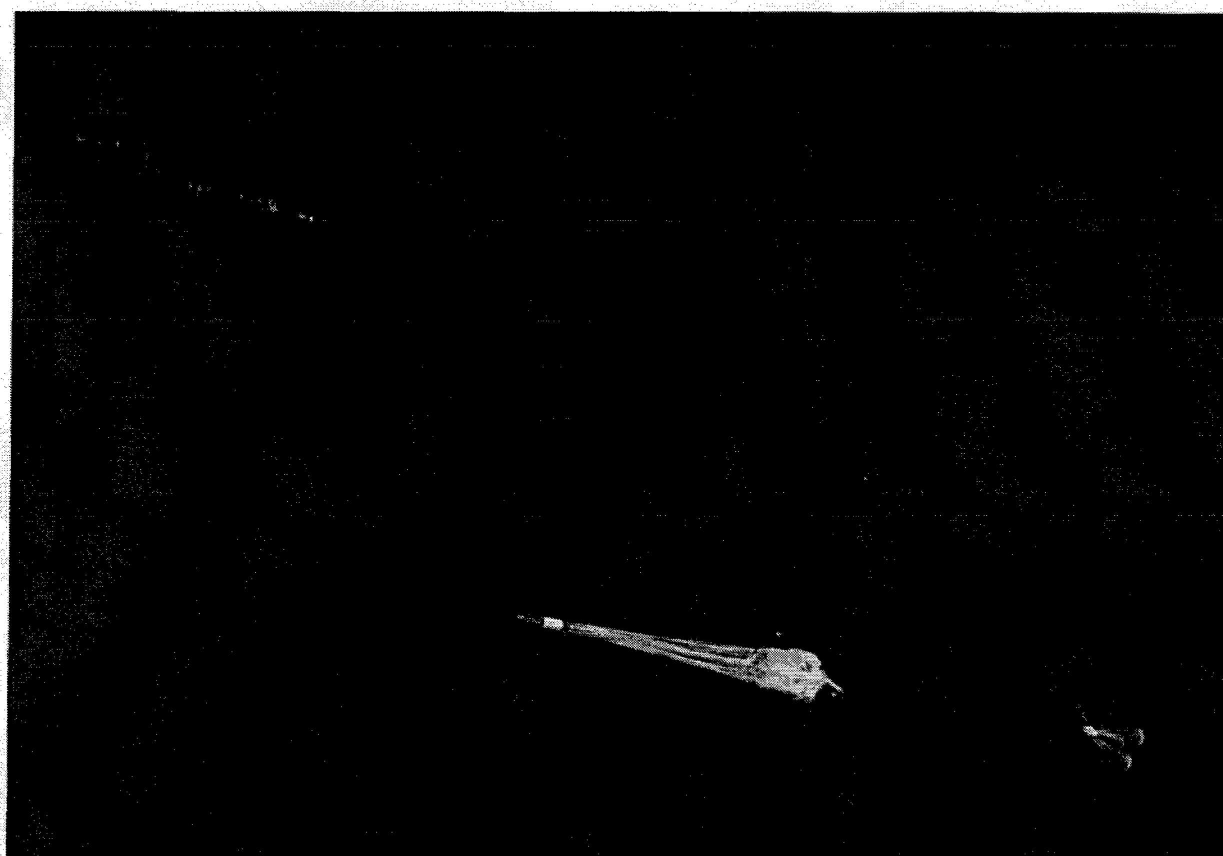
The B83 is a full-fuzing-option thermonuclear bomb. It is carried internally by Air Force B-1B, FB111A, and B-52G/H and externally by the FB-111A. IOC was 1983. Delivery options are free-fall air and ground burst, retarded airburst, and laydown.

DOE (b)(3), DOD (b)(1), (b)(3)

The B83 has enhanced nuclear detonation safety, meets the 1968 safety criteria, and incorporates IHE. Category D PAL and a command disablement system provide use control. There are no plans for replacement, modification, or retirement.

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Lawrence Livermore.



Average Age 4 yrs

DOE (b)(3)

W84

The W84 is the thermonuclear warhead for the Air Force Ground Launched Cruise Missile, the BGM-109 Tomahawk. It is fired from a mobile transporter-erector launcher. There are four missiles per launcher.

DOE (b)(3), DOD (b)(1), (b)(3)

Maximum range is 2780 km. IOC was 1983.

The warhead has an enhanced nuclear detonation safety subsystem, meets the 1968 safety criteria, and contains IHE. One of the safety strong links is a mechanical safing and arming warhead detonation system (MSAD). Use control is provided by a Category G PAL and a command disablement system. The W84 will be moved to inactive reserve in 1990 as a result of Intermediate-range Nuclear Forces treaty agreements.

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Lawrence Livermore.

Average Age 4 yrs

DOE (b)(3)

W85

The W85 is the thermonuclear warhead for the Army Pershing II missile. Maximum range is DOD (b)(1), (b)(3) The nuclear explosive design is similar to that of the B61-4. DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(3), DOD (b)(1), (b)(3)

The W85 has an enhanced nuclear detonation safety subsystem, meets the 1968 safety criteria, and has IHE. A Category F PAL and a command disablement system provide use control. Present planning calls for retirement in 1990.

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Los Alamos.

Average Age 5 yrs

DOE (b)(3)

W87

The W87 is the two-stage thermonuclear warhead for the Mk21 RV for the Peacekeeper (MX) missile system. The missiles can carry 10 Mk21s each.

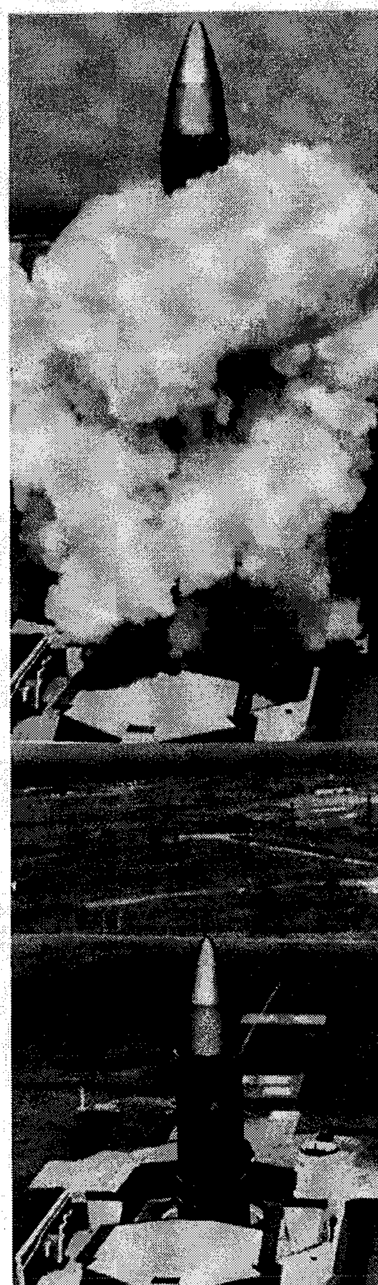
DOE (b)(3), DOD (b)(1), (b)(3)

A total stockpile retrofit to improve the reliability of the warhead began in September 1989 and was completed in 1990 .

The warhead has modern nuclear safety components, IHE, and a fire-resistant pit. One of the safety strong links is a mechanical safing and arming warhead detonation system (MSAD). There is no PAL or command disablement system. Use control is provided by the missile launch-control system. There is no authorized retirement plan.

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Lawrence Livermore.

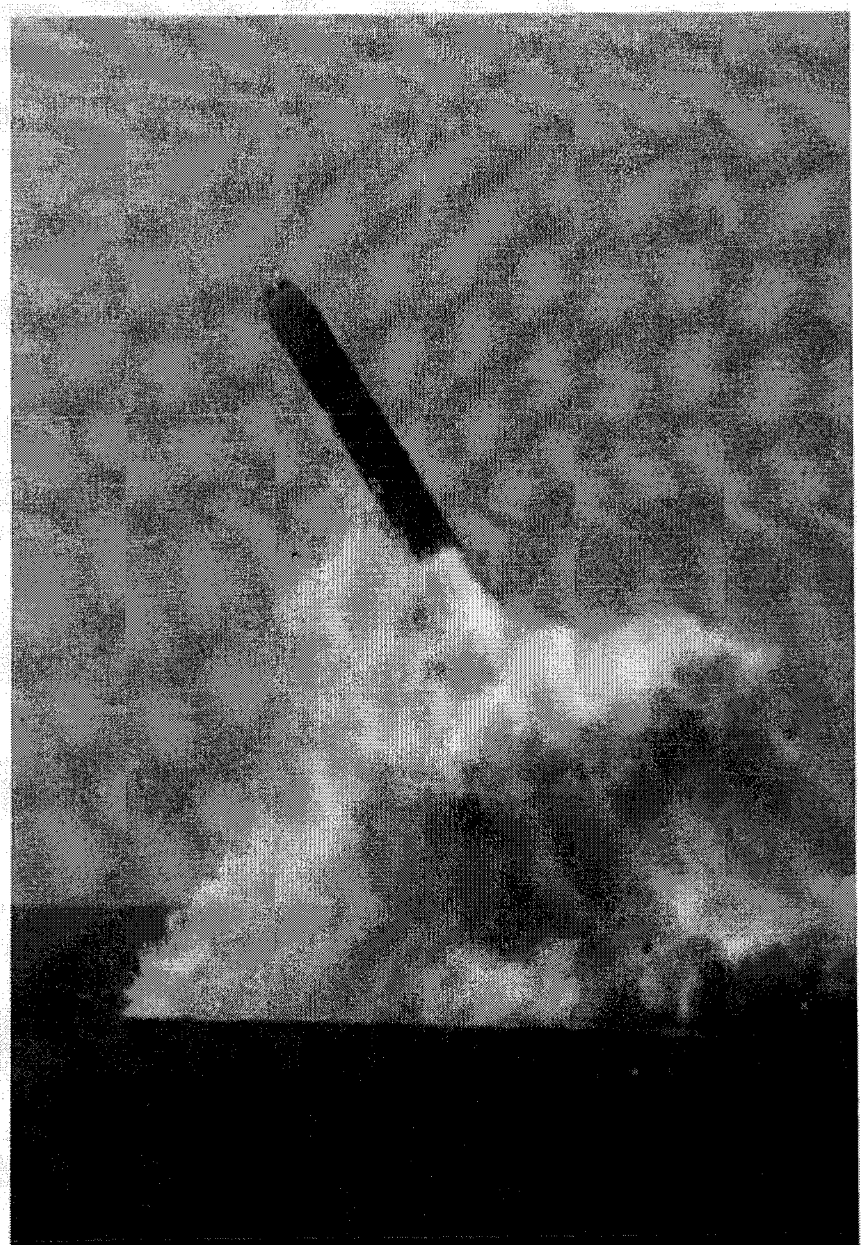


Average Age 3 yrs

DOE (b)(3)

W88

DOE (b)(7)f



The arming and fuzing system was developed by Sandia on a Navy reimbursable program. This system and the warhead firing components are assembled by DOE into an integrated package called the Mk5

DOE (b)(3), DOD (b)(1), (b)(3)

DOE (b)(7)f

Use control is achieved by missile launch-control procedures aboard the submarine. There is no authorized retirement plan.

DOE (b)(3), DOD (b)(1), (b)(3)

The design laboratories are Sandia and Los Alamos.

Average Age 1 yr

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Department of the Air Force
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Deputy Chief of Staff for Plans
and Operations
Attn: XOOSF (2 cys)

HQ PACAF/LGW (1 cy)

Headquarters, Pacific Air Forces
Attn: PACOPS/INAT (1 cy)

Department of the Air Force (cont)

San Antonio Air Logistics Center
Attn: SA-ALC-SWS (1 cy)

Headquarters
Strategic Air Command
(1 cy) Attn: INTC
(1 cy) Attn: LGWN
(1 cy) Attn: NRO
(1 cy) Attn: XOXO
(1 cy) Attn: XRFS
(1 cy) Attn: XPXC
(1 cy) Attn: XRHA
(1 cy) Attn: XPXF (8 cys)

Headquarters
Tactical Air Command
(1 cy) Attn: DRA
(1 cy) Attn: INAT (2 cys)

Headquarters
Military Airlift Command
(1 cy) Attn: IGFN
(1 cy) Attn: DOOMS (2 cys)

U.S. Air Forces in Europe
Attn: XPX (3 cys)

AFIA/INKD
Attn: INKD (1 cy)

Directorate of Aerospace Studies (AFSC) (1 cy)

Air Force Center for Studies and Analyses
Attn: AFCSA/SASM (1 cy)

3416 Technical Training Squadron (ATC)
Interservice Nuclear Weapons School
Attn: NCB (1 cy)

3480th Technical Training Wing (ATC)
Attn: TTVL (1 cy)

Secretary of the Air Force
Acquisition Division
Attn: AQQS (N) (1 cy)

Secretary of the Air Force
Attn: IGA (1 cy)

Strategic Weapons School
Attn: DOF (1 cy)

Department of Energy

Albuquerque Operations Office
(1 cy) Attn: Production Operations Division (POD)
(1 cy) Attn: NESD/WSSB
(2 cys) Attn: Quality Engineering Division (QED/WEB)
(1 cy) Attn: Classification Staff (CS)
(1 cy) Attn: Weapons Program Div. (WPD) (6 cys)

Director
Lawrence Livermore National Laboratory
(1 cy) Attn: Technical Information Department
(1 cy) Attn: Nuclear Design Department, L-38
(1 cy) Attn: Nuclear Test Program, L Div.
(1 cy) Attn: B Division, L-35
(2 cys) Attn: D Division, Data Ctr (L-82)
(1 cy) Attn: L-389
(2 cys) Attn: L-1 (9 cys)

Los Alamos National Laboratory
Attn: Report Library (15 cys)

Director, Office of Classification
(2 cys) Attn: DP-32
(1 cy) Attn: DP-20
(1 cy) Attn: DP-22
(1 cy) Attn: DP-23 (5 cys)

Office of Arms Control, DP-5 (1 cy)

Office of the Deputy Assistant Secretary for Intelligence
Department of Energy
Attn: Dissemination Center, DP-422 (1 cy)

Sandia National Laboratories Albuquerque
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(1 cy) Attn: Org. 25
(1 cy) Attn: Org. 30
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(10 cys) Attn: Org. 0420
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(1 cy) Attn: Org. 8524 (10 cys)

Other Government Agencies

Director, Central Intelligence Agency
Attn: Nuclear Weapons Branch (1 cy)

U.S. Arms Control and Disarmament Agency
(1 cy) Attn: MA/STP
(1 cy) Attn: VI/DV (2 cys)

Department of State
Attn: PM/TMP (1 cy)

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