[redacted]SSIFIED

SLBM PHASE 2 STUDY
EXECUTIVE SUMMARY

(U) The SLBM Phase 2 Study was conducted to identify and quantify alternatives to the W76/MK4 and W88/MK5 reentry systems. The study was in response to increased emphasis on safety, the limited production capability of the DOE complex, and the expected extremely long service life of the enduring stockpile. The alternatives were evaluated with respect to the following attributes:

- Enhanced weapon system safety
- Desensitization to aging effects
- Minimum need for refit
- Reliability
- Compatibility with existing DoD/DOE hardware
- Security and use control
- Reduced dependence on nuclear testing
- Producibility
- Effectiveness

b(3)

(CRD) A broad range of MK5A candidates has been proposed. [redacted] One candidate offers a safety capsule enveloping a W76 NEP and there are three all-Oy (Oralloy) designs, which contain no plutonium. Most MK5A alternatives incorporate ENDS (Enhanced Nuclear Detonation Safety), e.g., advanced detonator safing, and robust exclusion barriers, IHE (Insensitive High Explosive), FRP (Fire Resistant Pits), and devices for use control and denial.

b(3)

[redacted] DOE

Since the TRIDENT II accuracy is better than its original objective, several MK5A candidates provide effectiveness that is greater than the W88/MK5 at its original accuracy objective.

UNCLASSIFIED

[redacted]

(CFRD) Reducing the need for nuclear testing is a significant challenge to a design philosophy that has relied on testing to demonstrate reliability and performance of complex systems that operate in regimes that cannot be simulated any other way. Current test moratoriums are expected to continue and development tests for new warheads are not likely to be available.

b(3)

DOE

(CFRD) The nuclear design laboratories have not yet reached agreement on the tests required for certification of the leading, new-design MK5A candidates. It is the technical position of Los Alamos National Laboratory (LANL) that any primary considered as a candidate for this Phase 2 should have or have had two successful nuclear tests in its final design configuration. Without this minimum number of tests, the confidence level of any laboratory certification would be significantly less than that of the system it will be replacing. Thus, the leading candidates that meet minimum yield and other military characteristics do not have a sufficient test basis to allow certification without a serious degradation of the accompanying confidence level; the confidence level would be unknown.

b(3)

DOE

(CFRD) MK4A warhead alternatives were much more difficult to design because of volume and mass property constraints.

b(3)

DOE

candidates offer pit reuse. Alternatives with modified AF&F configurations were provided to add detonator safing and/or to maintain system performance. No MK4A candidates can be certified without nuclear testing.

b(3) DOE

Effectiveness studies show significant value to new MK4A height of burst options for capability against harder targets.

b(1) DTRA

(SRD) The MK4A and MK5A candidates have been evaluated against normal, abnormal, and hostile environments. Most candidates, including the leading candidates, were found to be satisfactory.

b(3) DOE

Many candidates offer enhanced nuclear safety and reduced probability of plutonium dispersal, with minimal impact to the weapon system. No candidates can meet an FY99 IOC without high risk, because production and development test facilities required may not be available, unless national priorities are set accordingly.

ICTION &
IVES

1. INTRODUCTION & OBJECTIVES

1. (U) INTRODUCTION AND OBJECTIVES

(U) The purpose of this study was to identify and quantify alternatives to the W76/MK4 and W88/MK5 for use on the TRIDENT weapons systems. These alternatives have been designated MK4A and MK5A throughout this report. While there are no presently identified deficiencies in performance, safety or service life, current strategic force planning will keep MK4 and MK5 in the deployed inventory for an extremely long time and therefore decreased sensitivity to aging was emphasized. Also stressed were enhanced safety, system reliability, decreased need for underground tests (UGT), and flexibility in meeting future requirements. Warhead yield was de-emphasized in favor of other attributes. A goal was to maximize the use of existing DoD hardware in order to minimize system costs. [redacted]

b(3) DOE

(U) Based on the above broad guidance, the study ground rules included no changes to the D5 or C4 missile system hardware or to missile-to-RBA (Reentry Body Assembly) interfaces. External MK4 and MK5 aeroshells, including nosetip and heatshield, were to be unchanged. Changes to the MK4 AF&F (Arming Fuzing & Firing System) were allowable to enhance reliability and safety. System mass properties were kept as close as possible to MK4 and MK5 values to preserve the flight test and accuracy database, and minimal change to existing Stockpile-to-Target Sequence (STS) normal, abnormal and hostile environments was desired.

(SFRD) Draft Military Characteristics (MCs) for the WXX/MK5A and WYY/MK4A increased emphasis on modern safety features and on the potential for minimizing plutonium dispersal. [redacted] Intrinsic radiation levels are TBD, but as low as possible (Reference 4).

b(3) DOE, DTRA

(U) The study was conducted by the SLBM Phase 2 Study Group, which was formed from the W88/MK5 Project Officers Group, with the addition of the LLNL/Sandia team as study members. Observers included DOE/Headquarters, ATSD(AE) and

CNO(N514). DoD/DOE reentry concepts were developed and evaluated by technical working groups, including Design Integration, Safety, Vulnerability, Joint Test, Quality and Reliability, Logistics and Production, Fail-Safe and Risk Reduction, and Systems Performance and Effectiveness. An additional working group developed draft Military Characteristics and preliminary Stockpile-to-Target Sequences (References 4, 5 and 6).

2. BACKGROUND INFORMATION

2. (U) BACKGROUND INFORMATION

(U) In recent years, the character of the US strategic deterrent has been changing. The total US strategic inventory has been reduced by START I and II agreements, and this has increased emphasis on the SLBM force. Nuclear weapon safety has received additional attention from policy makers, with desire for increased margins, while a stringent budget climate has reduced funding for weapons-related activities. [redacted] b(3) DOE

(SFRD) The MK4 and MK5 TRIDENT reentry systems meet all goals and standards, and there are presently no identified deficiencies in performance, safety or service life. [redacted] b(3) DOE

[redacted] b(1) DTRA

(U) On 26 March 1992, the Director of Strategic Systems Programs (SSP) initiated a formal request to the Chairman of the Nuclear Weapons Council Standing Committee (NWCSC) for a joint DoD/DOE Phase 2 Study to identify and quantify alternatives to the W76/MK4 and W88/MK5 to increase service life and increase safety margins (Reference 1). Since the alternatives would not modify existing delivery systems, a Phase 1 study was not conducted.

(U) On 27 April 1992, the Chairman, NWCSC, requested the DOE to join with the DoD in Phase 2 activities (Reference 2). IOC for the replacements would be in the late 1990's and the quantity would be sufficient to replace the existing W76/MK4 and W88/MK5 systems.

(U) The DOE(DASMA) responded to the NWCSC request on 29 April 1992 and accepted the request for a Joint DoD/DOE Phase 2 Study (Reference 3).

UNCLASSIFIED

(U) The SLBM Phase 2 Study schedule is shown in Figure 2-1. The kickoff meeting was held in June 1992 and Study Group Meetings were held approximately every six weeks. Interface definitions and requirements were developed early in the study and the DOE identified preliminary warhead concepts. Candidate warheads and associated DOE hardware were integrated into DoD-produced MK5 and MK4 hardware by a joint DoD and DOE team. Evaluation of the MK5A and MK4A candidates was done throughout the study. A DOE Peer Review, including detailed nuclear safety and performance calculations, was conducted late in the Study and will be reported separately. The SLBM Phase 2 Study was completed in January 1994 with the issuance of the final report.

UNCLASSIFIED

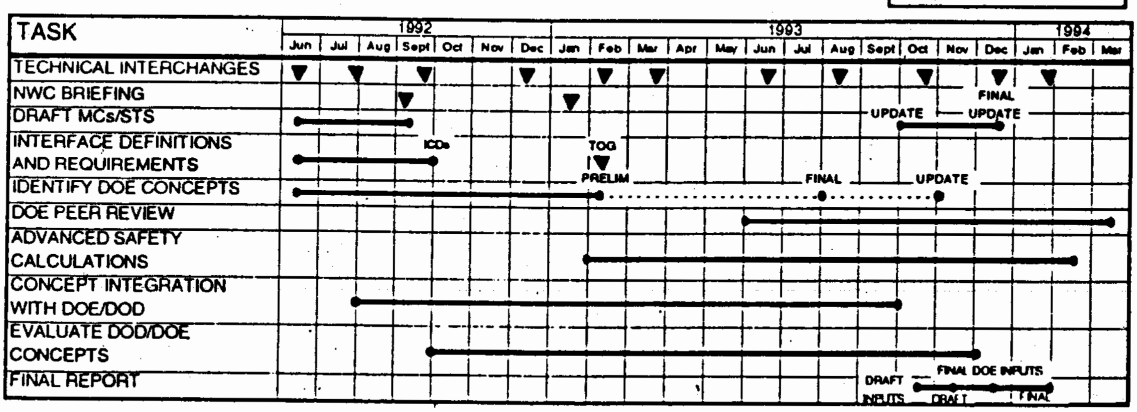


FIGURE 2-1
(U) SLBM PHASE 2 STUDY SCHEDULE

UNCLASSIFIED

~~SECRET FORMERLY RESTRICTED DATA~~

3. RELATED ISSUES

3.3 (U) REPORT OF THE HASC PANEL ON NUCLEAR WEAPONS SAFETY

The following section is an extract from the executive summary of the House Armed Services Panel Report, commonly known as the Drell Report. It is included here because of its relevance to the SLBM Phase 2 Study.

(U) Concerns that have been raised recently about the safety of several of the nuclear weapons systems in the U.S. arsenal have led the government to take immediate steps to reduce the risk of unintended, accidental detonations that could result in dispersing plutonium into the environment in potentially dangerous amounts, or even generate a nuclear yield. These steps include temporarily removing the short-range air-to-ground attack missiles, SRAM-A, from the alert bombers of the Strategic Air Command and modifying some of the artillery-fired atomic projectiles (AFAPs) deployed with U.S. Forces. In addition, the Departments of Defense and of Energy, which hold dual responsibility for the surety of the U.S. stockpile of nuclear weapons systems--i.e., for their safety, their security, and their control--have initiated studies looking more broadly into safety issues.

(U) This is a very important, as well as opportune, moment to undertake a safety review of nuclear weapons for reasons that go well beyond the immediate concerns of several specific weapons. As we enter the last decade of the 20th century, the world is in the midst of profound, and indeed revolutionary, changes in the strategic, political, and military dimensions of international security. These changes, together with a continuing rapid pace of technical advances, create an entirely new context for making choices in the development of our nuclear forces for the future. It is likely that, in the future, the U.S. nuclear weapons complex will evolve into a new configuration--perhaps smaller and less diverse and at lower operating expense but with enhanced requirements for safety and control.

(U) In this report we propose organizational initiatives to strengthen and make more fully accountable the safety assurance process, and we identify priority goals for enhancing safety in a timely fashion. We emphasize the importance of developing the data bases and performing credible safety analyses to support weapons design choices. We also affirm the importance of vigorous R&D efforts in the DOE weapons laboratories in search of new technologies leading to significant advances in safety-optimized designs.

(U) The starting point of our study is provided by two recent analyses which included inquiries into the nuclear weapons safety process: The 1985 President's Blue Ribbon Task Group on Nuclear Weapons Program Management, chaired by Judge William T. Clark, and the 1988 DOE Nuclear Weapons Safety Review Group, chaired by Gordon Moe. Both of these panels addressed long-standing concerns with stockpile safety and made important recommendations, a number of which were implemented, including in particular creation of a Nuclear Weapons Council (NWC) and an NWC Weapon Safety Committee. It is our present finding that although many problems have been, or are being, fixed, still more remain to be addressed. We are concerned, as were these earlier panels, that serious issues that had been known for at least a decade remained unattended for so many years.

(U) We make seven major recommendations for strengthening the safety assurance process. They should be implemented promptly and effectively.

(U) 1. Create joint DoD/DOE dedicated "Red Teams" with the important responsibility to scrutinize and challenge the weapons designs and operational procedures for each nuclear weapons system remaining in the stockpile or under development. The Red Teams would normally interact directly with the Weapons Design Teams. However, in case of unresolvable differences of views on safety issues, the Red Teams would have direct channels up the line of authority to the Nuclear Weapons Council and to the Secretaries of Defense and Energy if necessary.

(U) 2. Create a Joint Advisory Committee for Nuclear Weapons Surety which would report directly to the two Secretaries of Defense and

Energy. This committee would be responsible for examining ongoing practices in both DoD and DOE with respect to nuclear weapon surety, would have oversight of the surety reviews conducted on specific systems, and would identify and inform the Secretaries of any serious surety issue and provide advice as to the appropriate response.

(U) Together with the Red Teams, the Joint Advisory Committee will provide confidence that all surety issues and requirements for the U.S. stockpile are identified, given a thorough technical analysis, and addressed in a timely fashion.

(U) 3. Strengthen and more tightly focus the responsibilities of the two offices charged with managing nuclear weapons issues within the Departments of Defense and Energy. Within Defense this is the Office of the Assistant to the Secretary of Defense for Atomic Energy [ATSD(AE)]; and, in Energy it is the Office of the Assistant Secretary for Defense Programs (ASDP). To be effective the charters of both of these offices must clearly delineate their responsibilities and assure their direct access to their respective Secretaries on critical and dangerous issues of nuclear weapons system surety. In particular, the ATSD(AE) should be given a more senior status as a member of the Nuclear Weapons Council (NWC) and upgraded to the same status as an Assistant Secretary of Defense, with a direct line of reporting to the Secretary.

(U) 4. The Deputy Assistant Secretary for Military Applications (DASMA), who plays a crucial role within the DOE Office of the ASDP and also chairs the Nuclear Weapons Council Weapons Safety Committee (NWCWSC), currently is required to be a flag-rank officer on active military duty. We recommend that the occupant of this position be chosen as the most qualified individual--civilian or military.

(U) 5. Designate the Assistant Secretary for Defense Programs (ASDP) in DOE as chairman of the Nuclear Weapons Council, whose other two members are from Defense (the DDRE and the Vice Chairman of the

(U) The primary goal of these seven recommendations is to establish a process for safety assurance that is pro-active, effective, and vigilant in search of the desired balance between maximum safety and reasonable military requirements.

(U) Our four major recommendations for enhancing the safety of nuclear weapons systems by reducing the risks of an unintended, accidental, or unauthorized nuclear detonation or dispersal of plutonium apply both to the warheads themselves and to the entire weapon system. For the warheads they imply design choices for the nuclear components, the high explosives, and the electrical arming system. For the weapons system--i.e., the rocket motors to which the warhead is mated in a missile and the aircraft or transporter that serves as the launcher--safety implies choices of propellants and operational procedures as well as system designs.

(U) 1. Adopt and implement as national policy the following priority goals for improving the safety of the nuclear weapons systems in the stockpile, using available technology:

(U) • equip *all weapons* in the stockpile with modern enhanced nuclear detonation safety (ENDS) systems.

(U) • build *all nuclear bombs loaded onto aircraft*---both bombs and cruise missiles--with insensitive high explosives (IHE) and fire-resistant pits. These are the two most critical safety features currently available for avoiding plutonium dispersal in the event of aircraft fires or crashes.

(U) There are no technical reasons for the DoD and DOE to delay accomplishing these safety goals for existing stockpile weapons; they should be given higher priority than they currently receive.

(U) 2. Undertake an immediate national policy review of the acceptability of retaining *missile systems* in the arsenal without IHE or fire-resistant pits in their nuclear warheads and without using a safer safety levels before proceeding with new weapons developments. Provide the resources necessary to support this work.

(U) 4. Affirm enhanced safety as the top priority goal of the U.S. nuclear weapons program and direct and appropriately fund DOE weapons laboratories, in fulfilling their national responsibilities, to vigorously pursue R&D in search of new technologies that could create new possibilities for significant advances in safety-optimized designs.

(U) In a classified section of this report we discuss individual weapons systems and the safety concerns arising from the technology they incorporate and the handling and deployment procedures they experience. Finally we discuss improvements or changes that would enhance their safety.

(U) To accomplish the goals we have set out in this study the U.S. nuclear weapons program will have to give higher priority and devote more of its resources to efforts to enhance safety--taking a long-range view in search of big advances in technology beyond just evolutionary, incremental improvements. Such a call for reorienting the emphasis of the current program should not be viewed as requiring an enlargement of the total program particularly as we look forward to maintaining a smaller nuclear force in the new strategic environment. It does however require that adequate and steady resources be made available for the RDT&E needed to underpin such a program.

3.4 (U) <u>FARR BACKGROUND</u>

(U) As a result of a formal request by the Senate Armed Services Committee, the Federal Advisory Committee on Nuclear Fail-safe and Risk Reduction (FARR) was chartered on December 20, 1990 by Secretary of Defense Richard Cheney. The FARR Committee assessed the current and programmed capability of the U.S. Nuclear Command and Control Systems (NCCS) to meet the dual requirements of assurance against unauthorized use and the assurance of timely authorized use, when directed by the President. They also identified opportunities for enhancement of these capabilities. The FARR Committee was tasked to explore the desirability and feasibility of placing coded control devices in U.S. nuclear weapons at sea. The FARR Committee concluded that enhancements which would further improve the safety, security and control of U.S. nuclear weapons are both feasible and desirable. These conclusions were accepted by Secretary Cheney. Through appropriate channels, the TRIDENT Phase 2 Study Group was tasked to investigate appropriate FARR Committee recommendations for applicability and possible implementation. This is discussed in Section 10.2.

3.5 (U) DOE PRODUCTION CAPABILITY

3.5.1 (U) OBJECTIVE

(U) The Department of Energy (DOE) Production Capability section of this study was requested for the purpose of evaluating the impact on production timelines and capacity by the recently mandated DOE plant reconfiguration project.

3.5.2 (U) SUMMARY

(U) The DOE reconfiguration project consists basically of two major elements:

1. Non-nuclear Production activity; and
2. Nuclear Production activity.

(U) Hazel O'Leary, Secretary of Energy, announced May 27, 1993, that the DOE will proceed with the consolidation of its non-nuclear operations based on information from three independent consultants indicating the non-nuclear plan was cost effective and should be implemented. The nuclear reconfiguration project was basically driven by the "shutdown" of plutonium pit fabrication activity at the Rocky Flats Plant (RFP) near Golden, Colorado by the previous Secretary of Energy Admiral James D. Watkins, USN (Retired).

(U) The non-nuclear reconfiguration project was issued a Finding of No Significant Impact (FONSI) in late September 1993, one month after the scheduled date. Implementation of plans to notify facilities at the four receiver sites began October 1993. The RFP, Pinellas, and Mound donor plants will have equipment, documentation, and people transferred to the Kansas City, Los Alamos National Laboratory (LANL), Sandia National Laboratories, and Savannah River receiver sites. The last activity transfer (neutron generators) is scheduled to be completed October 1999.

(U) The nuclear reconfiguration project has proceeded through a public comment and scoping period at the various receiver candidate sites during the July - September 1993 period. After appropriate revisions to the implementation plan and drafting a Programmatic Environmental Impact Statement (PEIS), there will be another public comment and hearing period from January - March 1994. A final PEIS is scheduled by August 1994, and a decision by the DOE Secretary whether or not to proceed with the nuclear reconfiguration plan is scheduled in the September - December 1994 time frame.

(U) First Production Unit (FPU) delivery dates for all candidates were assessed based on the DOE reconfiguration schedule and basic guidelines. Candidate FPU delivery dates were analyzed in three time frames:

1. Less than five years;
2. Five to ten years; and
3. Greater than ten years.

(U) A basic DOE guideline is that pit reuse facilities would not be operational in less than five years, and plutonium (Pu) fabrication facilities would not be available within ten years.

(U) In conclusion, the FPU for all candidates is projected to be five or more years after an assumed Phase 3 beginning fourth quarter of FY94. The planned Pantex pit reuse facility is expected to have a capacity of 10 pits per month per shift, expandable to 20 if necessary, which raises concerns for producing an Initial Operational Capability (IOC) quantity by the end of 1999 for those candidates requiring this facility.

3.5.3 (U) BASIC GUIDELINES & GROUND RULES

A. (U) Assumes Phase 3 start fourth quarter FY94.

B. (U) Years to component FPU based on Phase 3 start date.

- Phase 3 delay would shorten time to FPU for mid and far-term in Tables 3.5-1 and 3.5-2.

b(3)

TABLE 4-1
(U) NEW MEXICO MK5A WARHEAD CANDIDATES

DOE

TABLE 4-2
(U) CALIFORNIA MK5A WARHEAD CANDIDATES

b(3)

DOE

TABLE 4-3
(U) MK4A WARHEAD CANDIDATES

b(3)

DOE

(CRD) The nuclear design laboratories have not yet reached agreement on the tests required for certification of the leading, new-design MK5A candidates. [redacted] (See Section 5.1.2.2.) [redacted]

DTRA b(3)

b(3)

DOE

(U) All MK4A candidates from both design teams would require additional nuclear testing for certification.

4.3.2 (U) NUCLEAR WARHEAD SAFETY

(CFRD) Many of the proposed candidates contain a number of safety features that have demonstrated significant improvement in nuclear safety and reduced risk of plutonium dispersal with minimal impact to the weapon system. [redacted]

DTRA b(1)

b(3)

DOE

5. (U) NUCLEAR WARHEAD DISCUSSION MK5A

5.1 (U) LANL/SANDIA MK5A CANDIDATES

5.1.1 (U) INTRODUCTION

(U) The LANL/Sandia team has identified a broad range of replacement warheads for the MK5 RB. Table 5.1-1 summarizes the attributes of all of the candidates. Each individual candidate is then illustrated and summarized on a separate page (Figures 5.1-1 through 5.1-9). Some components or subsystems are used in more than one candidate. To avoid repetition, these components and subsystems are described separately at the end of this section. As each nuclear system is described, appropriate reference will be made to other components.

5.1.2 (U) DESIGN GOALS

5.1.2.1 (U) General Goals

(CRD) Candidates proposed by the New Mexico team offer potential safety improvements to the deployed MK5 in a variety of ways. [redacted] b(3) DTRA b(3) DOE One design is offered that incorporates a CAT-F system for RB level use control.

(U) The W76/MK4 and W88/MK5 were designed by LANL/Sandia to be safe, high performance warheads. Security was achieved through CONUS only shipment and submarine deployment. This Phase 2 study was undertaken with the knowledge that tradeoffs with performance would likely be necessary to achieve improvements in safety and security in highly optimized systems. Those tradeoffs are discussed elsewhere in the report.

5.1.4.2 (U) <u>W76 Warhead in Safety Capsule (LA5-2)</u>

(CFRD) The W76 warhead inside a custom-designed protective envelope in the MK5 RB is a low cost, maximum reuse proposal that approaches nuclear weapon safety from a different perspective. While significant advances were made in the b(3) DTRA

5.1.4.2.1 (U) *Nuclear System Performance Record*

(U) The safety capsule has been designed to minimize the impact of the safety features upon the proven nuclear performance of the W76 weapon. The material nearest the case is insulating foam which is close to the density of the foam used to mount the W76 warhead in the MK4 RB. Thus the safety capsule is expected to have minimum perturbation on the normal function of the W76 NEP. Indeed the foam fully surrounding the case may even improve radiation case integrity.

(U) In order to demonstrate the viability of the nuclear system when surrounded by different materials than were used in the nuclear tests, an extensive local test program will be pursued. Hydrodynamic tests (hydros) of the baseline W76 will be compared to hydros of the W76 in the safety capsule.

b(3)
DOE,
DTRA

(CFRD) The W76 nuclear system is one of the most completely tested systems in the enduring stockpile.

b(3)
CG-W-5
710.1

The tests pertinent to this proposal are shown in Table 5.1-4.

DOE,
DTRA

TCG-NAS-2
801

DOE,
DTRA

b(3)

5.1.4.4.8 (U) *Electrical Support System Options, LA5-9*

(U) CAT-E PAL and detonator enabling/safing systems are included in LA5-9. Electrical support systems drawings that follow (Figures 5.1-17 and 5.1-18) are identical, except for detonator and neutron generator designator locations, to those systems described for LA5-4, -6, and -7. New detonator and neutron generator cables are required because of warhead orientation within the RB.

5.1.4.5 (U) All Oy Design (LA5-5)

(U) The usual approach to reducing the hazard of Pu scatter is to reduce the hazard of detonating the HE around Pu bearing pits. Building a pit that does not use Pu is another approach. Oy is an alternative nuclear material that poses a much lower hazard than Pu. This hazard reduction is several orders of magnitude, even after considering that more material is required to achieve a nuclear yield.

TCG UC 2

TCG NAS 2
50¢.1

(U) FIGURE 5.1-17

DOE
DTRA b(3)

(although it will affect our accelerated aging and compatibility studies) but rather on the planning and provisioning for the surveillance program. The total build quantity must allow for all of the test units that will be expended over the life of the program.

5.2.8.3.3 (U) *Major Differences of Candidates Relative to W88/MK5*

(U) One can obtain insight into the expected life of proposed designs relative to existing designs by comparing the proposed design with the existing design--Does the proposed system have components which are more likely or less likely to have aging problems, etc.?

(U) **Nuclear System**

(U) The LL5 candidate NEPs differ significantly from the W88 in the following areas of potential concern for lifetime.

(U) The designs include IHE, which the W88 does not. We have no indications that there are any potential aging problems with IHE as compared to CHE.

b(3)
DOE
DTRA

(U) **Electrical Systems**

(U) Our MK5A electrical systems include: those which use the existing W88/MK5 AF&F without change, those which use the existing W88/MK5 AF&F with minor changes, those which use the existing W88/MK5 AF&F with an additional programmer, and those which use the AF&F and include CAT-F PAL.

(U) Assessment Results

(U) The assessment of the LL5-1 aft warhead support design reflected margins equal to or greater than the W88/MK5 design. The wedge concepts have margins of safety ranging from 0 to 25%, respectively. The seal cover design has positive margins both for stress and buckling.

6.4.1.3 (U) LL5-1 Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

b(3)
DOE
DTRA

(U) Regarding the tamped impulse analysis, the issue of interest for the LL5-1 candidate was the potential damage to the syntactic foam forward support and its subsequent ability to provide buckling strength to the aeroshell. This foam material, with the addition of an aluminum liner, was used for the W88/MK5 forward support design and demonstrated hostile environment survivability in several underground tests. This candidate has a nickel liner which should make for a feasible design option. There are no other material vulnerability concerns based on the current design configuration.

(U) Structural Vulnerability Assessment

(U) Approach

(U) A full-body finite element analysis (DYNA3D) was performed to assess the effects of blast, TSR and impulse forcings. The model used was the existing LMSC MK5 full-body DYNA3D model in which the W88 NEP model and its support were replaced with LLNL-supplied models of the LL5-1 NEP and its supports. In addition, the thin foam sleeve utilized in the forward mount area was modeled and the seal cover model was modified to reflect the double-curvature feature of the new seal cover design (Figure 6.4.1-1). The analysis accounts for interface sliding and gap opening, elasto-plastic behavior of metal parts and dynamic structural instability.

(U) The aft-on impulse and TSR loads from the aft-on cold X-ray exposures were not analyzed because their effect is felt mostly at the aft cover and attenuates rapidly as it moves forward, as demonstrated by past MK5 ground test experience. Since the design in this region remains the same, no analyses were needed.

(U) Assessment Results

(U) The principal structural response results, in terms of peak stress and deflection values and their allowables were reviewed for the blast, TSR and impulse forcings. The bolt tension loads at the aft support and bracket interface were derived from interface element axial stress time histories.

(U) It was found that the blast loading controls the peak relative deflection at the DOE/DoD interfaces. The maximum induced relative deflections during blast responses were compared with the available clearances shown in the LL5-1 design (see Figure 6.4.1-1). DOE DTRA b(3)

This issue was addressed early in the assessment process and design modifications were made such that the current design will not have complete gap closure (i.e., physical impact) during a blast encounter.

b(3) DOE DTRA

(U) Aeroshell substrate buckling was found not to be an issue. This was confirmed for each loading condition by inspecting the deformation shape of the DYNA3D model at peak response times for any indication of buckling collapse.

6.4.1.4 (U) <u>LL5-1 Candidate Feasibility Statement</u>

b(3) DOE DTRA

6.4.2 (U) <u>LL5-2 STRUCTURAL ASSESSMENT SUMMARY</u>

6.4.2.1 (U) <u>LL5-2 Design Description</u>

b(3) DOE DTRA

[redacted] The required interface is accomplished by the addition of through connectors on the seal cover and aft closure with an interconnecting cable. The connectors and cable are the responsibility of the DOE. The connector on the aft closure will require RF and thermal protection. Other than the addition of the connector on the aft closure its design remains very similar to the W88/MK5. Candidate mass properties (RB weight and CG location) are shown in Figure 6.2-2.

b(3) DOE DTRA

(U) This design provides compatibility with the DoD hardware including the AF&F. The proposed CAT-E PAL use control capability is feasible and the concept is compatible with all the missile physical and functional interfaces. The concept has good aerodynamic stability margins.

6.4.5.2 (U) LL5-4a Normal Reentry Structural Assessment

(U) Analysis Approach

(U) The approach used to assess the LL5-4a concept was predicated on the design attributes of the forward warhead support wedge and the aft warhead support. (See Figure 6.4.5-1). The LL5-4a concept had an aft warhead support design that is similar to the MK5 IH design, and a forward warhead support wedge that is somewhat larger but is located slightly further aft than the W88/MK5 wedge. Since these two pieces of structure were similar to the MK5 tactical design, the MK5 capability curves were used to determine the feasibility of the design. A parametric study of the MK5 tactical nub concept versus the MK5 IH bolted concept established a set of knock-down factors that were used on this assessment to adjust for the difference between the MK5 tactical and the MK5 IH designs. The seal cover has a double curved design similar to the LL5-1 and was assessed based on that design. (See Figure 6.4.5-1). The warhead attachment, the wedge, and the seal cover designs were assessed for the three critical MK5 $V-\gamma$ trajectories (upper middle-UM, upper left-UL, and upper right-UR).

(U) Assessment Results

(U) The assessment of the LL5-4a aft warhead support design reflected margins equal to or greater than the W88/MK5 design. The wedge concept has positive margins of safety. The seal cover design has positive margins both for stress and buckling based on the LL5-1 assessment.

6.4.5.3 (U) <u>LL5-4a Hostile Reentry Structural Assessment</u>

(U) Because LL5-4a and LL5-4c have identical designs except for warhead internal mass distribution, the vulnerability responses were expected to be the same except for possible differences in their low-frequency responses. These differences are noted below.

(U) <u>Material Vulnerability Assessment</u>

(U) The LL5-4a candidate has a much larger foam forward warhead support than does the W88/MK5 (Figure 6.4.5-3). Tamped impulse generated at the foam and NEP case interface is alleviated by the thin layer of nickel applied around the foam. No additional material vulnerability issues were found.

(U) <u>Structural Vulnerability Assessment</u>

(U) For the LL5-4a candidate only the substrate stress response in the vicinity of the aft warhead mount under side-on impulse loading was examined for high frequency responses because evaluation of LL5-1, a similar design, has indicated that the impulse loading created the greatest stress in the candidate hardware.

(U) A DYNA3D finite element model was developed to predict the local stress response in this vicinity. The results showed that the peak stresses developed at critical points in the substrate and in the connecting bolts and bracket were below the corresponding material allowables (i.e., yield strengths).

(U) In evaluating the low-frequency responses only blast loading was analyzed since it imposed a greater load on the candidate than cold and hot X-ray loadings. The approach to assess blast response is illustrated by the flow diagram of Figure 6.4.3-5. The centerpiece of the analysis was the low-order full-body model dynamic analysis. The required warhead spring and mass constants were calculated using the warhead stiffness and mass distribution information supplied from LLNL.

(U) The results showed that the highest stresses occurred near the manufacturing joint area. However, these stresses were below material limits and were lower than those of a similar design, LL5-4c (see section 6.4.7) which has a heavier warhead and a center of gravity that is more forward in the RB. The stresses at the aft warhead mount region were well below yielding due to the strong "wishbone" support design.

(U) The DOE/DoD component relative deflection responses at potential physical impact locations indicated that the relative lateral deflections between the chimney and the aeroshell substrate is most critical. This issue was addressed with the LL5-1 candidate in that design modifications were made so that there will not be complete gap closure (i.e., physical impact) during a blast encounter. This same design modification has now been made to the LL5-4a .

6.4.5.4 (U) LL5-4a Candidate Feasibility Statement

(U) Based on the current design information and the assessments performed, the LL5-4a design was assessed to be feasible.

6.4.6 (U) LL5-4b STRUCTURAL ASSESSMENT SUMMARY

6.4.6.1 (U) LL5-4b Design Description

b(3)
DOE
DTRA

UNCLASSIFIED

TABLE 9-3
(U) MEASURES OF EFFECTIVENESS

[redacted]

DTRA

9.3.1.1. (U) MK4A Measures of Effectiveness

9.3.1.1.1. (U) *SSPK Against 27P0 Target on C4*

[redacted] The SPETWG calculated the SSPK of each candidate against a target with a vulnerability number (VNTK) of 27P0. [redacted] When the W76/MK4 was developed, the weapon system CEP was such that this type of target was considered difficult to successfully attack. With the improvements in CEP experienced by the C4 missile, this target is no longer the challenge it once was. Nevertheless, the SPETWG considered it to be an important MOE for this system, and used it in their analyses. [redacted]

b(3)
DOE
DTRA

DTRA

UNCLASSIFIED
[redacted]

(3)
DOE
DTRA

FIGURE 9-7
(U) MK4A SSPK FOR A 27P0 TARGET ON C4

9.3.1.1.2. (U) *SSPK Against 46L8 Target on D5*

[redacted] The SPETWG also calculated the SSPK of the MK4A candidates on a D5 missile against a hard target.

b(3)
DOE
DTRA

Figure 9-8 shows the values of this MOE for each of the candidates.

b(3)
DOE
DTRA

FIGURE 9-8
(U) MK4A SSPK FOR 46L8 TARGET ON D5

9.3.1.1.3. (U) *Average SSPK for Potential MK4A Target Set*

[redacted] The SPETWG calculated the average SSPK across the total set of potential MK4 targets softer than VNTK 46L8. This represents a set of targets likely to be eligible for the MK4A. Figure 9-9 shows the values of this MOE for each of the candidates. [redacted]

b(3)
DOE
DTRA

FIGURE 9-9
(U) MK4A AVERAGE SSPK

b(3) DTRA

9.3.1.1.4. (U) *Fraction SSPK*

[redacted] The SPETWG calculated the fraction of potential MK4 targets that are softer than 46L8 [redacted] This MOE provides a concise measurement of how much of the target base is held at risk. Figure 9-10 shows the values of this MOE for each of the candidates.

b(3) DTRA

b(3) DOE DTRA

9.3.1.1.8. (U) *Weighted Worth Damaged in Strike*

(U) The SPETWG calculated the effectiveness of various strike plans developed by SPETWG analysts using MK4A RBs against Russian target bases. Different kinds of target installations were assigned different relative values by the various analysts, and the overall effectiveness of the strikes were assessed as a percentage of the weighted worth of the total target base damaged in those strikes. In these assessments, strike effectiveness was calculated using CEPs that depended on the range of the target installations from the assumed launch points. Choices of target bases, target-worth weightings, and missile launch points all varied from analyst to analyst. Even so, the results were close enough that the SPETWG was able to arrive at a single set of values representing this measure of effectiveness. This measure of effectiveness proved insensitive for MK4A comparisons, varying by only 5 per cent. Figure 9-14 shows this MOE for each of the candidates.

b(3)
DOE
DNA

FIGURE 9-14

(U) MK4A WEIGHTED WORTH DAMAGED IN STRIKE

9.3.1.1.9. (U) *Damage to Other Military Targets*

(U) Finally, the SPETWG calculated the effectiveness of various strike plans developed by SPETWG analysts against Russian target bases. The effectiveness of these overall strike plans in attacking that subset of the target base identified as Other Military installations was calculated. The SPETWG believes that Other

9.3.1.1.10. (U) *Summary of MK4A MOE Values*

(U) A summary of the MOE values and relative scores for the MK4A is given in Table 9-4.

TABLE 9-4
(U) MEASURE OF EFFECTIVENESS VALUES FOR MK4A

b(3)
DOE
DTRA

9.3.1.2. (U) MK5A Measures of Effectiveness

(U) In addition, the SPETWG defined nine MOEs for the MK5A candidates (see Table 9-3).

9.3.1.2.1. (S) *SSPK Against 52L7*

([redacted]) The SPETWG calculated the SSPK of each candidate against a target with a VNTK of 52L7.

b(3)
DOE
DTRA

When the W88/MK5 was developed, this was the assessed VNTK of the hardest Soviet silos. Although those SS-18 silos have since been assessed to be much harder than 7000 psi, the SPETWG considers 52L7 to be a significant figure of effectiveness for this system because of the history of its use. The was used, and the results varied monotonically with yield, with a

b(3)
DTRA

b(3)
DOE
DTRA

FIGURE 9-17
[redacted] MK5A SSPK AGAINST 64L9 TARGET

b(3)
DOE
DTRA

FIGURE 9-18
MK5A AVERAGE SSPK (U)

b(3)
DTRA

9.3.1.2.4. (U) *Fraction SSPK*

[redacted] The SPETWG calculated the fraction of MK5A targets that are harder than 46L8 and where This MOE is one estimate of how much of the MK5A target base is held at risk. Differences in this MOE between specific candidates can be very sensitive to the assumed hardness and SSPK

b(3)
DTRA

FIGURE 9-21
(U) MK5A FOOTPRINTING EFFICIENCY

9.3.1.2.7. (U) *Number of DGZs to Cover Target Base*

[redacted] The SPETWG compared the numbers of DGZs (Designated Ground Zeros, or aimpoints) that would be required for each MK5A candidate to cover, or attack, a START II target base in Russia. Weapons requiring fewer DGZs to cover the target base would be more effective than those requiring more DGZs. The target base used in this particular calculation included classified as Strategic Military, categorized as Other Military, categorized as National Leadership, and categorized as War-Supporting Industry. The Strategic Military installations included only the numbers and types of ICBM silos permitted by the START II treaty.

The SPETWG methodology associates with a given DGZ all target installations that are close enough to the DGZ that the minimum SSPK for all installations offset from the actual aimpoint, PKmin(offset), would be not less than DGZ development is insensitive to CEP and PKmin(offset), but it is sensitive to yield. Thus these resulting measures of effectiveness decreased monotonically as yield decreased. Candidate yields for the MK5A in this study ranged from Because of the dispersed nature of the target bases used in this study, this figure of merit varied by only about 10 per cent. Figure 9-22 shows the values of this MOE for each of the candidates.

b(3)
DOE
DTRA

FIGURE 9-22
(U) MK5A NUMBER OF DGZS REQUIRED

9.3.1.2.8. (U) *Weighted Worth Damaged in Strike*

(U) The SPETWG calculated the effectiveness of various strike plans developed by SPETWG analysts using MK5A RBs against Russian target bases. Different kinds of target installations were assigned different relative values by the various analysts, and the overall effectiveness of the strikes were assessed as a percentage of the weighted worth of the total target base damaged in those strikes. In these assessments, strike effectiveness was calculated using CEPs that depended on the range of the target installations from the assumed launch points. Choices of target bases, target-worth weightings, and missile launch points all varied from analyst to analyst. Even so, the results were close enough that the SPETWG was able to arrive at a single set of values representing this MOE. This MOE was monotonic with yield, and there was a 25 per cent swing in the values that are shown in Figure 9-23.

b(3)
DOE
DTRA

FIGURE 9-23
(U) MK5A WEIGHTED WORTH DAMAGED IN STRIKE

9.3.1.2.9. (U) *Damage to Strategic Military Targets*

(U) Finally, the SPETWG calculated the effectiveness of various strike plans developed by SPETWG analysts against Russian target bases. The effectiveness of these overall strike plans in attacking that subset of the target base identified as Strategic Military installations was calculated. The SPETWG thought that Strategic Military would be an important target set for MK5A weapons. In these assessments, strike effectiveness was calculated using CEPs that depended on the range of the target installations from the assumed launch points. Choices of target bases, designations of particular installations as falling into the Strategic Military category, and missile launch points all varied from analyst to analyst. Even so, the results were close enough that the SPETWG was able to arrive at a single set of values representing this MOE. Due to the large variation in the yields of the various candidates, there was a 30 per cent swing in the values that are shown in figure 9-24.

b(3)
DOE
DTRA

FIGURE 9-24
(U) MK5A DAMAGE TO STRATEGIC MILITARY TARGETS

9.3.1.2.10. (U) *Summary of MK5A MOE Values*

(U) A summary of the MOE values and relative scores for the MK5A is given in Table 9-5.

TABLE 9-5
(U) MEASURE OF EFFECTIVENESS VALUES FOR MK5A

b(3)
DOE
DTRA

[redacted]

[redacted]

9.3.1.3. (U) Decision Analysis Tools

9.3.1.3.1. (U) *Computational Techniques*

(U) Each analyst used his own calculational techniques and tools to study some or all the MOEs that the SPETWG used. Different analysts felt that certain MOEs were more important than others and combined them in ways resulting in different overall scores. In addition, combinations of MOEs and different relative weighting schemes were studied considering possible arms control treaty scenarios.

(U) Since each analyst used his own data bases, there were small differences between values calculated by different analysts for such MOEs as damage to Other Military targets and damage to Strategic Military targets. In addition, each analyst used his own relative-weighting scheme to value the various types of target installations, thus adding yet another dimension to the assessments of weighted worth damaged in a strike. Once all the calculations had been performed, the analysts compared the various calculational results and derived a set of final numbers to be used in the overall comparisons of candidates. The SPETWG believes this method of comparing diverse techniques and tools offered robustness to the assessments.

9.3.1.3.2. (U) *Analytical Spreadsheet Models*

(U) Two different spreadsheet-based tools were used to combine the many individual calculations into an overall assessment of relative effectiveness.

(U) ROMA

(U) The ROMA (Relative Overall Merit Assessment) spreadsheet calculates an overall effectiveness score by linearly adding the scores of each of the MOEs for each of the candidates in a weighted fashion. The result is then expressed in a normalized value with the W76/MK4 or W88/MK5 having a score of one. The MOE weights used in the overall score reflect the relative importance assigned by the SPETWG consensus and by individual analysts.

(U) WESVA

(U) The WESVA (Weapon Safety Value Assessment) spreadsheet model provides a method for aggregating selected MOEs into a single number called "total military value." The WESVA approach considers how performance penalties on one MOE compare in importance to penalties on the other MOEs, and whether a severe enough penalty on any particular MOE can essentially nullify any value provided by the other MOEs.

9.3.1.3.3. (U) *Force Analyses Methodology*

(U) The SPETWG performed a number of force effectiveness analyses to help assess the relative contributions of the various candidates to the overall effectiveness of an SSBN/SLBM force. Various analysts calculated the effectiveness of various strike plans that they developed using both MK4A and MK5A RBs against selected target bases. The results of all the analysis approaches described here are consistent with the overall conclusions of the study.

(U) One model developed by the SPETWG determined an allocation of warheads for a given distribution of FBM forces using a particular target database and submarine patrol areas. The correct range dependent CEP and weight-dependent maximum-range cutoff was used in determining target accessibility and damage capability for a given set of MK4 and MK5 warhead parameters (yield and weight) and force mix (numbers of C4 and D5 available for an attack). Pseudo-footprinting was used in that each target set was sorted into geographic grid cells that are the approximate size of the missile footprinting capability. Three target databases were used for this analysis. Two covered Russia, under two different arms control agreements (START I and Bush/Yeltsin[1]), and one covered China. The Chinese database was used for studying the effects of range capability on force disposition for

[1](S) The arms control negotiations for START II were underway while this study was being conducted. Independent positions on START II were established by Presidents Bush and Yeltsin early in 1992. These positions were used for the formation of the "Bush/Yeltsin" target database. The eventual agreement, reached at a later date, established levels somewhat different than the Bush/Yeltsin target database assumed and it represents a softer target database with 154 fewer SS-18 silos remaining. This is why the second target database is referred to here as Bush/Yeltsin and not START II.

a target set different from a Russian one, especially for potential use in hostile third world areas.

(U) For other force level assessments, each analyst assumed an overall SSBN force, a force at sea with specific numbers of RBs per SLBM, and a specific set of target installations, usually with more target installations than could be attacked by the assumed SSBN/SLBM force. Most of the analysts considered different sets of launch points within the assumed operating areas and used range dependent CEPs, but some used fixed CEPs. Different kinds of target installations were assigned different relative values by the various analysts, and different analysts used different rules to determine whether a MK4A or a MK5A RB would be assigned to strike a particular target. Different analysts used different metrics to assess the overall effectiveness of the various strikes. The usual practice was to change types of candidates being used in MK4A RBs while holding the MK5 warhead constant, then to change the types of candidates being used in MK5A RBs while holding MK4 warhead constant. This approach indicated the sensitivity of the effectiveness of the total SSBN/SLBM force against a total target base to the choice of warhead candidate.

(U) Submarine Operating Areas

[redacted] Another SPETWG force effectiveness model assumed that the ocean operating areas are constructed for a candidate option based on the range at maximum footprint of the shortest range missile in each ocean. In the Atlantic, the backline of the operating area is defined by the range to Moscow or is constrained by the SOA and South America. In the Pacific, the backline is defined by the range to the nearest SS-18 silo field for TRIDENT II (D5) SSBNs. This constraint also provides an adequate set of targets for TRIDENT I (C4) SSBNs. Table 9-4 shows the missile ranges and operating areas used for various configurations of the D5 missile carrying W88/MK5 warheads. Backlines for the MK4A and MK5A candidates are similarly developed using their missile ranges.

U) The analysis was conducted using a model that reflects the values of nuclear warhead yield and accuracy and estimates damage recognizing target hardness. The groups of targets were "attacked" in priority order from the most important to the least important. Weapons were selected from the appropriate legs of the TRIAD and were allocated to assure complete coverage of a group before proceeding to the next group. Although targets were assigned to different priority groups, all targets were given equal value. The allocation of weapon resources to priority groups was handled by heuristics meant to simulate STRATCOM implementation of national policy directives. Within a single priority group, optimum weapon assignments were achieved by using a modified Simplex Algorithm.

(U) This approach to estimating strategic damage effectiveness indicated that in some cases, where the candidate SLBM warheads were less effective, other legs of the TRIAD could recover some of the loss in effectiveness.

DOE b(3)

9.4. (U) EFFECTIVENESS ASSESSMENTS AND RESULTS

9.4.1. (U) SUMMARY OF EFFECTIVENESS STUDIES

9.4.1.1. (U) MK4A

(U) Figure 9-26 shows the overall effectiveness scores for each MK4A candidate. These scores are based on an average of all the various SPETWG approaches, from combinations of MOEs to overall force effectiveness assessments. This result is a summary of all analysis approaches averaged together; for force level analysis alone, for MK4A.

b(3)
DOE
DTRA

FIGURE 9-26a
(U) OVERALL MK4A EFFECTIVENESS RELATIVE TO W76

b(3)
DOE
DTRA

9.4.1.1.1. (U) *Details of Effectiveness Analysis -- MK4A*

(U) Values comprising the overall SPETWG effectiveness scores are shown in figure 9-26b for the MK4A candidates. Each line represents a different figure of merit used in the overall average, from a basic SSPK MOE to force effectiveness assessments. The ROMA and WESVA categories represent effectiveness scores from the effectiveness sections of these spreadsheet models.

6(3)
DOE
DTRA

FIGURE 9-26b
(U) OVERALL MK4A EFFECTIVENESS

9.4.1.2. (U) MK5A

(U) Figure 9-27 shows the overall effectiveness scores for each MK5A candidate. These are also based on an average of all the various SPETWG approaches, from combinations of MOEs to overall force effectiveness assessments. This result is a summary of all analysis approaches averaged together; for force level analysis alone, the trend for MK5A is similar between candidates.

b(3)
DOE
DTRA

FIGURE 9-27a
(U) OVERALL MK5A EFFECTIVENESS RELATIVE TO W88

b(3)
DOE
DTRA

9.4.1.2.1. (U) *Details of Effectiveness Analysis -- MK5A*

(U) Values comprising the overall SPETWG effectiveness scores are shown in figure 9-27b for the MK5A candidates. Each line represents a different figure of merit used in the overall average, from a basic SSPK MOE to force effectiveness assessments. The ROMA and WESVA categories represent effectiveness scores from the effectiveness sections of these spreadsheet models.

b(3)
DOE
DTRA

FIGURE 9-27b
(U) OVERALL MK5A EFFECTIVENESS

9.4.2. (U) SPECIFIC EFFECTIVENESS RESULTS

9.4.2.1. (U) SSPK Effectiveness

(U) Because of the importance of SSPK in evaluating effectiveness, the following section will present an SSPK summary for the candidates against a variety of target hardnesses.

9.4.2.1.1. (U) *MK4A*

[redacted] Figure 9-28 compares the effectiveness of MK4A candidates on a C4 missile for targets up to 1000 psi and shows the hardness distribution of targets in the 1992 NTB (Russia Only).

b(3)
DOE
DTRA

FIGURE 9-29
(U) EFFECTIVENESS OF MK4A CANDIDATES
ON C4 VERSUS 27P0 TARGETS

[redacted]

FIGURE 9-31
(U) EFFECTIVENESS OF MK4A CANDIDATES
ON D5 VERSUS 46L8 TARGETS

b(3)
DOE
DTRA

FIGURE 9-33

(U) EFFECTIVENESS OF MK5A CANDIDATES ON D5 VERSUS 52L7 TARGETS

[redacted]

FIGURE 9-34

(U) EFFECTIVENESS OF MK5A CANDIDATES ON D5 VERSUS 64L9 TARGETS

b(3)

[redacted]

UNCLASSIFIED

9.4.2.2. (U) Force Effectiveness Analysis

9.4.2.2.1. (U) *Summary*

(U) Four force level effectiveness assessments were performed by the SPETWG. Choices of target bases, target worth weightings, missile launch points, and assessment metrics all varied from analyst to analyst. Even so, the normalized results showed consistent overall trends.

(U) Three of the studies used START II forces and target bases, one used START I forces and target base. Each target base was different. In each case there were more targets than weapons. All the studies except one used range variable CEPs from a set of assumed launch points; one used a constant CEP value. One of the studies used a weighting function to value some of the targets more than others; all others counted all targets equal.

9.4.2.2.2. (U) *MK4A*

(U) Figure 9-35 shows the normalized results of these four assessments for the MK4A candidates, along with a curve representing the the average of the values. As seen, the four studies agree closely that all the MK4A candidates have essentially equivalent force effectiveness with respect to the MK4/W76.

b(3)
DOE
DTRA

[redacted]

UNCLASSIFIED

9.4.2.2.4. (U) *MK5A Yield*

b(3)
DOE
DTRA

[redacted] Figure 9-39 shows an example of this tradeoff over the yield range of interest for this study. The changes in effectiveness result from an increase in the number of targets killed with higher yield versus a loss in effectiveness due to the increased weight necessary to obtain the higher yields and the resulting loss in missile range. While, increased yield gives a greater probability of damage (P_d) against a target, the increased weight and resulting decrease in range mean that fewer targets can be reached from the launch areas assumed. As a result, the number of targets killed can go down even as yield is increased. For each yield shown on the abscissa, the number of targets killed with a P_d greater than either 0.5, 0.7, or 0.9 is shown on the ordinate. The only targets considered for this assessment are ICBM silos under START I. Choosing a minimum P_d, an optimum yield can be found.

b(3)
DOE
DTRA

Selecting a different minimum P_d or a different target base will alter the results. A harder target base will drive the optimum yield up. A larger target base with many softer targets will drive it down. A smaller acceptable P_d will also drive the optimum yield down. Note that the baseline W88 is optimum for its yield and weight regime, and is shown in Figure 9-39 on the far right.

10.1.2 (U) SAFETY FEATURE DISCUSSION

10.1.2.1 (U) Insensitive High Explosive (IHE)

(U) The IHE formulations used by LLNL and LANL for nuclear weapon main charge high explosives are based on plastic bonded triaminotrinitrobenzene (TATB). LX-17 (92.5/7.5 wt% TATB/Kel-F 800) is used in LLNL designed weapons, while PBX 9502 (95/5 wt% TATB/Kel-F 800) is used in LANL weapons. The overall characteristics of these formulations are almost identical in safety and performance properties. The LX-17 has slightly higher physical strength properties when compared to PBX 9502.

(U) The IHEs have been demonstrated to be highly resistant to accidental initiation of a high explosive violent reaction or detonation that would result in Pu scatter in abnormal environments. Weapon systems containing IHE have been subjected to high velocity impact, fuel fires, propellant fires, bullet impacts, and sympathetic detonations from near-by warheads. Los Alamos and Sandia conducted rocket sled tests in which weapons containing PBX 9502 were impacted into rigid concrete targets at velocities ranging from 500 ft/s to 2000 ft/s. In these tests the PBX 9502 did not respond in a violent reaction or detonation. Both LANL and LLNL have subjected weapons containing IHE to fuel fires (~1 hour duration) and propellant fires (<20 minutes). In these tests the IHEs did not react violently or detonate as a result of the abnormal thermal environments. Bullet tests using 0.223 cal., 0.30 cal., 0.50 cal., 30-mm uranium and 30-mm tungsten projectiles have not resulted in violent reactions of the IHEs in full scale weapon and weapon cross-section targets. Nearby warhead sympathetic detonation tests were conducted by LANL using B61 bombs with stockpile separation distances for testing. In these configurations, the "donor" warhead, when initiated, did not produce a reaction in the near-by "acceptor" warhead. Pieces of PBX 9502 and the mock pit were recovered after the tests. Full scale tests, along with many component safety tests, conducted by LANL and LLNL have demonstrated the safety properties of IHE in these abnormal environments.

[redacted] The Warhead Sensitivity Study (Reference 8) found that IHE would detonate in response to a hypothetical third stage rocket motor detonation.

b(3)
DOE
DTRA

b(3)
DOE
DTRA

(U) Helium builds up in the plutonium from radioactive decay. In elevated temperature-aging studies on plutonium from old W68 pits, no change in density or other undesirable characteristics were detected. Upon melting in containment tests, a release of the helium has been noted, but there has been no detectable adverse effect on the containment capability. Helium build-up does not appear to be an issue.

b(3)
DOE
DTRA

10.1.2.3 (U) Detonator Safing

10.1.2.3.1 (U) *LLNL/Sandia Detonator Safing Stronglink (DSSL)*

(U) The Detonator Safing Stronglink employed by LLNL/Sandia is a nuclear safety subsystem which embeds one of the two safety-critical stronglinks deeply within the NEP. It is designed to provide a safe and predictable response in all credible environments until receipt of the correct unique prearm signal. The DSSL reduces the risk of inadvertent nuclear detonation over conventional detonators with fireset-based stronglinks by interrupting the detonation train within the NEP. This is particularly valuable in the case of severe combined accident environments in which the fireset may become separated from the NEP resulting in exposed detonator cables.

(U) The DSSL safety subsystem was developed for the W89 (SRAM-II and SRAM A). It is a mature technology (low technical risk) which has been developed well into Phase 4. It was derived from the MSAD (Mechanical Safe and Arm Detonator) which is in the stockpile in the MK21/W87 on the Peacekeeper ICBM and on the W84 ground launched cruise missile (GLCM) now in inactive reserve (IR).

(U) The DSSL consists of two basic subsystems: the actuator and warhead detonators (which each contain a unique-signal discriminator/safing mechanism). The actuator is mounted external to the NEP and receives a unique electrical signal from either the missile or a unique signal generator. The actuator uses the unique signal to enable the discriminator/safing mechanism associated with each detonator inside the NEP.

(U) The detonators each contain an electrical bridge which can be exploded by high current. The exploding bridge drives a flyer plate, which, in normal operation, impacts and detonates a small PETN explosive pellet. The PETN detonation, in-turn, drives an aluminum flyer which initiates a large booster pellet leading to the detonation of the main explosive charge. In typical (non-DSSL) flyer plate detonator designs, these components of the detonation chain are in the aligned position. For these aligned detonators, initiation of the bridge will light the main charge. Similarly, abnormal environment initiation of the PETN pellet will also initiate the main charge.

(U) In DSSL the PETN pellet is mounted in a cogged wheel, known as the discriminator wheel. Prior to prearming the DSSL, the discriminator wheel is positioned such that the PETN pellet is not aligned with either the detonator bridge or the detonator output barrel. In this position, firing the detonator bridge cannot initiate the PETN, nor could initiation of the PETN initiate the booster. Thus, the PETN pellet is isolated from the electrical source which can initiate it (the exploding bridge and flyer) and the main explosive charge is isolated from the PETN. Even if the PETN were initiated directly by some shock wave from other than the exploding bridge, it would not be able to initiate the IHE from its safed position. The detonator is inoperable until it receives the correct unique signal.

(U) To prearm the DSSL, the discriminator wheel is rotated by a series of pushes and pulls which are sent down a mechanical cable from the DSSL Actuator. If an incorrect sequence of signals is applied, the discriminator wheel will be driven to an irreversible, mechanically-locked, and safe state. The explosive pellet would remain out of line and incapable of detonating the IHE main charge. The DSSL mechanism and unique signal have been designed such that the device is highly unlikely to be enabled by energy sources found in normal or abnormal environments.

(U) The PETN pellet acts as a thermal weaklink. The pellet completely decomposes (does not detonate or ignite) at around 450°F, rendering the detonator predictably and irreversibly inoperable well before the discriminator mechanism and the stainless steel DSSL barrier lose their integrity. The DSSL does not have a defined mechanical weaklink. Therefore, Sandia cannot categorically state that it is impossible for mechanical environments to drive the code wheels into their prearmed positions. However, as the cables are not directly connected to the discriminator wheel, it would be extremely unlikely for this to occur. An abnormal mechanical environment is much more likely to detach or damage the cables than to apply the required unique series of pushes and pulls. This is particularly true relative to detonators, which do not require any unique signals for prearming.

(U) The DSSL is much less vulnerable to mechanical abnormal environments than many other safety subsystems. A single g-time pulse is insufficient to prearm the device regardless of duration or amplitude. Performance can be contrasted to an ESD, which can be set by a single linear g-time pulse.

(U) The DSSL is also insensitive to electrical environments including direct lightning strikes. Each DSSL detonator has two cable assemblies: the detonators use flat detonator cables to their bridges; and the DSSL mechanisms have mechanical drive cables. During development of the W89, special attention was given to preventing detonation through the propagation of lightning along these lines resulting in an improved and tested design.

10.1.2.3.2 (U) <u>*LLNL/Sandia Paste Extrudable Explosive (PEX) Booster*</u>

(U) The Paste Extrudable Explosive (PEX) booster found in some LLNL/Sandia designs is a recently-developed nuclear safety subsystem. Its function is to provide a second stronglink buried within the NEP - thus complementing the DSSL system described earlier. It eliminates the potential for even an armed DSSL to initiate the main charge by removing a essential component of the HE initiation chain.

(U) The output from a warhead detonator (including a prearmed DSSL or the detonators in the W76 or W88) is not sufficient to directly initiate the IHE main charge. Initiation of IHE by firing one of these detonators requires that the detonator first initiate a small explosive charge (booster) which is more easily initiated than the IHE, and which has higher output than the detonator. The output from the booster is sufficient to initiate the IHE. In the PEX booster design, the booster explosive is a paste, which is stored outside the NEP and injected into the NEP only after prearming (receipt of a unique signal). The paste explosive is a thick, viscous gel of HMX explosive, thickener, and solvents.

(U) The PEX for each booster is stored in its own separate reservoir which is connected by tubing to a booster cavity in the NEP. The plumbing for each booster is entirely separate from any other booster, so that an initiation of one booster, anywhere along the transfer tube, at the cavity, at the reservoir, etc., cannot propagate through the plumbing to another booster. This precludes the possibility of multi-point initiation of the IHE caused by single-point initiation of the PEX. The tubing between the reservoirs and the NEP is interrupted by a unique signal-operated stronglink valve. The PEX cannot be transferred into the NEP unless the stronglink valve receives its unique signal to operate.

b(3) DOE

10.1.2.4 (U) Exclusion Regions and Barriers

10.1.2.4.1 (U) *LLNL Robust Exclusion Barrier*

(U) The purpose of the robust exclusion barrier is to provide a stronger exclusion barrier between the stronglinks in the AF&F and the NEP. The barrier will fully contain the detonator leads and will provide improved thermal protection up to and including fuel fires.

b(3) DOE

10.1.2.4.2 (U) *LLNL Tough Case*

(U) Due to the characteristics of IHE, its very slow burn rate, and its insulating thermal properties, it provides a very good thermal blanket which may be capable of protecting the pit in abnormal fire environments. The difficulty, however, is that as the IHE burns, it generates massive amounts of gas which can "overpressure" the NEP leading to disassembly of the mechanical joints. The tough case design addresses a number of issues associated with maintaining NEP case integrity during a fire environment.

b(3)
DOE
DTRA

10.1.3 (U) ENHANCED NUCLEAR DETONATION SAFETY (ENDS)

10.1.3.1 (U) Electrical Nuclear Safety Theme

10.1.3.1.1 (U) *LANL/Sandia MK5A Electrical Nuclear Safety Theme*

(U) The electrical nuclear safety theme for almost all Phase 2 MK5A replacement warheads is similar to that of the W88/MK5 with the additional positive isolation feature of detonator safing to preclude initiation of detonators until specific functions occur enabling them. A summary of the W88/MK5 electrical nuclear safety theme is provided and is applicable to essentially all MK5A candidates.

(U) The electrical nuclear safety theme for the W88/MK5 is based on the principles of isolation, incompatibility, and inoperability and has two major parts, (1) to preclude unintended charging of the fire set Capacitor Discharge Unit (CDU) capacitors, and (2) to preclude shorts to the weapon detonator cables that could bypass the CDU.

(U) The following design objectives were formulated for the W88/MK5 to achieve the nuclear safety requirements specified in the MCs.

1. The system shall remain safe until an unambiguous indication of intended use is received.
2. The warhead shall respond to abnormal environments in a predictably safe manner.
3. The design shall meet nuclear safety requirements without the need for a detailed description of the abnormal environments that might be encountered in credible accident scenarios.

(U) The design effort to implement the electrical nuclear safety theme resulted in the following system features:

1. Three independent safety subsystems, Intent, Trajectory, and Arming.
2. Exclusion region barriers to isolate the safety-critical components from available electrical energy sources.
3. Stronglink devices requiring unique enabling signals to control the transfer of electrical energy into the exclusion region.
4. Dual exclusion regions, each containing a CDU for detonator firing, without a common interconnection.
5. Collocation of stronglink and weaklink devices to ensure that each receives similar environment exposure.
6. Weaklink (HE) that becomes irreversibly inoperable in abnormal thermal environments before stronglink or barrier failures occur.
7. Widely separated (foam isolator protected) and shielded detonator cables.

(U) The Intent and Trajectory subsystems each provide independent 24-event unique signals for driving the dual stronglink assembly to the enabled position. Intent requires human action and implies a person's intention to launch the missile. Trajectory signals are derived from information developed by the missile in flight. The Arming subsystem includes the issuance of two independent electrical signals and the resultant charging of the CDU. The two required electrical arming signals are isolated from the receptor circuits by a fuse switch and by the launch accelerometer inside the AF&F. Critical circuitry of the fire set is contained within two independent exclusion regions to exclude all energy sources until intended mode operation is initiated.

(U) The electrical nuclear safety theme features and characteristics for the Phase 2 Study replacement warhead candidates are similar to the features designed into the W88/MK5 system. A third major part is added to those candidates that are compatible with detonator safing technology "to preclude initiation of system detonators until specific action is taken to enable those detonators". The Intent and Trajectory subsystems provide the unique signals required to enable the detonator enable/safe system. Detonator safing is described in the Safety Feature Discussion section of this report. In addition, if the Phase 2 Study constraints are changed to allow modification of the MK5 AF&F, a new doped-mylar "weak-link" capacitor will be included in the fire set output.

(U) The thermal weaklink in the W88/MK5 is the conventional HE in the warhead. Tests and analyses show this to be an acceptable weaklink. A study was undertaken in FY93 to identify potential thermal failure modes within the MK5 AF&F. Testing confirmed the existence of failure modes in the Dual Stronglink Assembly (DSA) inside the AF&F prior to loss of electrical isolation. These failure modes enhance the likelihood of a safe response in thermal environments and complement the HE weaklink degraded by the change to IHE and the increased high explosive spacing in the Phase 2 candidates.

(U) The study has identified irreversible, independent, yet predictable, failure modes in the MC3831 DSA resulting from exposure to abnormal thermal environments. The abnormal temperature requirement for the DSA is 650°C due to the nuclear critical safety springs in the Module D becoming indeterminate at that temperature. Study results identified two failure modes, one involving the Duplex Bearings used in the Module C Intent Stronglink, and the second involving transformers. Module C permanent bearing seizure occurs at a temperature between 350°C and 400°C. Permanent transformer failure, precluding transfer of energy into the exclusion regions, occurs between 280°C and 435°C. Failure mode temperatures are reached in both the bearings and the transformers, under worst-case conditions (smart fire directed at the flat side of the fireset housing closest to the springs), before the spring temperature reaches 650°C.

10.1.3.1.2 (U) *LANL/Sandia MK4A Electrical Nuclear Safety Theme*

(U) The electrical nuclear safety theme for all Phase 2 MK4 replacement warheads is similar to that of the W76/MK4 with the additional positive isolation feature of detonator safing to preclude initiation of detonators until specific functions occur enabling them. A summary of the W76/MK4 electrical nuclear safety theme is provided and is applicable to all MK4A candidates.

(U) The electrical nuclear safety theme for the W76/MK4 is based upon isolation of electrical signals, diversion of electrical energy, and a predictable response relationship between components in credible abnormal environments.

(U) Isolation consists of positive measures (accelerometer and decelerometer) to preclude application of medium-voltage thermal battery power to the fire set except under intended use conditions.

(U) Energy diversion complements isolation. It consists of positive measures (Lightning Arrestor Connector (LAC)) to divert any electrical energy sufficient to cause weapon detonation.

(U) The predictable response relationship consists of positive measures to:

1. Preclude warhead operation except under normal flight conditions.
2. Assure absence of any credible warhead detonator electrical initiation source other than the armed firing set.
3. Preclude operation of critical safety components by available energy sources other than the intended source.
4. Assure that the reaction of critical safety components to environmental stresses is such as to result in a fail-safe response.

(U) A stronglink-weaklink approach is incorporated in the implementation of the safety theme. The accelerometer and decelerometer (stronglinks) provide electrical isolation by sequentially controlling access to the arming and firing circuits. The fireset itself is the weaklink and is designed to become irreversibly inoperable at environmental stress levels below those which could cause stronglink failure. Protection from a direct lightning strike is provided by the combination of the LAC, the incorporation of two stronglink switches, and the exclusion region barrier surrounding the safety-critical components.

(U) The electrical nuclear safety theme for the Phase 2 Study replacement warhead candidate LA4-1 is similar to the W76/MK4 weapon system theme. An additional positive isolation feature, detonator safing, is added in the LA4-2 candidate which modifies the safety theme "to preclude initiation of system detonators until specific functions occur enabling the detonators."

10.1.3.1.3 (U) *LLNL/Sandia MK5A Electrical Nuclear Safety Theme*

[redacted] All of the LLNL/Sandia MK5A candidates are based on using the existing W88/MK5 MC3810 AF&F and are compatible with DSSL. The larger size and weight capacity of the MK5A (as compared to the MK4A) allow freedom to explore significantly different safety themes.

b(3) DOE DTRA

LLNL MK5A candidates can be grouped into five categories. The ENDS themes for each category are discussed below.

(U) 1) LL5-1, -2, -3. These candidates all incorporate a DSSL and a robust exclusion barrier between the AF&F and the NEP. The robust exclusion barrier between the AF&F and the NEP provides enhanced safety in abnormal mechanical environments. It may reduce the likelihood that the AF&F will become detached from the warhead, thus exposing the detonator cables and bypassing the stronglinks within the AF&F. However, in these designs, the DSSL maintains safety in this situation as detailed in the DSSL description.

(U) 2) LL5-4a, -4c. These candidates have all of the safety features of the LL5-1, -2, -3 designs. In addition, the nuclear package is surrounded by an accident-resistant case. The accident-resistant case enhances safety in abnormal thermal environments.

(U) 3) LL5-4b. This candidate has a nuclear package that is similar to the LL5-4a, -4c designs. The primary difference is that LL5-4b contains a Category F Permissive Action Link (CAT-F PAL). Because of volume constraints, the accident-resistant case is not used in this design. The CAT-F PAL requires relocation of the firing set, and also requires two stronglinks between the relocated firing set and the primary detonators. The stronglinks in the existing MC3810 AF&F do not play an IND safety role in this design. In their place the DSSL and PEX booster are substituted.

b(3) DOE DTRA

b(3)
DOE
DTAA

10.1.3.1.4 (U) *<u>LLNL/Sandia MK4A Electrical Nuclear Safety Theme</u>*

(U) From an ENDS perspective, all of the LL4-Xa candidates are the same. Therefore, they all use the same ENDS themes. The LLNL/Sandia candidates proposed for the MK4A are designed to enhance two aspects of nuclear safety: reducing the likelihood of structural breakup and providing detonator safing.

(U) To provide positive protection, even if the NEP becomes exposed in an accident, LLNL/Sandia candidates include a DSSL downstream of the detonator cables, within the NEP itself. As long as the DSSL has not received the correct unique signal (i.e., been prearmed), firing of the detonator bridges cannot initiate the main charge explosive.

(U) This aspect of nuclear safety can be further improved in the LL4-Xb candidates by incorporating PEX Booster. Including a PEX booster system requires a new AF&F.

(U) The DSSL in LLNL/Sandia candidates provides improved safety in abnormal environments. Prearming stronglinks by unique signals which require many separate events provides greater assurance that the stronglinks will not be prearmed inadvertently. A signal generated by many events is much less likely to be inadvertently generated than one which requires only one event.

(U) The MK4A candidates could be fielded without DSSL or PEX booster.

(U) Unique Signal Generation: On the D5 missile, the unique signal to prearm DSSL would come from the Intent word which is sent in flight from the missile to the RBs. The use of a human intent signal to prearm DSSL provides the optimal safety for this design. However, the C4 missile system does not have any unique signal capability, and, therefore, is currently incompatible with this implementation. Therefore, for LLNL MK4A warheads on C4 missiles, an ESSG will be required to construct a unique signal by sensing a series of combinations of go/no-go environmental inputs, including acceleration and electrical signals from the missile. This ESSG would be designed to prearm the DSSL if the ESSG sensed events consistent with an SLBM flight, and will lock the DSSL in a safe position if it senses events which are not consistent with SLBM flight (i.e., abnormal environment). These SLBM events would be selected to discriminate between an SLBM flight and any abnormal environment, such as an aircraft crash.

(U) Modifying the MK5 to MK4 Adapter Cable on the D5 missile, which is outside the Phase 2 study groundrules, would allow the MK5 unique signal messages to be transmitted to the MK4A when mated to the D5 missile. This would eliminate the need for an Environmental Sensing Signal Generator in that application.

10.1.4 (U) INRAD EXPOSURE LEVELS

(U) Predictions for INRAD operational exposures for all Phase 2 warhead candidates have been made. The predictions are based upon a methodology that requires knowledge of neutron and gamma INRAD dose rates for each candidate, as well as operational exposure data that can be unambiguously linked to specific existing

10.1.6 (U) CONCLUSIONS

(U) The STWG developed the following conclusions from its Phase 2 study effort:

1. (U) The W76/MK4 and the W88/MK5 meet the intent of all safety requirements as specified in the MCs and STSs. The STWG has not identified any safety concerns with the as-designed weapon systems. New advanced technology developments could be incorporated into system designs that offer safety enhancements to the existing MK4 and MK5.

2. (U) The proposed candidates take advantage of new technology design features/enhancements. Safety systems that can be implemented on Phase 2 candidates which are common to a number of candidate warheads are IHE, fire resistant pits, robust exclusion barriers, and advanced detonator safing (DSSL, SALAD).

3. (U) The enhanced safety concepts and features discussed herein can be incorporated into the Phase 2 candidates without violating groundrules with the exception of the LA4-1 and 2, LA5-5, LL5-5 and LL5-6 designs, and the candidates that incorporate CAT F use control features in their designs.

4. (U) The electrical nuclear safety theme to prevent inadvertent nuclear detonation for MK5A candidates is similar to that of the W88/MK5, with the additional positive isolation feature of detonator safing.

5. (U) The electrical nuclear safety theme to prevent inadvertent nuclear detonation for MK4A candidates is similar to that of the W76/MK4 with the additional positive isolation feature of detonator safing.

6. (U) No attempt was made to quantify the merits of any proposed safety features. An extensive trade-off study would be required to evaluate safety features and their impact on system performance and reliability. Further detailed studies would also be required to quantify safety enhancements and improvements in system safety.

b(3) DOE DTRA

8. (U) The STS fire and nearby explosion environments have not been completely defined. Additional details on the DOE SST operations and the nearby explosion environments are needed for continued assessments.

10.2 (U) USE CONTROL

(U) This section addressed the implications of recommendations made by the Fail-Safe and Risk Reduction Committee (FARR) affecting SLBM reentry systems. The FARR working group reviewed the 58+ FARR Committee recommendations for their applicability to the TRIDENT Phase 2 Study.

(U) The following two FARR recommendations, dealing with coded control and use denial, were found to be applicable to the TRIDENT Phase 2 Study:

b(3) DOE DTRA

(U) The issues of coded control and use denial can be addressed at the reentry system level by employing combinations of four warhead use control implementations:

b(3) DOE

b(3) DOE

b(3) DOE

(U) MK5A warhead candidates have been proposed that can incorporate each type of use control device (CAT-D, E, and F PALs). MK4A warhead candidates have been proposed that can incorporate only CAT-D and CAT-E PALs. b(3) DOE

Table 10.2-1 summarizes which use control features can be implemented in the various warhead candidates.

(U) The Phase 2 Study was limited to identifying alternate warhead candidates for the W76/MK4 and W88/MK5. Consequently, the study group could only address implications of coded control and use denial options in the warhead and Reentry systems.

(U) Incorporation of various combinations of coded control and use-denial devices can satisfy the FARR recommendations. However, an optimal solution that incorporates coded-control and use-denial devices in combination must consider the entire weapon systems. Determining the impacts of design changes in other subsystems of the weapon systems, such as Fire Control, Launcher, etc., were beyond the scope of this study.

(U) The impacts of CAT-D, E, and F PAL and CD warhead implementations on the weapon systems likewise were not evaluated. Areas that would be affected include the following:

- Missile/Reentry body interfaces
- Fire Control
- Launcher
- Logistics/Operations
- Safety

b(3)
DOE
DTRA

11. (U) ENVIRONMENTAL EFFECTS ASSESSMENT

(U) There will be no adverse environmental effects from the development, production, testing or stockpiling of the MK4A and MK5A reentry body assemblies and their warheads that are outside of Department of Energy and Department of Defense guidelines for nuclear weapons. Information concerning the environmental impact assessment of the TRIDENT strategic weapon system may be obtained from the Director, Strategic Systems Programs.

12. CONCLUSIONS

12. (U) CONCLUSIONS

12.1 (U) BACKGROUND

(U) The guidelines established for this Phase 2 Study included tasking to "identify and quantify a broad range of alternate reentry systems for use on the TRIDENT weapon systems that emphasize longevity, increased safety margin, system reliability, and future requirements."

(U) Although the present systems are, as President Clinton, the Navy and DOE have said, safe and reliable, all of the replacement warhead candidates considered in the Phase 2 study offer surety enhancements over the currently deployed systems. Most candidates incorporate IHE, improved ENDS, FRP, and use control features. The Phase 2 Study Group evaluated these surety enhancements, and associated performance penalties and system impacts.

(U) The viability of some of the candidates depends upon the DOE's ability to produce new plutonium pits and whether the DOE weapons laboratories are permitted to conduct UGTs.

12.2 (U) EVALUATION APPROACH

(U) To examine the tradeoffs between attributes of candidates, two different evaluation approaches were developed in the System Performance and Effectiveness Technical Working Group (SPETWG). One approach is Weapon Safety Value Assessment (WESVA) (Reference 10) and the other is Relative Overall Merit Assessment (ROMA) (Reference 11).

(U) Both evaluation approaches make use of computer spreadsheets to combine figures of merit (FOMs) for each of the candidate warheads. These FOMs include the following: surety, effectiveness, vulnerability, production/logistics, engineering evaluation, and physics evaluation. Input is taken from the Phase 2 technical working groups.

(U) WESVA uses tradeoffs that measure how much the decision maker is willing to give up of one FOM to gain on another. ROMA assigns weighting coefficients to each of the FOMs that correspond to their assessed importance in overall value. The SPETWG members were polled for their preferences to establish the weighting and tradeoff measures. The spreadsheet format lends itself to interactive use, allowing the decision maker to easily test the sensitivity of results to input assumptions.

(U) The overall value of each candidate was estimated, along with its ranking relative to the W76 or W88. In all cases, no replacement candidates, MK4A or MK5A, were ranked higher than existing systems. The results presented in Section 12.3 are candidate groups which were differentiated from other candidates given the input assumptions. The candidate groups were found to be insensitive to a wide range of variations.

12.3 (U) <u>FINDINGS</u>

(U) The findings are presented for three potential situations which represent fundamentally different political realities and real world constraints.

12.3.1 (U) <u>WITH UGT AND NEW PLUTONIUM PITS</u>

(U) In this situation, the current UGT moratorium is lifted, thereby allowing development testing to demonstrate reliability and performance of replacement candidates that use new plutonium primary pits. This situation further assumes that the DOE weapons complex can manufacture new primary pits.

(U) Both the WESVA and ROMA assessment models indicate that the best alternatives for further consideration are **(the order is not significant)**:

<u>MK4A on C4/D5:</u>	LL4-3
	LA4-1
<u>MK5A on D5:</u>	LL5-2
	LA5-1

12.3.2 (U) WITH UGT AND REUSED PLUTONIUM PITS

(U) In this situation, the current UGT moratorium is lifted, but the DOE weapons complex precludes manufacture of new plutonium pits. Development testing is permitted to demonstrate reliability and performance of replacement candidates using existing primary pits.

(U) Both the WESVA and ROMA assessment models indicate that the best alternatives for further consideration are **(the order is not significant)**:

MK4A on C4/D5:	LL4-1
	LA4-2
MK5A on D5:	LL5-1 (H, M, or L)
	LL5-3a
	LL5-3b
	LA5-4 (H, M, or L)
	LA5-6

12.3.3 (U) WITHOUT UGT

(U) In this situation, the DOE nuclear design laboratories are precluded from conducting UGTs to develop replacement candidates. Historically, nuclear testing has been a necessary part of warhead development. Reducing the need for development nuclear testing is a significant challenge to a design philosophy that has relied on nuclear testing to demonstrate reliability and performance of complex systems that cannot be simulated any other way.

12.3.3.1 (U) MK4A Without UGT

(U) This study has not identified any MK4A candidates for further consideration without UGTs.

12.3.3.2 (U) MK5A Without UGT

(U) The Los Alamos and Livermore nuclear design laboratories have not reached agreement on how MK5A development and certification would be done without UGT.

(U) Pending the results from the joint laboratory peer review process and future inter-laboratory reviews during a Phase 2A or Phase 3, two positions, one each from Livermore and Los Alamos, are presented for the preferred candidates.

12.3.3.2.1 (U) *LLNL Position Without UGT*

(U) Many, but not all, of the development issues for several MK5A warhead candidates can be addressed with existing data from past nuclear tests. The following candidates have such a nuclear test background and merit further consideration as to whether or not they could be developed without additional nuclear testing. See Sections 5.2.2.1.2 and 5.2.2.2.2.

MK5A on D5	LL5-1
	LL5-2
	LA5-1

12.3.3.2.2 (U) *LANL Position Without UGT*

(U) It is the technical position of Los Alamos that any primary considered as a candidate for this Phase 2 should have or have had two successful nuclear tests in its final design configuration. Without this minimum number of tests, the confidence level of any laboratory certification would be significantly less than that of the system it will be replacing. Thus, the leading candidates that meet minimum yield and other military characteristics do not have sufficient test basis to allow certification without a serious degradation of the accompanying confidence level; the confidence level would be unknown. It is also the Los Alamos position that relaxation of MCs would still require at least one more test for certification of candidates LL5-1, LL5-2, and LA5-1. See Section 5.1.2.2.

MK5A on D5: No candidates meet the requirements.

APP. A PHASE 2 REQUEST LETTERS

APPENDIX A

PHASE 2 REQUEST LETTERS (U)

(All Portions of This Appendix are UNCLASSIFIED)

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
WASHINGTON, DC 20350-2000

IN REPLY REFER TO

653C/2U639009
10 Apr 92

SECOND ENDORSEMENT on DIRSSP memo 4900 Ser SP272 Ser U032692113 of 26 Mar 92

From: Chief of Naval Operations (OP-65)
To: Chairman, Nuclear Weapons Council Standing Committee

Subj: SUBMARINE LAUNCHED BALLISTIC MISSILE (SLBM) REENTRY SYSTEM PHASE II STUDY

1. Forwarded, concurring with the recommendation to initiate a DOD/DOE Phase II study to identify and quantify technical alternatives to the MK4/W76 and MK5/W88.

R. L. TINDAL

Copy to:
OP-091B
DIRSSP

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
WASHINGTON, DC 20350-2000

IN REPLY REFER TO
3960
Ser 21/2U584166
3 Apr 92

FIRST ENDORSEMENT on DIRSSP memo 4900 Ser SP272 Ser U032692113 of 26 Mar 92

From: Chief of Naval Operations (OP-21)
To: Chairman, Nuclear Weapons Council Standing Committee
Via: Chief of Naval Operations (OP-65)

Subj: SUBMARINE LAUNCHED BALLISTIC MISSILE (SLBM) REENTRY SYSTEM PHASE II STUDY

1. Forwarded, concurrring with the recommendation to initiate a DOD/DOE Phase II study to identify and quantify technical alternatives to the MK4/W76 and MK5/W88.

R. A. RIDDELL
By direction

Copy to:
DIRSSP

APP. B MILITARY CHARACTERISTICS

APPENDIX B

MILITARY CHARACTERISTICS FOR THE WARHEAD
FOR THE TRIDENT II (D-5) MK5A AND MK4A REENTRY BODY (U)

(This page is UNCLASSIFIED)

MILITARY CHARACTERISTICS FOR THE WARHEAD FOR THE TRIDENT II (D-5) MK5A REENTRY BODY (U)

1. (U) GENERAL

(U) 1.1 Purpose. These Military Characteristics define the Department of Defense (DOD) requirements for a warhead compatible with the Navy MK5A Reentry Body (RB) used on the TRIDENT II (D-5) Submarine Launched Ballistic Missile Weapon System. This warhead will be a replacement for the existing W88 warhead.

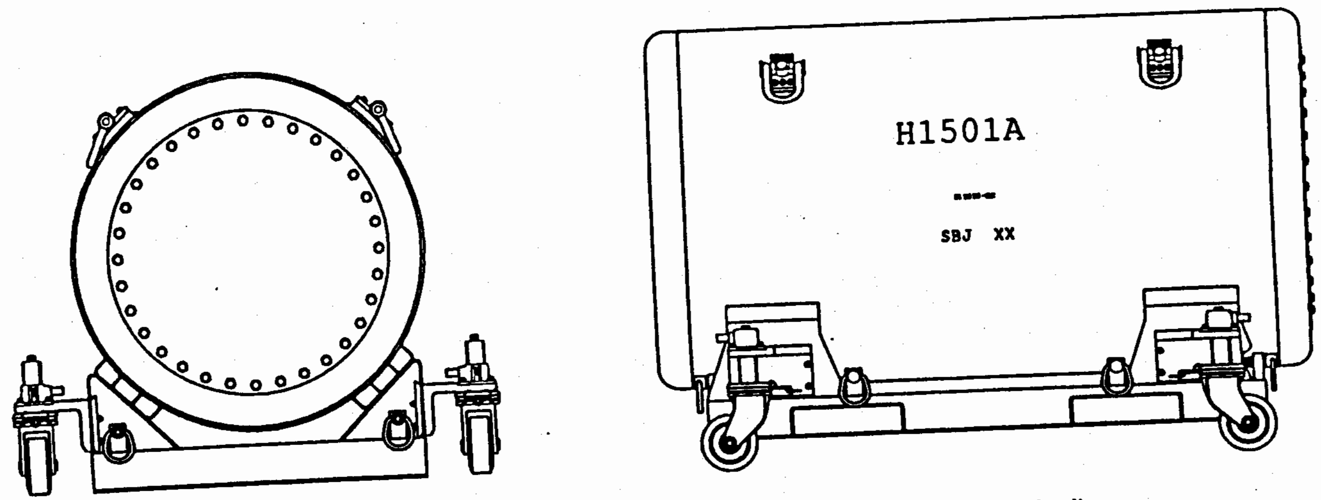
(U) 1.2 Contingencies. Should it appear impractical to meet any of these characteristics or should it appear that meeting of any criterion specified herein will unduly delay development or production of this warhead, or require unreasonable amounts of critical material, or incur unreasonable costs, prompt notification shall be made to the NWC.

(U) 1.3 Competing Characteristics Criteria. As a general rule, priority of consideration shall be given to nuclear safety, reliability and other operational characteristics, in that order. It is understood that technical feasibility, schedule and cost are to provide the basis for making tradeoffs among the desired competing characteristics.

(U) 1.4 Development Schedule. The warhead development schedule shall support an Initial Operational Capability of no earlier than the late 1990's.

(U) 1.5 . Design Philosophy. Attention must be directed toward a design that offers high reliability in a device that will remain in the strategic arsenal well into the next century. Warhead design should be conservative and should not attempt to extend performance beyond well established regimes. More specifically, the warhead design which is developed for this system should:

- (U) Minimize the likelihood of deleterious changes during stockpile life.
- (U) Enhance insensitivity to any changes that may occur.
- (U) Optimize the capability to replicate the design should a warhead rebuild program be required in the future.
- (U) Incorporate new modern safety features to the extent feasible consistent with yield, range and reliability requirements.



End View (Castors Retracted)

Side View (Castors Extended)

FIGURE C-9

(U) H1501 TRANSPORTATION ACCIDENT RESISTANT CONTAINER