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JOINT DOD/DOE TRIDENT MK4/MK5 REENTRY BODY ALTERNATE WARHEAD PHASE 2 FEASIBILITY STUDY REPORT (U)

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ACRONYMS & REFERENCES

CSA	(U) Canned Subassembly
CTB	(U) Comprehensive Test Ban
CTE	(U) Coefficient of Thermal Expansion
D5	(U) Trident II SLBM
DASMA	(U) Deputy Assistant Secretary for Military Applications
DDRE	(U) Department of Defense, Research ,and Engineering
DGZ	(U) Designated Ground Zero
DIA	(U) Defense Intelligence Agency
DIRSSP	(U) Director, Strategic Systems Programs
DISA	(U) Defense Information Systems Agency
DITWG	(U) Design Integration Technical Working Group
DoD	(U) Department of Defense
DOE	(U) Department of Energy
DNA	(U) Defense Nuclear Agency
DSA	(U) Dual Stronglink Assembly
DSSL	(U) Detonator Safing Stronglink
D-T	(U) Deuterium - Tritium
EAM	(U) Emergency Action Message
ECA	(U) Electronic Component Assembly
EHW	(U) Explosives Handling Wharf
EMP	(U) Electromagnetic Pulse
EMR	(U) Electromagnetic Radiation
ENDS	(U) Enhanced Nuclear Detonation Safety
EOL	(U) End Of Lifetime
EPOT	(U) Enclosure for the Protection of Ordnance in Transit
ESD	(U) Environmental Sensing Device
ESSD	(U) Environment Sensing Signal generating Device
ESSG	(U) Environmental Sensing Signal Generator
FARR	(U) Fail-safe and Risk Reduction Study
FBIA	(U) Force-Balancing Integrating Accelerometer
FBM	(U) Fleet Ballistic Missile
FEM	(U) Finite Element Model
FOM	(U) Figures of Merit
FONSI	(U) Finding of No Significant Impact
FOUO	(U) For Official Use Only
FPU	(U) First Production Unit

FRD	(U) Formerly Restricted Data
FRC	(U) Fire-Resistant Capsule
FRE	(U) Fire-Resistant Enhancement
FRP	(U) Fire-Resistant Pit
GLCM	(U) Ground-Launched Cruise Missile
GTS	(U) Gas Transfer System
HASC	(U) House Armed Services Committee
HERO	(U) Hazards of Electromagnetic Radiation to Ordnance
HMX	(U) Prime ingredient in a high explosive (Cyclotetamethylenetetronitramine)
HOB	(U) Height of Burst
ICBM	(U) Intercontinental Ballistic Missile
ICD	(U) Interface Control Drawing
IEMP	(U) Internal Electromagnetic Pulse
IFD	(U) In-Flight Disconnect
IH	(U) Inert Head
IHE	(U) Insensitive High Explosive
IND	(U) Inadvertent Nuclear Detonation
INRAD	(U) Intrinsic Radiation
IOC	(U) Initial Operational Capability
JCS	(U) Joint Chiefs of Staff
JTA	(U) Joint Test Assembly
LAC	(U) Lightning Arrestor Connector
LAE	(U) Large Accurate Evader
LANL	(U) Los Alamos National Laboratory
LANT OP	(U) Atlantic Operations
LIHE	(U) Light-Initiated High Explosive
LL	(U) Lower Left
LLC	(U) Limited-Life Component
LLCE	(U) Limited-Life Component Exchange
LLNL	(U) Lawrence Livermore National Laboratory
LMSC	(U) Lockheed Missiles and Space Company
MaRB	(U) Maneuvering Reentry Body
MARV	(U) Maneuvering Reentry Vehicle
MAST	(U) Multi Application Surety Technology
MCs	(U) Military Characteristics

MIRV	(U)	Multiple Independently-Targetable Reentry Vehicle
MK4	(U)	Mark 4 Reentry Body
MK5	(U)	Mark 5 Reentry Body
MK12	(U)	Mark 12 Reentry Vehicle
MK12A	(U)	Mark 12A Reentry Vehicle
MK21	(U)	Mark 21 Reentry Vehicle
MLC	(U)	Military Liaison Committee
MOE	(U)	Measures of Effectiveness
MOI	(U)	Moments of Inertia
MSAD	(U)	Mechanical Safe and Arm Detonator
N/F	(U)	Nose Fairing
NASA	(U)	National Aeronautics and Space Administration
NCCS	(U)	Nuclear Command and Control System
NEP	(U)	Nuclear Explosive Package
NG	(U)	Neutron Generator
NM	(U)	New Mexico
NORC	(U)	Nuclear Ordnance Record Card
NSA	(U)	US National Security Agency
NTB	(U)	National Target Base
NTS	(U)	Nevada Test Site
NWC	(U)	Nuclear Weapons Council
NWCSC	(U)	Nuclear Weapon Council Standing Committee
NWCWSC	(U)	Nuclear Weapons Council Weapons Safety Committee
NWEF	(U)	Naval Weapons Evaluation Facility
NWWG	(U)	New Warhead Working Group
OASD/ISP	(U)	Office of the Assistant Secretary of Defense/International Security Policy
OSD/ISP	(U)	Office of the Secretary of Defense/International Security Policy
Oy	(U)	Oralloy
PAC OP	(U)	Pacific Operations
PAL	(U)	Permissive Action Link
PASS	(U)	Pre-production Accelerated Stockpile Surveillance
PBV	(U)	Post-Boost Vehicle
PBCS	(U)	Post-Boost Control System
PEIS	(U)	Programmatic Environmental Impact Statement
PETN	(U)	Pentaerythritol Tetranitrate

PEX	(U) Paste Extrudable Explosive
PIGMA	(U) Pressurized Inert Gas Metal Arc
PINEX	(U) Pinhole Experiment (Neutron Imaging Pinhole Camera)
PK	(U) Probability of Kill
POC	(U) Probability of Clearance
POG	(U) Project Officers' Group
PRESS	(U) Pit Reuse for Enhanced Safety and Surety
PRP	(U) Personnel Reliability Program
R&D	(U) Research and Development
R/E	(U) Reentry
RA	(U) Release Assembly
RB	(U) Reentry Body
RBA	(U) Reentry Body Assembly (RB mounted on Release Assembly)
RBC	(U) Reentry Body Complex
RBM	(U) Reentry Body Magazine
RD	(U) Restricted Data
RDT & E	(U) Research, Development, Test, and Evaluation
REB	(U) Reentry Body Building
RF	(U) Radio Frequency
RFP	(U) Rocky Flats Plant
ROM	(U) Read Only Memory
ROMA	(U) Relative Overall Merit Assessment
RS	(U) Reentry System (includes WH, RB, AF&F, RA)
RUPL	(U) Radar-Updated Path Length
RV	(U) Reentry Vehicle
S	(U) Secret
SAFEPOT	(U) Small Arms Fire Enclosure for the Protection of Ordnance in Transit
SALAD	(U) Slide Armed Laser Actuated Device
SAS	(U) Sealed Authentication System
SASC	(U) Senate Armed Services Committee
SECDEF	(U) Secretary of Defense
SECNAV	(U) Secretary of Navy
SFRD	(U) Secret Formerly Restricted Data
SGEMP	(U) System-Generated Electromagnetic Pulse
SGT	(U) Safeguards Trailer

SHOB	(U)	Scaled Heights of Burst
SLBM	(U)	Submarine Launched Ballistic Missile
S.M.	(U)	Static Margin
SNL	(U)	Sandia National Laboratories
SNL/CA	(U)	Sandia National Laboratories/California
SNL/NM	(U)	Sandia National Laboratories/New Mexico
SNM	(U)	Special Nuclear Material
SOA	(U)	Speed of Advance
SPETWG	(U)	Systems Performance and Effectiveness Technical Working Group
SRAM	(U)	Short Range Attack Missile
SRD	(U)	Secret Restricted Data
SRD/N	(U)	SRD/CNWDI
SSBN	(U)	Submersible Ship, Ballistic, Nuclear
SSE	(U)	Surface Support Equipment
SSNT	(U)	Shape Stable Nosetip
SSP	(U)	Strategic Systems Programs
SSPK	(U)	Single Shot Probability of Kill
SST	(U)	Safe, Secure Trailer
SSU	(U)	Separation Sequencer Unit
START	(U)	Strategic Arms Reduction Treaty
STAS	(U)	Safe-to-Arm Signal
STRATCOM	(U)	Strategic Command
STS	(U)	Stockpile-to-Target Sequence
STWG	(U)	Steering Task Working Group
SU	(U)	Service Unit
SWF	(U)	Strategic Weapons Facility
SWFLANT	(U)	SWF, Atlantic (Kings Bay, GA)
SWFPAC	(U)	SWF, Pacific (Bangor, WA)
SWOP	(U)	Special Weapons Ordnance Publication

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DOE

U	(U) Unclassified
UC	(U) Use Control
UGT	(U) Underground Test (Nuclear)
UK	(U) United Kingdom
UL	(U) Upper Left
UM	(U) Upper Middle
UQS	(U) Unique Signal
UR	(U) Upper Right
USN	(U) United States Navy
V&H	(U) Vulnerability and Hardening
V-γ	(U) Reentry Velocity-Gamma (Flight Path Angle)
VNTK	(U) Target Vulnerability Number
WESVA	(U) Weapon Safety Value Assessment
WG	(U) Working Group
WH	(U) Warhead
WR	(U) War Reserve
WSR	(U) Weapon System Reliability
Z	(U) Atomic Number

10. Homsy, R.V., et al, "Weapon Safety Value Assessment (WESVA): A Decision Aid for Comparing Warhead Advanced Surety Designs," Lawrence Livermore National Laboratory, Livermore, CA, UCRL to be published 1994.

11. "Relative Overall Merit Assessment (ROMA), " Los Alamos National Laboratory, Los Alamos, NM, report to be published 1994.

EXECUTIVE SUMMARY

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.

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)

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.

(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.

SECRET//RESTRICTED//NOFORN

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.

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.

b(3)

DOE, USTRA

Intrinsic radiation levels are TBD, but as low as possible (Reference 4).

(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. 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. b(3) DOE

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

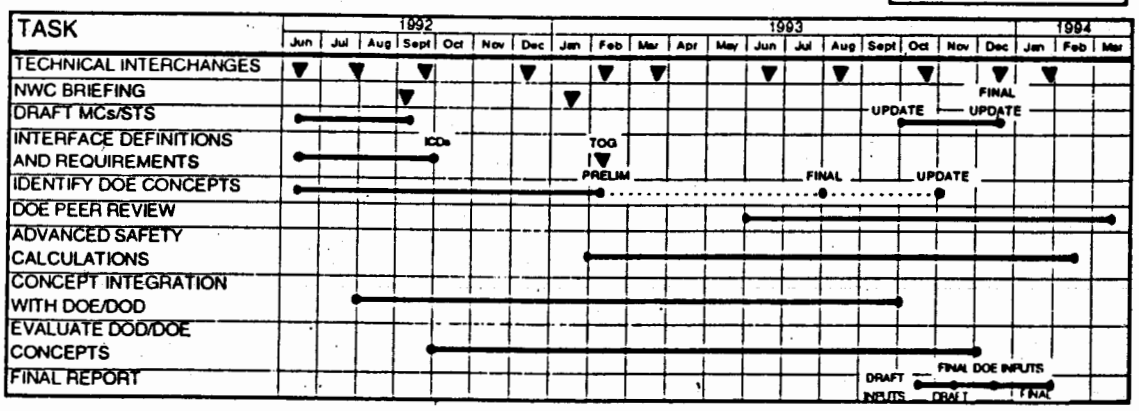

FIGURE 2-1
(U) SLBM PHASE 2 STUDY SCHEDULE

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) FARR BACKGROUND

(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.

UNCLASSIFIED

b(3)

DOE

TABLE 3.5-1

(U) COMPONENT FPU TIMES (LANL)

[redacted]

UNCLASSIFIED

b(3)

TABLE 3.5-2
(U) COMPONENT FPU TIME (LLNL)

UNCLASSIFIED

DOE

UNCLASSIFIED

TABLE 3.5-2 (Continued)
(U) COMPONENT FPU TIME (LLNL)

UNCLASSIFIED

TABLE 3.5-3

(U) CANDIDATE TECHNOLOGY AVAILABILITY AND FPU DELIVERY TIMES

UNCLASSIFIED

CANDIDATE	Near Term (< 5 yr)	Mid-Term (5-10 yr)	Far-Term (>10 yr)
LA5-1		T	FPU
LA5-2	T	FPU	
LA5-3		T FPU	
LA5-4		T FPU	
LA5-5		T FPU	
LA5-6		T FPU	
LA5-7		T FPU	
LA5-8		T FPU	
LA5-9		T FPU	
LA4-1		T	FPU
LA4-2		T FPU	
LL5-1	T	FPU	
LL5-2	T		FPU
LL5-3a		T FPU	
LL5-3b	T	FPU	
LL5-4a	T	FPU	
LL5-4b		T FPU	
LL5-4c		T FPU	
LL5-5		T FPU	
LL5-6		T	FPU
LL4-1a	T	FPU	
LL4-2a	T	FPU	
LL4-3a		T	FPU
LL4-1b		T FPU	
LL4-2b		T FPU	
LL4-3b		T	FPU

2. (U) The RFP production contingency mission was removed by DOE several months ago. The DOE Revised Notice of Intent and Programmatic Environmental Impact Statement for Complex-21 are very emphatic that RFP will no longer be able to fabricate Pu pits. Complex-21 will not be available to fabricate new pits until many years after FPU for SLBM. LANL and LLNL both have a capability to fabricate a small number of Pu test articles, but by no stretch of the imagination could this be considered a production capability. b(3) [redacted] DOE

3. (U) The Y-12 plant is currently at a semi-production level of capability and has a production capacity higher than the capability envisioned for the Pantex pit reuse program. If Y-12 were given the budget and programmatic requirement basis within the next few years, it could fabricate all Oy pits on a production basis within three years of notice to do so. Y-12 anticipates substantial budget reductions starting in FY95. If after the budget cuts, Y-12 is able to sustain a minimum capability, it could still begin Oy pit production within three years notice to do so. If the budget cuts reduce Y-12 to a storage-only mode, then five or more years advance notice would be required before Y-12 could start production of an all Oy pit. The year FY95 is a key decision date if the SLBM will use an all Oy pit and if its current production schedule is to be met. b(3) [redacted] DOE

For the CSAs or other Y-12 products required for a complete NEP, Y-12 would be able to meet production requirements subject to the same caveats given in the previous paragraph.

4. SUMMARY

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

b(3)

DOE

TABLE 4-2
(U) CALIFORNIA MK5A WARHEAD CANDIDATES

b(3)

DOE

TABLE 4-3
(U) MK4A WARHEAD CANDIDATES

b(3)

DOE

b(3)

DOE

FIGURE 4-1
(U) MK5A WEIGHT AND CG

b(3)

DOE

FIGURE 4-2
(U) MK4A WEIGHT AND CG

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

DTRA b(3)

[redacted] (See Section 5.1.2.2.)

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.

DTRA b(1)

b(3)

DOE

4.3.3 (U) USE CONTROL

(U) The FARR committee recommendations were reviewed for applicability to this study and it was determined that coded control and use control apply directly. These issues can be addressed in four implementations: CAT-D PAL, CAT-E PAL, CAT-F PAL and command disable. MK5A candidates have been proposed that can incorporate each of these implementations. CAT-E PAL was proposed for the MK4A candidates. CAT-D PAL and command disable are options for California MK4A candidates.

b(3) DTRA

The impacts of these on the weapon system are significant, but have not been fully assessed.

4.3.4 (U) VULNERABILITY

(SRD) No show stoppers were found in the mechanical vulnerability analysis of the leading warhead candidates.

b(3) DOE

Finite element model analyses have identified areas of concern that need to be closely watched during subsequent development activities, especially testing.

TCG-VH-1 3030

TCG-NAS-2 244.1

DOE, DTRA b(3)

4.3.5 (U) JOINT TEST

(U) Candidates with identical features (e.g., safety and use control) require similar types and quantities of joint tests. Many important test facilities are being decommissioned and personnel reassigned. This could be a significant problem. Of great concern are facilities to run the abnormal safety and vulnerability tests. In view of the suspension of UGT, the decommissioning of above ground vulnerability testing capability and the lack of experienced personnel is a particular concern.

4.3.6 (U) QUALITY AND RELIABILITY

(U) The reliability of the candidates is significantly influenced by the safety and use control features and by constraints on the modification of the existing AF&Fs. There are no significant reliability differences between the LANL and LLNL candidates with comparable features and design constraints.

b(3)

TCG-WPMD-1
1511

(C)

(U) The addition of CAT-E PAL use control features does not change the reliability of the warhead when the warhead is installed on the missile.

b(3) DOE

DOE

(C)

b(3)

CG-W-5
710.1

The analyses show DOE
significant value to new height of burst options, compared to the current fixed MK4 height of burst options.

TCG-WPMU-1
2214

b(3) DOE

b(3)
DTRA

4.5 (U) CONCLUSIONS

(CRD) A broad range of candidates has been proposed.

b(3)
DOE

Most candidates incorporate ENDS, with advanced detonator safing and robust exclusion barriers, IHE, FRP and devices for use control and denial.

b(3)
DOE

b(3)
DOE

(U) The Los Alamos and Livermore nuclear design laboratories have not reached agreement on how development and certification would be done for MK5A without UGT. The LLNL position is that many, but not all, of the development issues for some MK5A warhead candidates can be addressed with existing data from past nuclear tests. The following candidates have significant test backgrounds and merit further consideration as candidates for development without nuclear testing:

MK5A: LL5-1, LL5-2 and LA5-1

(CRD) 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,

b(3) DTRA

b(3) DOE

MK5A : No candidates meet the requirements.

(U) LA5-2 is reuse of an existing warhead and has been extensively tested in its original development program.

DOE CG-W-5 710.1

b(3)

b(3) DTRA

5. NUCLEAR WARHEAD DISCUSSION MK5A

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 [redacted] 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.

TABLE 5.1-1

(U) LOS ALAMOS/SANDIA NM MK5A CANDIDATES

b(3)

TCA-NAS-2
505.2.2
5.11

CAW-5
710.1

SAW88CG
2001.6
2001.7

SALAW76
200.6
200.7

DOE, DTRA

UNCLASSIFIED

b(3)

[redacted]

[redacted]

UNCLASSIFIED

(U) FIGURE 5.1-1

DOE, JIRA

[redacted]

b(3)

DOE, DTRA

(U) FIGURE 5.1-2

[redacted] b(3)

DOE, DTRA

(U) FIGURE 5.1-3

b(3)

(U) FIGURE 5.1-4

DOE, DTRA

b(3)

(U) FIGURE 5.1-5

DOE, DTRA

b(3)

(U) FIGURE 5.1-6

[redacted] b(3)

(U) FIGURE 5.1-8 DOE, DTRA

[redacted]

5.1.2.2 (U) Nuclear Testing

(U) In the Phase 2 request, the Navy asked for designs that *potentially reduce the need for post development nuclear testing*. This 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. The Navy's request anticipated future test restrictions. In actuality, test moratoriums have come into effect and are expected to continue. This means that development tests for new warheads are not available. As of this writing, the political acceptability of hydronuclear experiments is yet to be determined. These very low yield tests offer an important avenue for building confidence in both the continuing reliability of deployed systems and the performance of previously tested but not yet manufactured systems. New systems still require nuclear testing to demonstrate their design viability and to obtain a measure of their actual robustness. This provides the foundation for certification.

(U) Laboratory certification is a statement of the expected nuclear system performance, mainly yield and attendant yield range with some level of confidence. In the past with nuclear testing, this level of confidence was very high.

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Without this minimum number of tests, the confidence level of any Laboratory certification would be significantly less than that of the current SLBM systems.

b(3)

TCG-NAS-2 SOS. 2. 2

DOE, DTRA

(CRD) Nuclear test history and requirements for each candidate are described in Table 5.1-2.

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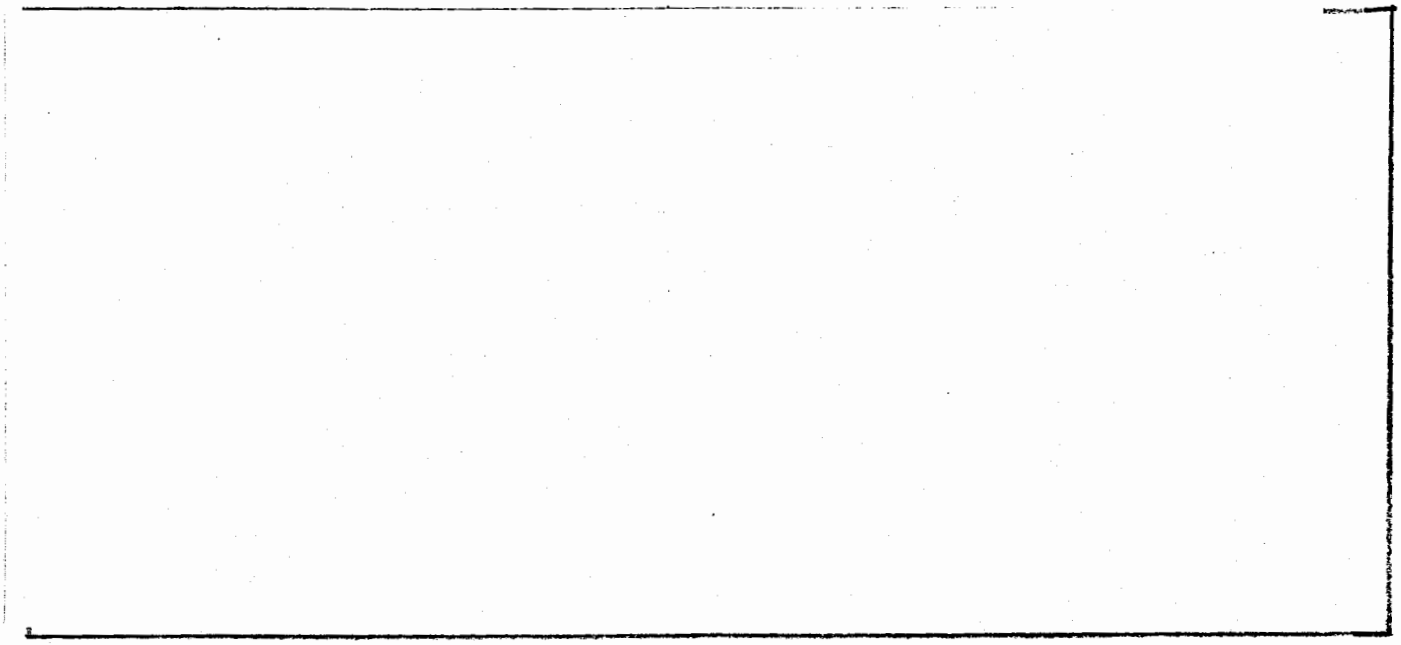
b(3)



DOE

5.1.3 (U) ARMING, FUZING, AND FIRING (AF&F) AND ELECTRICAL SUPPORT SYSTEMS OPTIONS

(U) The AF&F and the other electrical support systems included in the respective New Mexico Laboratories proposed nuclear assembly packages address two specific Phase 2 Study issues, e.g., Use Control (UC) and ENDS. Use Control is provided by individual or combined usage of Category D, CAT-E, or CAT-F Permissive Action Link (PAL) systems. Descriptions of those PAL systems and discussion of their implementation is provided elsewhere within the Phase 2 Study Report. A laser actuated detonator safing device called SALAD (Slide Armed Laser Actuated Detonator) provides additional positive safety measures in the New Mexico candidates, addressing combined abnormal environments. SALAD is discussed in Section 10.1.2.3.3. Due to design and/or device subsystem reuse constraints, not all of the New Mexico nuclear assemblies are compatible with Use Control and/or detonator safing. Specific implementation is addressed in the discussions and accompanying figures in the descriptions that follow for each candidate proposed.

(CFRD) Figures describing two electrical systems configurations for detonator safing implementation are included in the majority of the respective nuclear assembly descriptions.

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DOE

5.1.4.1.2 (U) *Primary Design, Test History*

DOE, DTRA b(3)

TCG-NAS-2 505.2.2 506.1 +

TCG-NAS-2 505.2.2

TCG-NAS-2 505.2.2 441 421 +

TCG-NAS-2 505.2.2 +

b(3)

DOE DTRA

TCG-NAS-2 505.2.2

5.1.4.1.3 (U) *Secondary Design, Test History Performance*

b(3)

TCG-NAS-2 505.2.2 801

TCG-WO-1 101.2

DOE DTRA

b(3)
DOE, DTRA

TCG-NAS-2 801 (+)

5.1.4.1.4 (U) *Nuclear System Engineering*

b(3)
DOE, DTRA

TCG-NAS-2 441 517

TCG-WM-1 T601.3

DOE DiRA b(3)

TCG-NAS-2 505.2.2

TCG-DS-1 111

TCG-NAS-2 911.3
721

DOE, DTRA b(3)

SALAD and Terrazzo are described in the Subsystem Descriptions at the end of Section 5.1.

5.1.4.1.5 (U) *Electrical Support System*

b(3)
DOE, DTRA

b(3)

[redacted]

DOE

The first figure below (Figure 5.1-10) details the electrical system for LA5-1 when the MC3810 AF&F is modified to rebuild the fire set assembly. [redacted] b(3) DTRA

(CRD) The second figure (Figure 5.1-11) details another electrical support systems configuration to provide detonator enabling/safing. The MC3810 AF&F is not modified in this configuration. Additional component development is necessary to provide the hardware required for power generation, signal capture and processing, and device functioning. b(3)

DOE

b(3) DOE, DTRA

(U) FIGURE 5.1-10

b(3) DOE, DTRA

(U) FIGURE 5.1-11

5.1.4.2 (U) W76 Warhead in Safety Capsule (LA5-2)

(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. [redacted] b(3) DOE, DTRA

(CFRD) The W76 nuclear system is one of the most completely tested systems in the enduring stockpile. [redacted] b(3) CG-W-5 710 1 DOE, DTRA

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

[redacted] TCG-NAS-2 801 DOE, DTRA b(3)

b(3)

TCG-NAT-2 · 505.2.2
TCG-WO-1 101.2

DOE, DTRA

5.1.4.2.2 (U) *One-point Safety of the W76 as Deployed*

b(3)

TCG-WAS-2 585.2.2
255.2.1
TCG-WD-1 104.1

DOE, DTRA

5.1.4.2.3 (U) *Effect of Safety Capsule on One-point Safety*

b(3)

DOE, DTRA

A careful study of this effect would be done during development.

5.1.4.2.4 (U) *Multi-point Safety*

(CRD) A precisely formulated multi-point safety criterion comparable to the one-point safety criterion is not available.

b(3)

TCG-DS-1 111
TCG-WAS-2 312

DOE, DTRA

(U) The outer steel shell contains the NEP and mounts it to the RB. This shell has an integral flange with a bolt circle that rests on the RB, mimicking the inert head (IH) design that is recommended by LMSC. The forward end of the outer steel layer is fastened to the AF&F mounting ring with a "telescoping joint". With the AF&F in the usual way fastened to the mounting ring in the usual way an "exclusion region" is formed. That is, an essentially continuous high temperature metal case encloses the NEP, detonator cables, and the AF&F. This exclusion region improves nuclear detonation safety by better shielding the detonator cables from abnormal electrical sources. To meet all the requirements for ENDS , an exclusion region must meet the following criteria: 1) the telescoping joint must provide positive electrical continuity between the capsule and the AF&F; 2) AF&F mounting scheme must be as strong as the safety capsule so that in an accident the AF&F cannot be severed from the NEP hence exposing the detonator cables.

5.1.4.2.6 (U) *Electrical Support Systems*

(U) Disassembly required to add use control and/or detonator enabling/safing systems would violate the "drop-in" concept of this candidate. This candidate configuration, with the exception of neutron generator and device detonator location, is identical to the W88 stockpile electrical systems configuration as shown in Figure 5.1-12. The compatibility of the MK5 fire set and the W76 series detonators was demonstrated as part of the Alternate Warhead Working Group Study. (Reference 7)

b(3)

(U) FIGURE 5.1-12

5.1.4.2.7 (U) *Gas System*

DOE, DTRA b(3)

(CRD) There are two options.

TCG, BTS 1 Chp 2 RG

b(3)

b(3) DTRA

SALAW76 310.26.1.1

TCG NAS 2 505.2.2 5.11

DOE, DTRA b(3)

b(3)
ibid
DOE, DTRA

LA5-6 is the Los Alamos baseline design for this study.

5.1.4.3.1 (U) *Primary Design*

DOE, DTRA b(3)

TCG-NAS-2 441 (+)

DOE, DTRA b(3)

TCG NAS 2 505.2.2 (H)

Safety calculations in the hypothetical third stage rocket motor detonation scenario have not yet been performed.

5.1.4.3.2 (U) *Secondary Options*

DOE, DTRA b(3)

TCG-WO-1 101.2

TCG-NAS-2 505.2.2 B01

DOE, DTRA b(3)

TCGNAS 2 505.2.2, 801, 5.11

DOE, DTRA b(3)

TCG-NAS-2 Multiple

b(3) DOE, DTRA

TCG NAS 2 505. 2. 2
823
(1)

b(3) DOE, DTRA

5.1.4.3.3 (U) *Nuclear System Engineering Design, LA5-4, 6, 7*

(U) **Primary Engineering**

DOE, DTRA b(3)

TCG-NAS-2
441

(See the Fire Resistant Pit discussions in Sections 5.1.5.2 and 10.1.2.2.2.)

DOE, DTRA b(3)

TCG WM 1
TE01.3

YCG-990
23433

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TCG-BTS-1
111

CG-SSP-1
263.1.1

TCG-WM-1
T.101.9

TCG-NAS.2
505.3.2

TCG BTS 1
111

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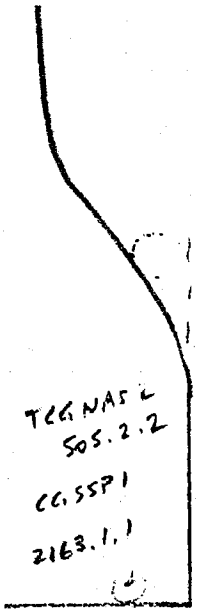

TCG NAS L
505.2.2
CG, SSP1
2163.1.1

(U) LA5-6, LA5-7, and LA5-4 each require a new isolator, forward mount, aft mount, and seal cover.

b(3)
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Both the Acorn and Terrazzo are described in detail in Section 5.1.5.3, the gas transfer section of this report.

(U) LA5-6 Secondary Engineering and Mounting

DOE, DTRA b(3)

TCG-NAS 5.11 S17

TCG NAS 5 S17

[redacted]

b(3)
DOE,
DTRA

(U) LA5-4 Engineering and Mounting

DOE,
DTRA b(3)

[redacted]

TCG-NAS-2
801
505.2.2

(U) Electrical Support Systems, LA5-4, -6, -7

b(3)
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(CFRD)

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DOE,
DTRA

[redacted] The remaining systems supporting detonator enabling/safing are identical to those described for

Nuclear Assembly LA5-1. The electrical support systems for these three candidates are detailed in Figures 5.1-13 and 5.1-14.

b(3) DOE DTRA

TCG-NAS 2 505.2.2

5.1.4.4.1 (U) *Primary Design*

DOE, DTRA b(3)

A version is available using the W76 pit. For reasons of performance, lower INRAD, and reliability due to newer manufacture, the W76 pit has been selected as baseline for candidates LA5-3 and LA5-9.

DOE DTRA b(3)

TCG-NAS-2 505.2.2 (+)

b(3)
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(U) FIGURE 5.1-13

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b(3)
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DTRA

(U) FIGURE 5.1-14

(

The IHE explosive model used in the studies has been developed to calculate many local and NTS tests. Zero yield experiments could be conducted to verify the conclusions of these calculational studies.

5.1.4.4.2 (U) *Secondary Design, LA5-3*

[redacted]

TCG WAS 2 823

[redacted] DOE DTRA 6(3)

5.1.4.4.3 (U) *Secondary Design, LA5-9*

DOE DTRA 6(3)

[redacted]

TCG WAS 2 801
505.2.2
5.11

DOE
DTRA

b(3)

TCI.NAS.2
550.2.2

TCG.NM1
T911.3

TCG.NHSZ
574

.GSSP1
163.1.1

5.1.4.4.5 (U) *Secondary Engineering, Mounting*

DOE b(3)

TCG NAS 2
517

5.1.4.4.6 (U) *Gas System*

TCG NAS 2
505.2.2
TCG BTS 1
3104.2

b(3)
DOE
DTRA

5.1.4.4.7 (U) *Electrical Support System, LA5-3*

(SFRD) Detonator enabling/safing and CAT-F PAL systems are included in the LA5-3 design.

DOE
DTRA b(3)

TCG UC 2
1143
3212

TCG WPNU 1
2530

TCG-UC-2 3145

5-47

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DOE OTRA b(3)

TCG UC 2
1143
3145

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DOE
DTRA b(3)

TCG-UC-2

TCG-NAS-2
504.1

(U) FIGURE 5.1-15

TCG UC 2

TCG-NAS 2
504.1

(U) FIGURE 5.1-16

DOE b(3)
DTRA

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 WAS 2 SOW.1

(U) FIGURE 5.1-17

DOE DTRA b(3)

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DOE DTRA b(3)
TCG-NAS 2 411

(U) Safing

DOE DTRA b(3)
TCG-NAS-2 243.2

(U) Warhead Engineering

TCG-NAS-2 243.2

Therefore, SALAD will not be used to further safe this primary.

DOE DTRA b(3)

(U) Mounting

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(U) The mounting scheme for this proposal is similar to the mounting scheme in the W88. The warhead is bolted directly to the aft mount in the RB. The forward mount is a foam wedge glued to the RB which allows "telescoping" of the RB/warhead assembly at different temperatures and provides lateral support for the assembly.

5.1.5 (U) SUBSYSTEM DESCRIPTIONS

5.1.5.1 (U) Slide Armed Laser Actuated Detonator (SALAD)

DOE DTRA b(3)

Alternatives to the SALAD device that would provide additional safety enhancements are being studied.

(U) An alternate SALAD type system could be developed, compatible with the Los Alamos NEP designs, and consistent with space allocations for detonator safing, that would provide the following enhancements:

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DOE DTRA b(3)

FIGURE 5.1-19
(U) TERRAZZO DEVICE

5.1.5.3.3 (U) *Acorn*

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DTRA b(3)

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FIGURE 5.1-20
(U) ACORN DEVICE

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(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.

[redacted]

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(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) All of these should have lifetimes at least as long as that of the existing W88/MK5; the limiting factor may be the remaining life of the AF&F.

(U) **Gas Transfer Systems**

(U) The tritium-portion of gas transfer systems are inherently limited-life components that must be replaced regularly throughout the lifetime of the warhead. Because we know in advance that these components must be replaced, we consider their replacement activities as part of our design of the system.

[redacted]

b(3) DOE DTRA

(U) **Other Limited-life Components**

(U) Some of our designs include PEX. PEX may have limited life either because it is corrosive and interacts with its container, or because its constituent materials segregate or degrade. Because of these potential concerns, we currently plan for the PEX reservoirs to be limited-life components that would be changed out in conjunction with the gas transfer system changeout.

5.2.8.4 (U) Reliability

b(3) DOE DTRA

[redacted]

[redacted]

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4. (U) What development problems can be foreseen that appear difficult to solve? Do any problems require development effort on a scale that is greater or less than normal?

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DTRA

5. (U) What special training, operational, or logistical problems are foreseen concerning the warhead that should be considered for Phase 3 development engineering?

(U) The inclusion of use control features will impact the Navy's current logistics and operations. Mounting of the all-Oy candidates on the missile will affect logistics.

6. (U) What, if any, additional experimental or theoretical investigation is required to establish feasibility?

(U) Beyond-one-point-safety analysis will not have been completed for all candidates during Phase 2. Selection of a candidate that has not been checked would mean additional theoretical and possibly experimental investigation would be required. A nuclear test would be required to establish the feasibility of candidate LL5-6.

7. (U) What is the technical evaluation and/or recommendation made by the DOE representatives concerning nuclear testing prior to weaponizing the device for stockpile?

(U) Except for candidate LA5-2, all of the candidates would normally require nuclear testing for their development. The laboratories do not agree on whether exceptions could be made under certain circumstances. See Section 12.3 for a

(U) Except for candidate LA5-2, all of the candidates would normally require nuclear testing for their development. The laboratories do not agree on whether exceptions could be made under certain circumstances. See Section 12.3 for a summary. Technical discussions are presented in Sections 5.1.2.2, 5.2.2.1.2, and 5.2.2.2.2.

8. (U) What possible technical or economic advantages or nuclear materials savings would accrue from reasonable warhead/weapon system tradeoffs and changes in the requirements stated in the authorization for the Phase 2 feasibility study such as use of "natural" versus specified yields, alternative warhead or limited life component lifetimes, tradeoff of physical parameters to achieve nuclear materials savings, etc.? What effects would these changes have on the orderly development of the delivery system?

b(3) DOE DTRA

9. (U) What is the quantity of nuclear materials required for the proposed device? Will the number of weapons desired present any predictable problems in providing the necessary nuclear materials?

This study will not select a particular device. The nuclear material needs vary over a large range.

b(3) DOE DTRA

Some candidates assume the availability of existing DoD assets. It is DOE policy to provide the quantity of nuclear material needed for warheads when the national leadership so directs and funds.

10. (U) If the stated time scales of Question 3 are to be met, what would be the estimated impact, if any, on other authorized DoD programs which would be concurrently supported by DOE.

(U) There are no known impacts on other authorized DoD programs concurrently supported by DOE, mainly because none are anticipated.

6. COMPATABILITY OF MK5A CANDIDATES W/WS

6. (U) COMPATIBILITY OF MK5A WARHEAD CANDIDATES WITH THE WEAPON SYSTEM

6.1 (U) INTRODUCTION

(U) In June of 1992, a MK5A Phase 2 (Design Feasibility) effort was kicked off using the groundrules of Table 6.1-1. As part of this effort LMSC 1) defined a design space within which the DOE laboratories could create various alternative warhead concepts and 2) assessed the feasibility and compatibility of these candidate concepts with the MK5 RB on the D5 missile system. The design space selected for this Phase 2 effort dealt with the reentry body (RB) total weight (i.e., aeroshell + warhead + AF&F + ... etc.) and the RB center of gravity (CG). Figure 6.1-1 shows the MK5A weight/CG design space. In providing the design space it was understood that design dependent analyses such as reentry body structural response would be delayed until candidate concepts had matured to the point where such analysis had meaning.

(U) The feasibility and compatibility assessments made by LMSC can be categorized in a couple of different ways. First, those analyses which could be performed independent of the specific warhead design such as boost phase loads, reentry aeroshell heating and general aerodynamic performance, were accomplished early in the Phase 2 program and were included in shaping the available "design space" mentioned above. Next, physical and functional interfaces were examined. Some of these assessments required specific design information (e.g., circuit designs and wiring diagrams), but most of the interface issues were covered by the program groundrules (see Table 6.1-1). Finally, analyses which required relatively detailed design information (e.g., aeroshell structural response) were performed on each candidate.

(U) Section 6.2 summarizes the analysis which produced the boundaries seen in Figure 6.1-1. Each of the boundaries represents limitations imposed by a component of the overall missile system. Section 6.2 addresses the principal limits imposed by the MK5 on D5.

TABLE 6.1-1

(U) PHASE 2 STUDY GUIDELINES AND GROUNDRULES

[redacted]

• **Prime Groundrule:** No changes to the Trident I or II Missile Systems except in the RBA. No change to missile/RBA physical and functional interfaces. Fire control software changes to accommodate a new RB ballistic coefficient (B) are allowed, but are yet to be determined. A new, unique electrical signal required into the RBA is not allowable. No new wires/connectors are allowed (DSSL-like hardware may require a unique signal box that could be attached to the release assembly).

• **Other Groundrules/Guidelines for the Phase 2 Study:**
- Identify and quantify a broad range of warhead alternatives.
- Need to keep breadth of study under control - no global license for change.
- The DOE will focus on a limited set of point designs each having a balance of desirable properties rather than a large number of different designs each of which optimizes a particular benefit.
- No change in missions (i.e., full target spectrum).
- Reductions in V-gamma map coverage may be considered/evaluated providing maximum range doesn't decrease.
- All candidates will incorporate modern safety features that significantly enhance system safety.
- IOC goal in the late 1990s
- System lifetimes of interest approach 60 years.
- Minimize need for underground tests (UGTs).

[redacted]

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[redacted] UNCLASSIFIED

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TABLE 6.1-1 (CONTINUED)

(U) PHASE 2 STUDY GUIDELINES AND GROUNDRULES

- A warhead candidate that may be deficient in a particular quality (e.g., vulnerability), may be retained in the candidate list for study purposes if its other qualities are particularly attractive (e.g., robustness).
- No change to planned SSBN or missile procurements and schedules, although RB downloading will probably occur. May need to be readdressed as new arms control agreements occur.
- Minimal changes to Interface Control Drawings (ICDs).
- No invalidation of MK4 and MK5 flight test data.

- For purposes of the study, a solution employing a new pit can be presented.
- Minimal changes to normal, abnormal and hostile environments.

- No changes to MK5 AF&F; MK4 AF&F changes may be investigated.
- If a new MK4A AF&F is proposed, its functionalization in fire control must be consistent with the MK4 or MK5 functionalization that currently exists.
- No mixing of RBAs on the same missile.
- C4 and D5 missiles are not allowed on the same boat.
- U.S. cannot produce new MK4 aeroshells but has potential to produce new MK5 aeroshells.
- No joint test requirement for DoD hardware is part of this Phase 2 study. Requests for DoD hardware to support DOE testing should be submitted to the Director, SSP.
- C4/D5 Technical Objectives and Guidelines (TOG) requirements related to safety, allowable materials, and abnormal environments apply to Phase 2 study (e.g., lithium batteries are not acceptable for use in submarines).

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FIGURE 6.1-1

(U) MK5A WEIGHT AND CENTER OF GRAVITY DESIGN SPACE

6.2 (U) MASS PROPERTY LIMITATIONS

(U) This section summarizes the MK5A RBA on D5 missile component limitations imposed on the design candidates. All phases of RBA and, as applicable, missile life (e.g., logistics and flight environments) were investigated in order to identify an appropriate design space. The list of phases included land based storage, stowage on the submarine, underwater launch, powered flight (ignition/staging events), post boost control system (PBCS), RB deployment and reentry (both normal and hostile). Each of the limiting boundaries shown in Figure 6.2-1 was identified and the limiting mechanism called out. The MK5A limits are as follows:

- Release assembly structural limit during first stage ignition
- Reentry body aerodynamic stability during reentry
- Heatshield/substrate temperature limits during reentry
- Maintain current MK5/D5 Interface Control Drawing (ICD) minimum weight limit

The rationale for each of these limitations as well as other investigations are summarized in the following sections.

6.2.1 (U) POWERED FLIGHT

(U) Several missile events were investigated during the early portion of Phase 2, that is, during the time the design space was defined. The impact of these events on RBA performance was assessed and limits drawn. The environments of concern included the following: 1) stowage shock event; 2) underwater launch; 3) first stage ignition and flight; 4) second stage ignition and flight; and 5) post boost flight and RB deployed. Third stage ignition and flight was not seen as a potential driving environment.

[redacted]

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FIGURE 6.2-1
(U) MK5A MASS PROPERTIES LIMITATIONS

be noted that missile body structural components were assessed and were found not to be design drivers and hence, did not limit the design space.

[redacted]

b(3) DOE DTRA

6.2.2 (U) SEPARATION MECHANICS

(U) During the design space definition process no limiting condition was identified for separation mechanics (deployment) which would further reduce the design space of Figure 6.2-1.

(U) Reentry body separation velocities and spin rates all varied as expected as weight and CG combinations were evaluated, but again no limiting condition was found.

6.2.3 (U) AERODYNAMICS

(U) Reentry Aerodynamics assessed the MK5 RB's ability to maintain basic stability as weight and CG were varied. Aerodynamically, there was no concern, and therefore no limitation, for the CG in the most forward possible position (i.e., towards the nosetip). The objective was to define the aft CG position limit for possible MK5A candidate designs, which still maintained a positive static margin and hence a stable RB for the current flight environments.

(U) The analysis concentrated on the upper-left (UL) null range deployment and the lower-left (LL) zero angle of attack deployments as the trajectories that would set the CG requirements. For null range deployment, minimum static margin

occurs during high altitude reentry, while for zero angle of attack minimum static margin occurs at low mach numbers at impact (as the mach number decreases the center of pressure moves forward toward the center of gravity). For MK5, the null range trajectory is aerodynamically more restrictive, but for the purposes of the Phase 2 study only zero angle of attack deployment was considered.

(U) The aerodynamic analysis employed a Monte Carlo procedure to probabilistically determine the static margin for each weight/CG configuration. Nine weight/CG configurations were analyzed to define the limits shown in Figure 6.2-1. For the MK5A candidates the stability limit was selected to be 0.5% static margin at LL. Due to the inherent uncertainties associated with extrapolating aerodynamic and thermodynamic performance and given the immaturity of the design candidates it was felt that the design laboratories should be encouraged to keep the CG as far forward in the RB as possible therefore a 1.0% static margin line was also drawn. The space in between these lines was the uncertainty area.

6.2.4 (U) THERMODYNAMICS

(U) One of the concerns that was investigated for both the MK4A and MK5A RB Phase 2 candidates was the heatshield and substrate temperature performance. Increasing the total RB weight will increase the RB ballistic coefficient and accordingly, the reentry velocities. The increased velocities will in turn increase the heat rates and potentially the total heating on the body (increased velocities will also reduce the down time, therefore a trade-off is made with heat rate and time in the atmosphere).

(U) Three separate regions in the aeroshell have temperature limitations which are used as limiting criteria. First, the temperature of the aluminum substrate; second, the temperature of the bond material between the substrate and the heatshield; and third, the heatshield temperature 50 mils from the bondline is monitored. For the MK5A RB, some additional weight can be accommodated before being limited by one of these three criteria. Several reentry velocity and gamma (V-γ) conditions were evaluated and limiting conditions were found at the upper left V-γ point. The thermodynamic limit in Figure 6.2-1, which is weight driven only, shows this limitation.

6.2.5 (U) ADDITIONAL LIMITATIONS ANALYSES

(U) In order to increase confidence in the calculated limitations and to insure that as many as possible of the design drivers had been investigated several other reentry body and missile body analyses were performed. None of the analyses described in this section limit the design space except the Interface Control Drawing (ICD) minimum weight limit, although other limits exist just "outside" of the limits shown in Figure 6.2-1.

(U) Interface Control Drawing

(U) During the Phase 2 program one of the goals or groundrules (see Table 6.1-1) has been to keep the candidate designs within the current "flight database". With this in mind a minimum total RB weight equal to the minimum weight allowed by the MK5 Physical Interface Control Drawing was adopted as a lower limit. Again, see Figure 6.2-1 for the location of this limitation on the weight/CG design space.

(U) MK5A Nosetip Erosion

(U) Performance of the MK5 Shape Stable Nosetip (SSNT) was evaluated at several critical V–γ points relative to the variations in reentry body weight and center of gravity. It was found that greater than 10% additional weight could be accommodated before the nosetip overhang would be used up and a limit imposed. It should be noted that the increased weight would result in an increased ballistic coefficient (higher reentry velocities) and that the stagnation pressure seen by the nosetips would be larger than current flight test experience.

(U) MK5A Nosetip Thermal Strains

(U) The MK5A SSNT analysis was performed to qualify this nosetip over the entire V–γ map for a 10% increase in reentry weight (CG location was not an issue). In this study, the finite element stress analysis results together with failure criteria based on stress and strain capability were used to evaluate the structural safety and margin calculations. The analytical results indicate positive margins for the parent material over the V–γ map but there are concerns with the core material.

(U) In order to resolve the concerns with the core, a possible failure mechanism which could result in nosetip failure was identified. This failure mechanism was a crack initiation in the core material, which propagates as a sharp radial crack and extends into the parent material.

(U) Fracture mechanics analysis was performed to evaluate the possibility of crack extension from the core into the parent material. The crack extension was located in the region of the nosetip that produced the highest magnitude and largest volume of tensile stresses in the parent material. The results of this study indicate that crack initiation in the core material due to core degradation would not result in crack extension into the parent material. Thus, there was adequate structural integrity for the MK5A SSNT with a 10% increase in RB weight reentry environments.

(U) MK5A Thruster Pad Stress

(U) With the increased weights being considered for candidate MK5A RBs, the resulting stress levels in the RB thruster pads were investigated. For the design space weight increases, thruster pad stresses remained below critical levels and therefore were not a limiting issue.

(U) MK5A Moments of Inertia Variations

(U) After reviewing many of the proposed candidate designs it was found that the moments of inertia (MOI) associated with the increased weight concepts were larger than anticipated. The increased MOIs were evaluated to see if any of the limiting conditions would be effected. It was found that little change resulted from the increased MOIs and therefore the design space remained the same.

(U) MK5A Deployment Separation and Bumping

(U) MK5 Phase 2 candidate RB nominals and variabilities for mass property extremes (variations in weight and center of gravity) for deployment/separation clearance were analyzed. Equipment section mass properties were modified to reflect a system-wide change and a worst case fourth drop was simulated. This was the worst case configuration because this drop is the last RB off with MK5 RBs

immediately adjacent on either side.

(U) For these conditions the probability of clearance (POC) for a maximum forward CG shift is 0.9994 and likewise, for a maximum weight shift the POC is 0.9999. Both of these results are acceptable. It should be noted that POC is more sensitive to forward shifts in CG.

(U) D5 Nose Fairing and Third Stage Motor Clearances

(U) An RB clearance analysis was made to see if the proposed Phase 2 weight/CG limits could cause any RB contact with the nose fairing (N/F) or third stage (T/S) motor during any stowage or boost phase events. All current tactical missile payloads (including LAE protected interfaces) were evaluated and were found to have no RB contact with the N/F or T/S motor. For Phase 2, a weight/CG upper limit was defined for allowable designs which was selected based on the reentry body release assembly structure limit. (See section 6.2.1). The largest RB motions for the "tactical" D5 missile payloads occurred during the first stage motor ignition transient. Motions during second stage motor ignition and athwartships stowage shock were smaller (although for some RBs the motions were only 8 to 12 percent less). The MK5 has a relatively large clearance of at least 3.86 inches towards the T/S motor, thus the evaluation was made using the first stage motor ignition event.

(U) For these conditions it was found that no contact was experienced with either the N/F or the T/S motor (this analysis covered 4 through 8 body configurations). Therefore, there should not be any contact concerns with the MK5A Phase 2 designs.

6.2.6 (U) MASS PROPERTIES SUMMARY

(U) The design space defined by the above mentioned limiting phenomena (shown in Figure 6.2-1) constituted the initial boundaries for the design laboratories. As noted on the figure, some areas in the weight/CG space were not investigated and therefore candidates which fell within these areas were assessed on a case by case basis. Figure 6.2-2 shows the location of all the MK5A candidate

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FIGURE 6.2-2
(U) MK5A CANDIDATE WEIGHTS AND CENTERS OF GRAVITY

designs. Candidate LA5-5 will require some additional work to remove some weight and to move its CG forward to obtain mass properties feasibility as it was outside of the acceptable design space. LA5-9 fell into the "evaluate case by case" design space. It was assessed and found to be acceptable. All other designs were in the appropriate design space.

6.3 (U) ELECTRICAL COMPATIBILITY

(U) This section describes the electrical compatibility assessments performed on the MK5A candidates. These assessments are divided into two sections. Section 6.3.1 describes the functional interface compatibility assessment which evaluates compatibility between the MK5A candidates and the D5 missile. Section 6.3.2 addresses compatibility between the MK5A RBA and the existing W88/MK5 normal, abnormal, and hostile electrical environments, all of which were incorporated into the WYY/MK5A STS. Descriptions of MK5A use control features and their associated impacts on the D5 missile system are provided in Section 10.

6.3.1 (U) FUNCTIONAL INTERFACE COMPATIBILITY ASSESSMENT

(U) The functional interface compatibility assessment was a top level evaluation which examined the functional interface requirements of each of the candidates except LA5-8. The information provided on this candidate was insufficient to conduct an assessment. Functional block diagrams were used for the evaluations because complete electrical system definition for any of the MK5A candidates has yet to be completed.

(U) The groundrule which governs physical and functional interface requirements between the MK5A RB and the D5 missile requires that no changes are to be made in the physical or functional interfaces which impact the D5 missile, except for software changes in fire control. Based on the data provided by the DOE agencies, no issues have been identified which result in the violation of this groundrule for any of the candidates evaluated. Consequently, all of the candidates are feasible from a functional interface standpoint.

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like the EMR environment, is mainly influenced by the shielding characteristics of the RB. Consequently, if similar grounding, bonding and shielding design attributes are implemented during the incorporation of additional electrical components as part of the MK5A program, achieving feasibility with regard to the lightning environment should not be a concern.

6.3.2.2 (U) Hostile Environment Assessment

(U) As with the normal and abnormal electrical environments, the hostile environments of an electrical nature were analyzed by design similarity with the MK5. Electromagnetic effects such as electromagnetic pulse (EMP) and hostile electro-magnetic radiation (EMR) are substantially mitigated by the shielding integrity of the RB. Since there are large margins associated with these environments and the grounding, bonding and shielding attributes associated with the MK5 aeroshell are unchanged, there are no issues associated with achieving feasibility for any candidate.

(U) All of the candidates are feasible with respect to system generated electromagnetic pulse (SGEMP) due to the large margins inherent in the MK5 design, and by implementing design features in additional components for the mitigation of SGEMP. Likewise, by implementing circuit hardening techniques that are similar to those incorporated in the MK5 design, all of the candidate electrical designs are feasible with respect to hardness against nuclear effects (x-rays, neutrons, etc.).

6.4 (U) INDIVIDUAL CANDIDATE STRUCTURAL ASSESSMENTS

(U) The approach taken to assess the structural feasibility of the individual Phase 2 candidate designs is illustrated in Figure 6.4-1. As shown, when the candidate designs were received, an initial screening occurred which evaluated whether the candidate designs fit within the weight and center of gravity (CG) design space described in section 6.2 (see Figure 6.2-2). Included in the screening was a check to see if an adequate set of analysis information was provided (i.e., candidate drawing, mass properties, mass distribution and stiffness). Then two sets of analyses were performed: one covering the candidate response to the normal reentry

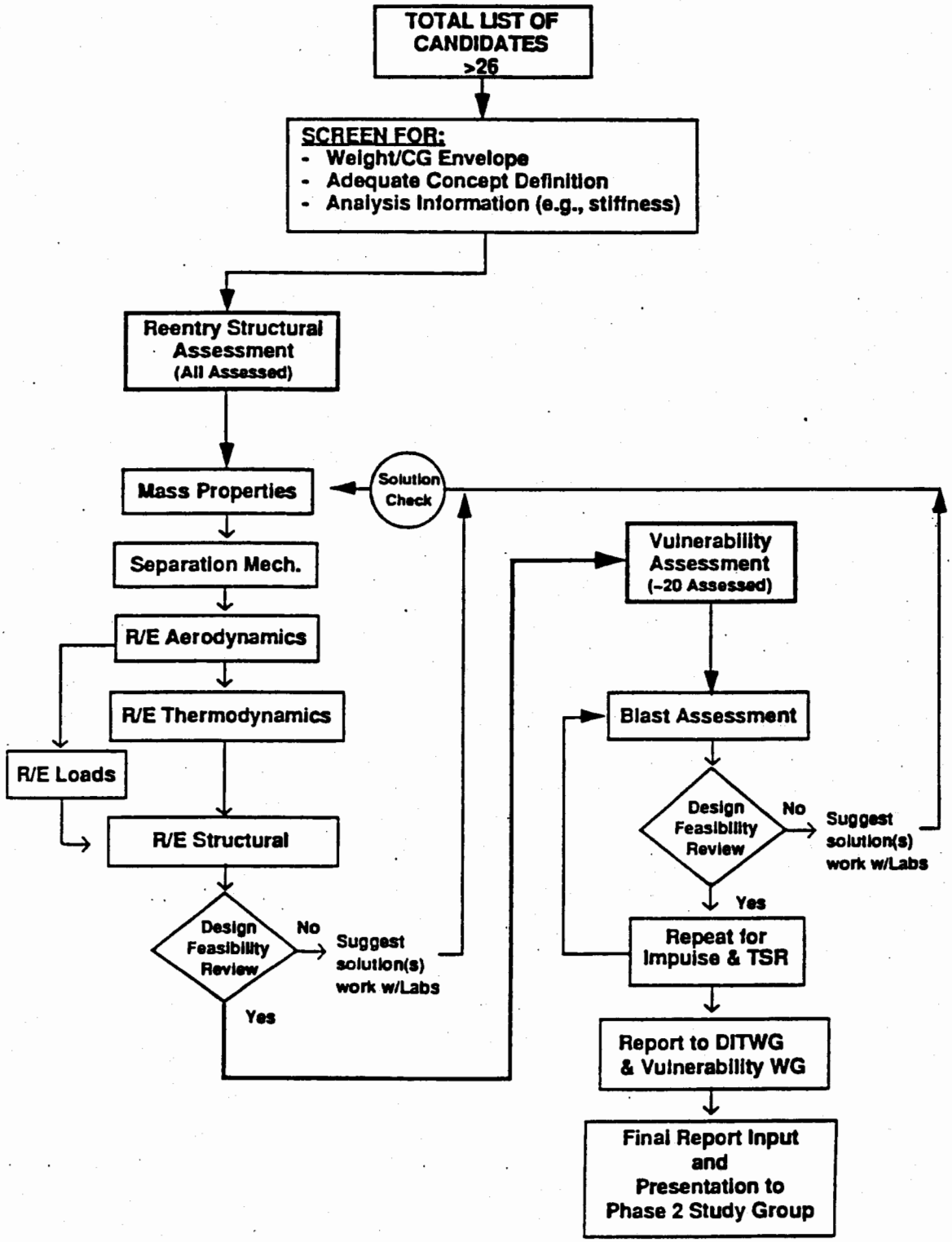

FIGURE 6.4-1 UNCLASSIFIED

(U) CONCEPT STRUCTURAL FEASIBILITY

environments of the MK5A STS and one covering the candidate response to the hostile environments of the MK5A STS. The normal reentry analysis was performed first because of its more rapid turn-around time. Feedback was then made to the design laboratories through the Design Integration Technical Working Group (DITWG). This feedback included both normal and hostile/vulnerability inputs.

(U) The approach taken by the normal and hostile/vulnerability reentry assessments is provided below. Both normal reentry and hostile reentry analyses produced statements of feasibility which are summarized in Table 6.4-1.

(U) Normal Reentry

(U) The approach utilized during the normal reentry assessment consisted of the information flow which is illustrated in Figure 6.4-1 which culminated with the structural assessment. Existing MK4 and MK5 ground and flight test data, extensive reentry body design experience, design similarity and finite element modeling of the candidates were the tools used for analysis. Table 6.4-2 shows the analytic approach taken which was a function of the candidate design data received and the similarity of the design to past experience.

(U) Two reentry body to NEP design areas were of most importance to the normal reentry assessment; the configuration of the forward warhead support (or wedge) and the aft warhead support (or mount). The method of attachment and the type of material utilized each contributed in determining the analysis approach chosen. All of the candidate designs had common components in these two areas which aided in completing all of the analysis associated with twenty six or more candidates within the time allotted.

(U) Hostile Environments Approach

(U) To expedite the feasibility assessment, LMSC made maximum use of the available MK4 and MK5 RB analytical models developed from the prior MK4 and MK5 programs. The two types of models used were the DYNA3D MK5 full-body model and the low-order MK5 (lumped spring and mass) full-body model. These

TABLE 6.4-1

(U) SUMMARY OF MK5A CANDIDATE

STRUCTURAL FEASIBILITY STATEMENTS

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Candidate	Feasibility	Comments
• LA5-1	• Feasible with Modification	• "IH" Type Aft W/H Mount Recommended
• LA5-2	• Feasible with Modification	• Fwd Wedge Position, Thickness
• LA5-3	• Feasible with Reservations	• Insufficient Data to Adequately Assess
• LA5-4	• Feasible with Modifications	• Aft Warhead Mount Design Considerations
• LA5-5	• Feasible with Reservations	• Insufficient Data to Adequately Assess
• LA5-6	• Feasible with Modifications	• Aft Warhead Mount Design Considerations
• LA5-7	• Feasible with Modification	• Aft Warhead Mount Design Considerations
• LA5-8	• Feasible with Reservations	• Insufficient Data to Adequately Assess • Feasibility Likely
• LA5-9	• Feasible with Modification	• Forward Sleeve Support Considerations
• LL5-1	• Feasible with Modifications	• Aft Warhead Mount Design Considerations
• LL5-2	• Feasible with Modification	• Aft Warhead Mount Design Considerations
• LL5-3A	• Feasible as Proposed	
• LL5-3B	• Feasible with Modifications	• Aft Warhead Mount Design Considerations
• LL5-4A	• Feasible as Proposed	
• LL5-4B	• Feasible with Reservations	• Insufficient Data to Adequately Assess • Seal Cover Considerations
• LL5-4C	• Feasible with Modification	• Aft Warhead Mount Design Considerations
• LL5-5	• Feasible with Reservations	• Insufficient Data to Adequately Assess
• LL5-6	• Feasible as Proposed	

TABLE 6.4-2

(U) ANALYSIS DATA AND APPROACH

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Approach Number	Type of DOE Design Definition Provided	Aeroshell Structural Analysis Approach
1	• Finite Element Model	• DYNA FEM Assessment (Full Body)
2	• Drawings, Mass Properties, Mass Distribution, Stiffness	• Local FEM, Lump Mass Model and/or Similarity of Design
3	• Drawings, Mass Properties	• Local FEM, Lump Mass Model, Similarity of Design and/or Engineering Judgement
4	• Sketch	• Similarity of Design and/or Engineering Judgement

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models were used as appropriate during the assessment considering: 1) the required degree of accuracy, 2) the possibility of establishing concept feasibility by analogy/similarity and 3) by inference from previous analysis and test experience.

(U) In order to accommodate the assessment of the large number of candidates that have been generated during the Phase 2 program, LMSC utilized similarity in the candidate's forward and aft mounting design features to assemble them into three evaluation groups for the MK5A candidates. This grouping was done to more efficiently analyze the many proposed candidates. As successive candidates from these groups were analyzed the performance / response of the aeroshell due to the common design feature was better understood and this understanding was then applied to subsequent candidate assessments. This increased understanding also applied to identifying the hostile environment which most stressed the candidates and their common design feature. Figures 6.4-2 through 6.4-4 illustrate the three candidate groups associated with the MK5A, each group having similar forward and aft mounts.

(U) MK5A Sleeved Forward Support Group

(U) For the MK5A Sleeved Forward Support group both the forward and aft support designs are significantly different from the W88/MK5 design. Therefore, a coupled full-body DYNA3D analysis was performed for a representative concept, in this case the LL5-1, to establish confidence in assessing this type of design. All three hostile environments, cold X-ray impulse, hot X-ray thermal structural response (TSR) and blast, were analyzed. The remaining concepts in this group were analyzed using a more simplified approach. For high frequency loading, (i.e., the cold X-ray impulse environment), where the response/influence is localized, local DYNA3D warhead support models were developed for the assessment. For low-frequency blast forcing, a coupled low-order model analysis was performed using the scaling approach illustrated in Figure 6.4-5. In the figure the reference, "R", was the LL5-1 DYNA3D blast response results. TSR responses were not assessed for the remaining designs because LL5-1 results indicated that TSR responses were reasonably within the bounds of the impulse and blast results.

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FIGURE 6.4-5 (U) SCALING ANALYSIS APPROACH FOR SLEEVED FORWARD SUPPORT GROUP

(U) The statements of feasibility were structured so as to cover the range of possible analytic conclusions, and are provided below:

1) the design is feasible as proposed or feasible with identified modifications,
2) the design is feasible with reservations,
3) the design is not feasible, or
4) insufficient data provided to adequately assess the candidate.

The second statement covers candidates where the identified design modification may not have a high level of confidence; where the candidate may require a reduction in the hostile environment in order to be feasible; or where a reduction in candidate weight / center of gravity may be required for candidate feasibility.

(U) Inherent in a Phase 2 study are uncertainties due to design maturity and uncertainties in modeling the performance of new design configurations. With this level of uncertainty, results which indicated yielding of component hardware were identified and design solutions recommended.

(U) Scope

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(U) Structural vulnerability assessments of the reentry body aeroshell included the following: 1) evaluation of the relative deflection of DoD/DOE components (i.e., AF&F to aeroshell substrate, NEP to seal cover, and NEP to aeroshell substrate), 2) evaluation of forward warhead support stresses, 3) evaluation of aft warhead

FIGURE 6.4.1-3

(U) FORWARD WARHEAD SUPPORT

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FIGURE 6.4.1-4

(U) AFT WARHEAD SUPPORT

(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

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(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).

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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.

[redacted]

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(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) LL5-1 Candidate Feasibility Statement

[redacted]

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6.4.2 (U) LL5-2 STRUCTURAL ASSESSMENT SUMMARY

6.4.2.1 (U) LL5-2 Design Description

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FIGURE 6.4.2-1
(U) LL5-2 FULL BODY PROFILE

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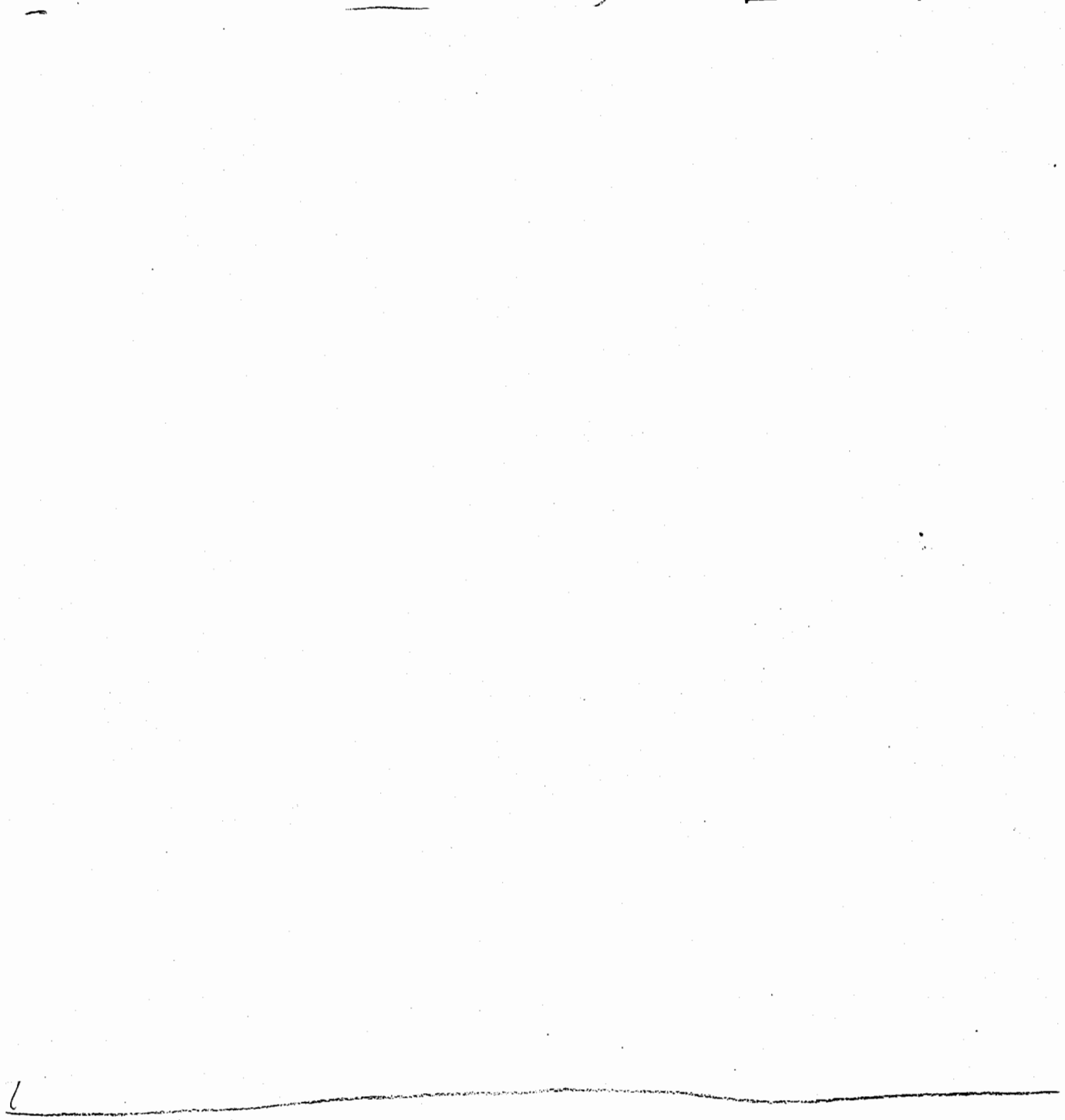

FIGURE 6.4.2-2

(U) NEP COMPARISON

FIGURE 6.4.2-3

(U) FORWARD WARHEAD SUPPORT

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FIGURE 6.4.2-4

(U) AFT WARHEAD SUPPORT

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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.

(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.

6.4.2.2 (U) LL5-2 Normal Reentry Structural Assessment

(U) Analysis Approach

(U) The LL5-2 aft warhead attachment design, the forward warhead support wedge, and the seal cover design are very similar to the LL5-1 design. (See Figure 6.4.2-1).

rates for each design were computed using the DIAL finite element code. The warhead model was constructed using LLNL supplied stiffness and mass distribution data. The LLNL data showed that the largest difference was in the stiffness of the forward segment of the warhead (forward of station 31) where the LL5-2 stiffness can be as low as 1/2 that of LL5-1. The results showed, however, that this difference did not cause significant changes in critical responses (deflections and stresses). As such, the only area which experienced yielding was the aft warhead mount flange on the aeroshell. Modifications to the aft warhead mount on the NEP would be required to eliminate this condition.

6.4.2.4 (U) LL5-2 Candidate Feasibility Statement

[redacted]

b(3) DOE DTRA

6.4.3 (U) LL5-3a STRUCTURAL ASSESSMENT SUMMARY

6.4.3.1 (U) LL5-3a Design Description

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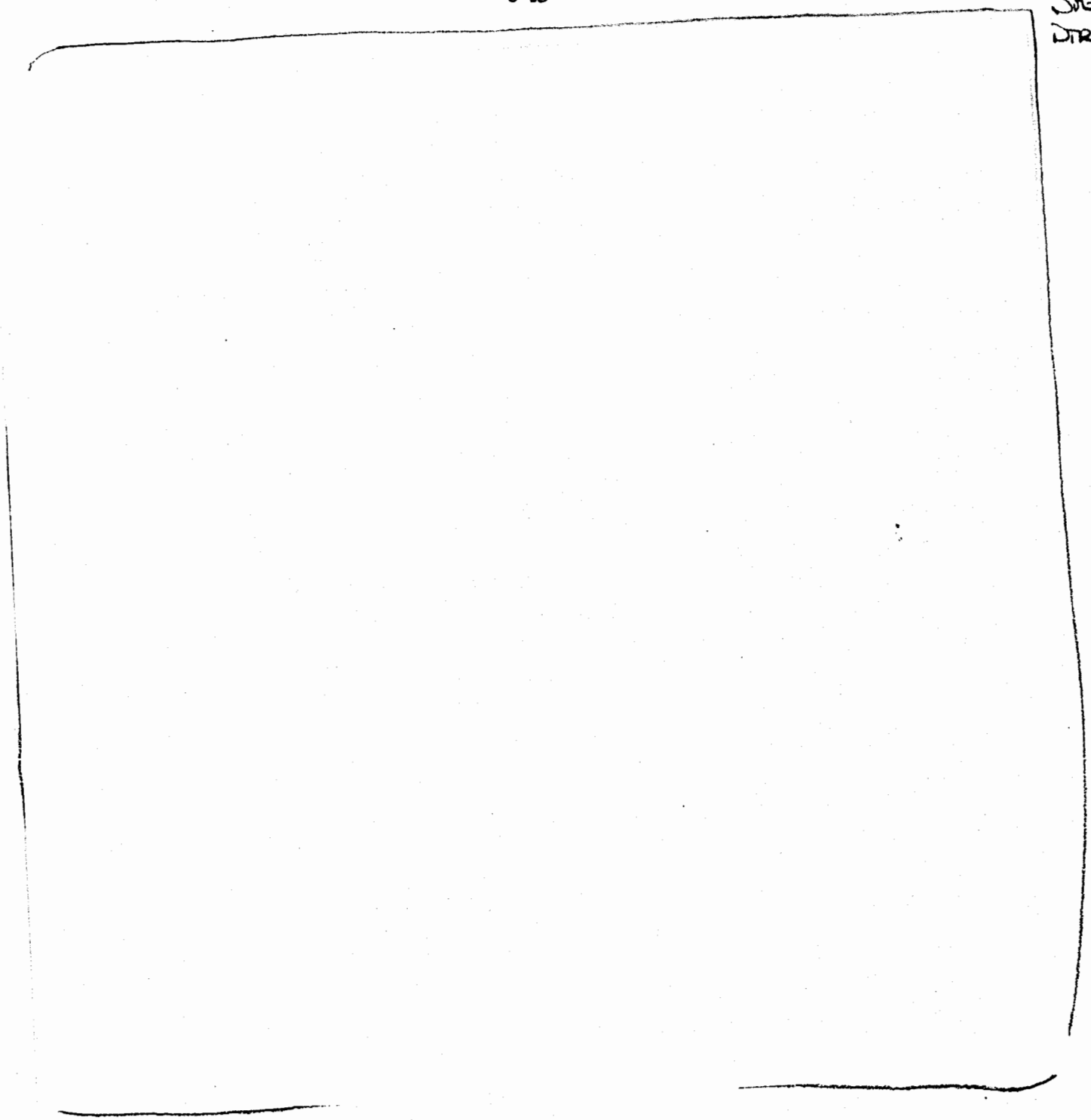

FIGURE 6.4.3-2

(U) NEP COMPARISON

FIGURE 6.4.3-4

(U) AFT WARHEAD SUPPORT

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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.

(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.

6.4.3.2 (U) LL5-3a Normal Reentry Structural Assessment

(U) Analysis Approach

(U) The approach used to assess the LL5-3a concept was to compare the design attributes of the forward wedge support area and the aft warhead support to designs that have already been assessed. (See Figure 6.4.3-1). The LL5-3a concept has an aft warhead support design that is similar to the LA5-6 design but with a thicker attachment flange, and a forward warhead support wedge that is structurally the same as the LL5-1 wedge. Both the LL5-1 and LA5-6 designs were extensively analyzed by finite element models. Since the aft warhead support and wedge area were the same or similar to the above mentioned designs, an engineering judgment was made as to the feasibility of the LL5-3a design. The seal cover has a

double curved design similar to the LL5-1 and was assessed based on that design. (See Figure 6.4.3-1). The warhead attachment, the wedge, and the seal cover designs were assessed for the three critical MK5 V–γ trajectories (upper middle-UM, upper left-UL, and upper right-UR) by comparison.

(U) Assessment Results

(U) The assessment of the LL5-3a aft warhead support, the forward wedge support area and the seal cover has margins equal to or greater than the W88/MK5 design based on engineering judgment.

6.4.3.3 (U) LL5-3a Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

(U) The candidate utilizes a foam sleeve similar to that used in the LL5-1 design and employs a bond material similar to that of LL5-1 as well. These configurations were assessed as feasible based on MK5 and LLNL UGT test experience.

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(U) Structural Vulnerability Assessment

(U) For the LL5-3a the high-frequency response effects were only investigated for the substrate stress response in the vicinity of the aft support under side-on impulse loading. This approach was taken because evaluation of a similar design (LL5-1) had indicated that the impulse loading imposed the largest stress on the candidate.

(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 allowable (i.e., yield strengths).

(U) With regard to low-frequency responses, only blast loading was analyzed since it had been identified as imposing larger stresses than cold or 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 is the low-order full-body model dynamic analysis. The required warhead forward and aft support stiffness data were determined from separate DIAL finite element analyses. The required warhead spring and mass constants were calculated using the stiffness and mass distribution information supplied from LLNL.

(U) The low-order blast analysis provided the general stress, internal forces/ moments and deflection responses. However, the local stresses (including shell bending effects) at the new warhead support junctions were not calculated. These responses were calculated using the DIAL finite element local support models where the boundary loads were the internal forces and moments obtained from the low-order analysis.

(U) The results showed that the most critical responses occurred in the vicinity of the aft warhead support (Figure 6.4.3-4). The highest stress, 42 ksi, occurred at the substrate inside surface located at the forward edge of the aft support on the hit side. This stress was below the static material (aluminum) yield strength of 49 ksi, at 200° F and was therefore assessed as acceptable.

(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 was most critical similar to LL5-1. The potential for impact between the chimney and the aeroshell can be eliminated by increasing the gap between the two components. This was accomplished for the LL5-1 design, and has now been accomplished for the LL5-3a design.

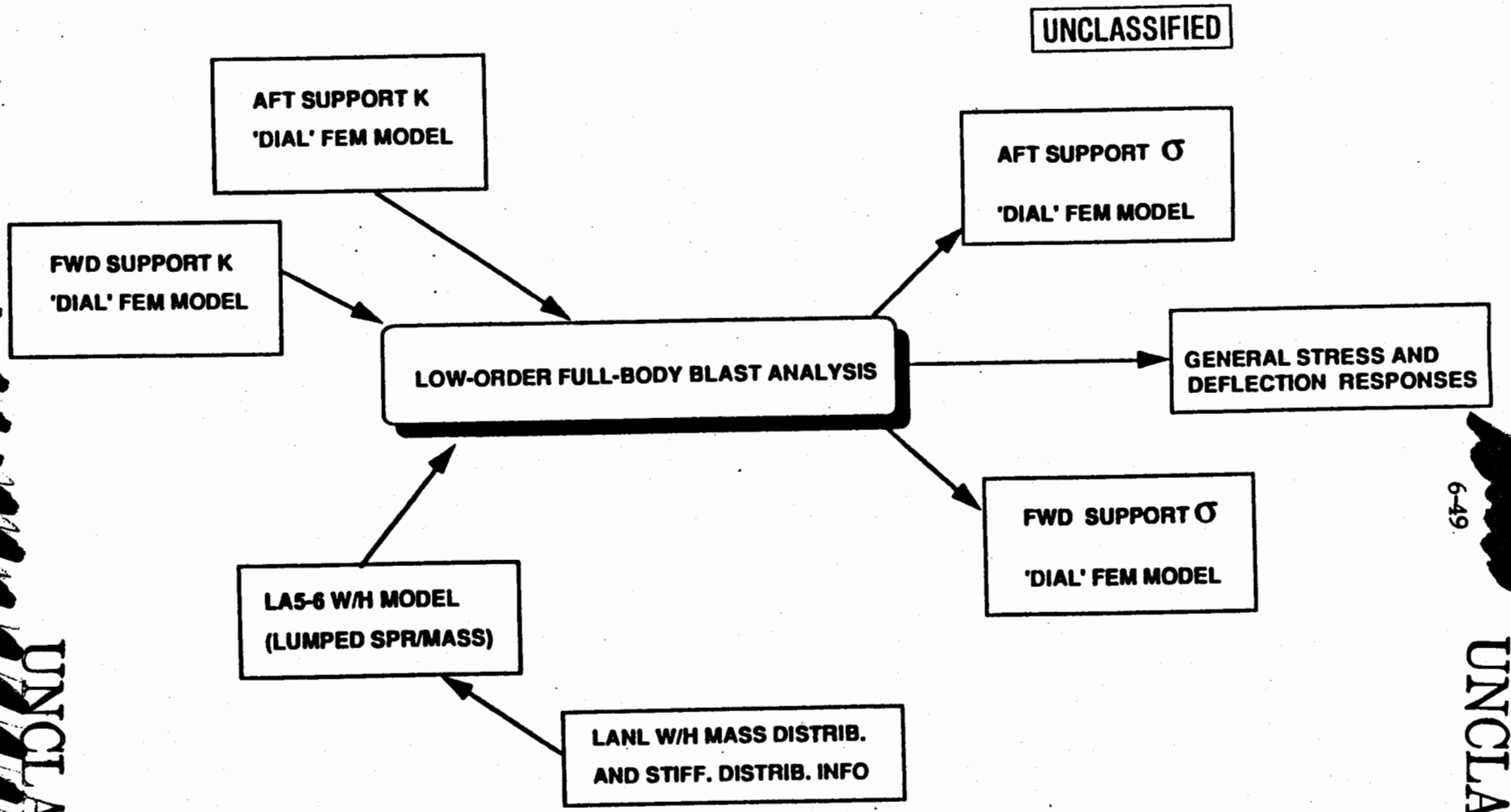

FIGURE 6.4.3-5

(U) BLAST ANALYSIS APPROACH

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6.4.3.4 (U) LL5-3a Candidate Feasibility Statement

(U) Analysis of the LL5-3a candidate was accomplished with the following conclusion: the LL5-3a candidate design is feasible. [redacted]

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6.4.4 (U) LL5-3b STRUCTURAL ASSESSMENT SUMMARY

6.4.4.1 (U) LL5-3b Design Description

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

FIGURE 6.4.4-1
(U) LL5-3b FULL BODY PROFILE

b(3)
DOE
DTRA

FIGURE 6.4.4-2

(U) NEP COMPARISON

UNCLASSIFIED DOE 6(3)

FIGURE 6.4.4-3

(U) FORWARD WARHEAD SUPPORT

UNCLASSIFIED

SECRET RESTRICTED DATA

UNCLASSIFIED

b(3)
DOE

FIGURE 6.4.4-4

(U) AFT WARHEAD SUPPORT

UNCLASSIFIED

W88/MK5. Candidate mass properties (RB weight and CG location) are shown in Figure 6.2-2.

(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.

6.4.4.2 (U) LL5-3b Normal Reentry Structural Assessment

(U) Analysis Approach

(U) The approach used to assess the LL5-3b concept was to compare the design attributes of the forward wedge support area and the aft warhead support to designs that have already been assessed. (See Figure 6.4.4-1). The LL5-3b concept had an aft warhead support design that is similar to the LA5-6 design, and a forward warhead support wedge that is similar to the LL5-1 design. Both of the above mentioned designs were extensively analyzed by finite element models. Since these two pieces of structure were similar to the above mentioned designs, an engineering judgment was made as to the feasibility of the design. The seal cover has a double curved design similar to the LL5-1 design and was assessed based on that design. (See Figure 6.4.4-1). The warhead attachment, the wedge, and the seal cover designs were assessed for the three critical MK5 V–γ trajectories (upper middle-UM, upper left-UL, and upper right-UR) by comparison.

(U) Assessment Results

(U) The assessment of the LL5-3b aft warhead support, the forward wedge support area and the seal cover has margins equal to or greater than the W88/MK5 design based on engineering judgment.

6.4.4.3 (U) LL5-3b Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

(U) The LL5-3b design has a new foam sleeve design with a bond similar to that of candidate LL5-1 which was assessed to be feasible based on MK5 and MK21/W87 UGT experience.

6(3)
DOE
DTRA

(U) Structural Vulnerability Assessment

(U) For high-frequency responses only the substrate stress response in the vicinity of the aft warhead mount, under side-on impulse loading was examined because evaluations made on similar designs (LL5-1 and LL5-3a) have indicated that this condition produces the maximum stress.

(U) In addition, because of their design similarities the high frequency response of LL5-3b was evaluated as being bounded by the responses of LL5-3a and LL5-1 (Figure 6.4.4-2). Therefore, since the high frequency stresses for both LL5-3a and LL5-1 were below material yield limits, the LL5-3b candidate was also expected to have positive high frequency response margin.

(U) Relative to low-frequency responses only the blast loading was analyzed since it is more critical 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.

6(3)
DOE
DTRA

UNCLASSIFIED

b(3) DOE DTRA

6.4.4.4 (U) LL5-3b Candidate Feasibility Statement

b(3) DOE DTRA

6.4.5 (U) LL5-4a STRUCTURAL ASSESSMENT SUMMARY

6.4.5.1 (U) LL5-4a Design Description

b(3) DOE DTRA

b(3) DOE DTRA

DoE DTRA

b(3)

UNCLASSIFIED

FIGURE 6.4.5-2

(U) NEP COMPARISON

UNCLASSIFIED

FIGURE 6.4.5-3

(U) FORWARD WARHEAD SUPPORT

UNCLASSIFIED

UNCLASSIFIED

b(3)
DOE

FIGURE 6.4.5-4

(U) AFT WARHEAD SUPPORT

UNCLASSIFIED

[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–γ 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) LL5-4a Hostile Reentry Structural Assessment

(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) Material Vulnerability Assessment

(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) Structural Vulnerability Assessment

(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

b(3)
DOE
DTRA

FIGURE 6.4.6-1
(U) LL5-4b FULL BODY PROFILE

UNCLASSIFIED

DOE
DTRA 6(3)

(U) NEP COMPARISON

UNCLASSIFIED

UNCLASSIFIED

b(3) 50

FIGURE 6.4.6-3

(U) FORWARD WARHEAD SUPPORT

UNCLASSIFIED

UNCLASSIFIED

L(3) DOE

FIGURE 6.4.6-4

(U) AFT WARHEAD SUPPORT

UNCLASSIFIED

UNCLASSIFIED

b(3) DOE DTRA

] Candidate mass properties (RB weight and CG location) are shown in Figure 6.2-2.

(U) This design provides compatibility with the DoD hardware including the AF&F. The proposed CAT-F PAL use control capability appears to be implementable with existing DoD hardware, although compatibility with all missile functional interfaces is in doubt. The concept has good aerodynamic stability margins.

6.4.6.2 (U) LL5-4b Normal Reentry Structural Assessment

(U) Analysis Approach

(U) The approach used to assess the LL5-4b concept was predicated on the design attributes of the forward warhead support wedge and the aft warhead support. (See Figure 6.4.6-1). The LL5-4b concept had an aft warhead support design that is similar to the MK5 IH design, and a forward warhead support wedge that is similar to the MK5 wedge design. Since the aft warhead support structure and wedge area are 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 differences in the stresses between the MK5 tactical and the MK5 IH designs. This design concept has a sealed warhead and not a seal cover as does the tactical MK5. The warhead case was not assessed for the pressure environment because of the lack of detail. (See Figure 6.4.6-1). The warhead attachment, the wedge, and the seal area designs were assessed for the three critical MK5 V–γ trajectories (upper middle-UM, upper left-UL, and upper right-UR).

UNCLASSIFIED

(U) Assessment Results

(U) The assessment of the LL5-4b aft warhead support design reflected margins equal to or greater than the W88/MK5 design. The wedge concept has positive margins of safety.

6.4.6.3 (U) LL5-4b Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

The LL5-4b aft and forward warhead supports are similar to the W88/MK5 in design and location (see Figure 6.4.6-1).

b(3) DOE DTRA

(U) Structural Vulnerability Assessment

(U) Since the LL5-4b aft and forward support were similar in design and position to W88/MK5, the high-frequency responses in the vicinity of these supports was expected to be acceptable.

(U) Low-frequency responses for the LL5-4b design were likewise examined without NEP mass distribution and dynamic properties. Since the LL5-4b NEP was considerably longer (extending near to the aft closure) (see Figure 6.4.6-1), its dynamic interaction with the aeroshell was expected to be somewhat different from the W88/MK5 even though the forward and aft support designs were similar. Since no stiffness and mass distribution information for the LL5-4b warhead was available to carry out a dynamic interaction assessment of the aeroshell with the warhead, no definitive conclusions can be reached at this time.

6.4.6.4 (U) LL5-4b Candidate Feasibility Statement

(U) Analysis of the LL5-4b candidate design was accomplished utilizing a conceptual drawing and mass property information. This constitutes less information than has been received for many of the other candidates and as such, has larger uncertainties associated with the assessment conclusions. With these caveats in mind the LL5-4b design was assessed to be feasible with reservations due to the need for NEP dynamic property information. The dynamic interaction of the aeroshell with a longer warhead is of most concern. In addition, the aft warhead case structure will need to be designed to withstand the launch tube pressure environments if this design is pursued.

6.4.7 (U) LL5-4c STRUCTURAL ASSESSMENT SUMMARY

6.4.7.1 (U) LL5-4c Description

b(3) DOE DTRA

(U) The NEP physical shape is identical to LL5-4a but its weight and CG have changed reflecting its increased weight and yield. Because it is identical in shape to LL5-4a the AF&F support, forward and aft warhead supports, and seal cover are identical.

b(3) DOE DTRA

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.

UNCLASSIFIED

FIGURE 6.4.7-1

(U) LL5-4a AND LL5-4c FULL BODY PROFILE

UNCLASSIFIED

DOE
DTRA 6/3

UNCLASSIFIED

FIGURE 6.4.7-2

(U) NEP COMPARISON

UNCLASSIFIED

UNCLASSIFIED

DOE b(3)

FIGURE 6.4.7-3

(U) FORWARD WARHEAD SUPPORT

UNCLASSIFIED

UNCLASSIFIED

DOE b(3)

FIGURE 6.4.7-4

(U) AFT WARHEAD SUPPORT

UNCLASSIFIED

(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.

6.4.7.2 (U) LL5-4c Normal Reentry Structural Assessment

(U) Analysis Approach

(U) The approach used to assess the LL5-4c concept was predicated on the design attributes of the forward warhead support wedge and the aft warhead support. (See Figure 6.4.7-1). This design is very similar to LL5-4a except the weight is 10% greater and the center of gravity is more forward. The LL5-4c 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 in stresses 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 6.4.7-1). The warhead attachment, the wedge, and the seal cover designs were assessed for the three critical MK5 V–γ trajectories (upper middle-UM, upper left-UL, and upper right-UR).

(U) Assessment Results

(U) The assessment of the LL5-4c aft warhead support design reflected margins slightly more negative for the aft warhead flange tapers 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.

6.4.7.3 (U) LL5-4c Hostile Reentry Structural Assessment

(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) Material Vulnerability Assessment

b(3)
DOE
DTRA

(U) Structural Vulnerability Assessment

(U) High-frequency responses for the LL5-4c candidate were investigated for side-on impulse loading only. And only the substrate stress response in the vicinity of the aft support under this side-on impulse loading was examined because evaluation of a similar design (LL5-1) indicated that the impulse loading imposed the largest stress on the 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) Regarding low-frequency responses, only blast loading was analyzed since it was found to be more critical 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 is 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. The LL5-4c stresses were higher than those of a similar design, LL5-4a (See Section 6.4.5) which had a lighter NEP and a more aft located CG. The stresses at the aft support region were well below yielding due to the strong "wishbone" support design. The DOE/DoD component relative deflection responses pose no concern with the current designs.

6.4.7.4 (U) LL5-4c Candidate Feasibility Statement

(U) Based on the current design information and the assessments performed, the LL5-4c concept is structurally feasible with potential modifications to the aft mount. The stresses in the aft warhead flange tapers should be examined more closely if this design is pursued.

6.4.8 (U) LL5-5 STRUCTURAL ASSESSMENT SUMMARY

6.4.8.1 (U) Design Description

b(3)
DOE
DTRA

(U) The AF&F mounting ring remains basically similar to the W88/MK5. The aft warhead support design is a two-piece IH type attachment, i.e. in-line, direct attachment. (See Figure 6.4.8-4). The NEP length and axial position has resulted in the need for a double curvature seal cover (Figure 6.4.8-1).

b(3)
DOE
DTRA

b(3)

DOE
DTRA

FIGURE 6.4.8-1

(U) LL5-5 FULL BODY PROFILE

b(3)
DOE
DTRA

FIGURE 6.4.8-2

(U) NEP COMPARISON

FIGURE 6.4.8-3

(U) FORWARD WARHEAD SUPPORT

b(3)
DOE

FIGURE 6.4.8-4

(U) AFT WARHEAD SUPPORT

b/3 DOE DTRA

Candidate mass properties (RB weight and CG location) are shown in Figure 6.2-2.

b(3) DOE DTRA

This candidate may violate a number of Phase 2 Study groundrules which could have far reaching impacts on the missile physical and functional interfaces. Further evaluation will be required to quantify all of the potential system impacts.

6.4.8.2 (U) LL5-5 Normal Reentry Structural Assessment

(U) Analysis Approach

(U) The approach used to assess the LL5-5 concept was predicated on the design attributes of the forward warhead support wedge and the aft warhead support. (See Figure 6.4.8-1). The LL5-5 concept has an aft warhead support design that is similar to the LL5-1 design, and a forward warhead support wedge that is similar to the MK5 wedge. The FE results from LL5-1 were used to assess the aft warhead support flange, then 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 differences in the stresses. Since the wedge support structure is similar to the MK5 tactical design, the MK5 capability curves were used to determine the feasibility of the design. The seal cover has a double curved design similar to the LL5-1 and was assessed based on that design. (See Figure 6.4.8-1). The warhead attachment, the wedge, and the seal area designs were assessed for the three critical MK5 V–γ trajectories (upper middle-UM, upper left-UL, and upper right-UR).

(U) Assessment Results

(U) The assessment of the LL5-5 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.

6.4.8.3 (U) LL5-5 Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

[redacted]

b(3)
DOE
DTRA

(U) Structural Vulnerability Assessment

(U) Since no information was available describing the warhead mass distribution and stiffness properties, no definitive structural response analysis could be made. The adequacy of the design was assessed using information from design layout drawings.

(U) As mentioned above the location and configuration of the forward and aft warhead supports in the LL5-5 were similar to those in the W88/MK5. Given this similarity a previously completed sensitivity study of the W88/MK5 was used to estimate the LL5-5 dynamic response. The study indicated that the warhead stiffness characteristics could vary without adversely affecting the structural survivability margins for the aeroshell. Thus, while additional analysis must be performed for a definitive assessment, the LL5-5 candidate design feasibility appears to be good.

6.4.8.4 (U) LL5-5 Candidate Feasibility Statement

(U) Analysis of the LL5-5 candidate design was accomplished utilizing a conceptual drawing and mass property information. This constitutes less information than has been received for many of the other candidates and as such, has larger uncertainties associated with the assessment conclusions. With these caveats in mind the LL5-5 design was assessed to be feasible with possible modifications due to the need for dynamic property information. However, it should be noted that the design appears to have a high probability of feasibility should further development be pursued.

6.4.9 (U) LL5-6 STRUCTURAL ASSESSMENT SUMMARY

6.4.9.1 (U) LL5-6 Design Description

[redacted]

b(3) DOE DTR

UNCLASSIFIED

b(3)
DOE
DTRA

FIGURE 6.4.9-1
(U) L15-6 FULL BODY PROFILE

UNCLASSIFIED

b(3)
DOE
DTR

FIGURE 6.4.9-2

(U) NEP COMPARISON

FIGURE 6.4.9-4

(U) AFT WARHEAD SUPPORT

6.4.10 (U) LA5-1 STRUCTURAL ASSESSMENT SUMMARY

6.4.10.1 (U) LA5-1 Design Description

b(3) DOE DTRA

(U) The NEP is very similar in external size and shape to the W88/MK5 (Figure 6.4.10-2). The AF&F mount and forward warhead supports (wedges) remain nearly identical to the W88/MK5 (Figure 6.4.10-3).

DOE DTRA b(3)

b(3) DTRA

(U) This design is very similar to the W88/MK5 and provides compatibility with the DoD hardware. The proposed CAT-E PAL use control capability, if implemented, is feasible and the concept is compatible with all the missile physical and functional interfaces. The concept has good aerodynamic stability margins.

6.4.10.2 (U) LA5-1 Normal Reentry Structural Assessment

(U) Analysis Approach

(U) The approach used to assess the LA5-1 concept was predicated on the design attributes of the forward warhead support wedge and the aft warhead support. (See Figure 6.4.10-1). The initial LA5-1 concept had an aft warhead support design with a titanium ring that traps the nub of the warhead against the aeroshell warhead flange in the same manner as the MK5 tactical design, and a forward warhead

b(3)
DOE
DTRA

FIGURE 6.4.10-1
(U) LA5-1 FULL BODY PROFILE

L(3)
DOE
DTRA

FIGURE 6.4.10-2

(U) NEP COMPARISON

DoE
DTRA
b(3)

FIGURE 6.4.10-3

(U) FORWARD WARHEAD SUPPORT

b(3)
DOE
DTRA

FIGURE 6.4.10-4

(U) AFT WARHEAD SUPPORT

support wedge which is the same size and is located in the same area as the 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. The MK5 aft warhead support is critical for stress in the both the forward and aft tapers and the forward warhead support wedge area is critical for both stress and buckling in the wedge aeroshell bay. The seal cover design is unchanged from tactical and is therefore good by inspection. (See Figure 6.4.10-1). The warhead attachment, the wedge, and the seal cover designs were assessed for the three critical MK5 V–γ trajectories (upper middle-UM, upper left-UL, and upper right-UR).

(U) Assessment Results

(U) The initial assessment of the LA5-1 design reflected positive margins with the exception of the aeroshell near the aft warhead support flange. In order to achieve a feasible design it was suggested that the attachment of the warhead to the aeroshell be modified to reflect a MK5 IH design concept, i.e., a direct attachment of the warhead to the aeroshell by bolts as opposed to the nub/ring concept. A parametric study of the MK5 tactical nub concept verses the MK5 IH bolted concept established a set of knock-down factors that were used on this assessment. This concept change produced a margin equal to the MK5 tactical margin for the warhead support flange.

6.4.10.3 (U) LA5-1 Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

b(3) DOE DTRA

Therefore, no material vulnerability concerns are expected.

(U) Structural Vulnerability Assessment

(U) Approach

(U) The structural assessment for the LA5-1 candidate focused on assessing the impact of the new forward NEP design on the critical vulnerability structural responses. This candidate has the same forward and aft warhead mounts and aft NEP design as the W88/MK5 (see Figure 6.4.10-1).

b(3)
DOE

The warhead support and much of the RB model were, again, not modified because they remained the same as for the W88/MK5.

(U) The high-frequency responses for the LA5-1 candidate are expected to remain essentially the same as for the W88/MK5 because of the above mentioned similarity in aeroshell and warhead support designs.

(U) Assessment Results

(U) The principle structural responses of peak stress, interface loads and component deflection did increase in the LA5-1 candidate, but all remained within the allowable limits for the blast, TSR and impulse forcings. Both low and high frequency responses for the critical aeroshell region as assessed by DYNA3D blast, TSR and impulse analyses indicate that these small increases in low-frequency responses could be accommodated in the LA5-1 design.

6.4.10.4 (U) LA5-1 Candidate Feasibility Statement

(U) The LA5-1 concept is structurally feasible with the above suggested modification to the aft warhead support flange/aeroshell attachment.

6.4.11 (U) LA5-2 STRUCTURAL ASSESSMENT SUMMARY

6.4.11.1 (U) LA5-2 Design Description

b(3) DOE DTRA

(U) The NEP is similar in external shape to the W88/MK5 (See Figure 6.4.11-2). The AF&F mount remains nearly identical to the W88/MK5 while the forward warhead supports (wedges) have been modified to accommodate the larger forward end of the NEP (See Figure 6.4.11-3). The aft warhead support proposed used an IH direct mount design. This design provides compatibility with DoD hardware.

6.4.11.2 (U) LA5-2 Normal Reentry Structural Assessment

(U) The LA5-2 design was assessed by engineering judgment based on limited details of a 8-1/2 x 11 layout shown in the 11-12 August 1993 Phase 2 Study Group. No aft warhead support was defined in this layout. The concept, as proposed, was approximately 100 pounds underweight which allowed for a large degree of flexibility in designing an acceptable aft warhead support. In addition, the forward warhead wedges appeared to be further aft in the forward bay than other designs, therefore buckling could be an issue.

(U) Subsequent to the completion of the normal reentry assessment an updated design was received and briefly reviewed.

b(3) DOE

There remains a concern that the forward warhead wedges may be positioned too far aft to provide adequate support to the forward bay. Additional analysis would be required to provide a more definitive conclusion, although a solution seems probable.

b(3)
DOE
DTRA

FIGURE 6.4.11-3
(U) LA5-2 FORWARD WARHEAD SUPPORT

6.4.11.3 (U) LA5-2 Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

b(3)
DOE
DTRA

If this candidate is pursued there appear to be design options available to mitigate this effect.

(U) Structural Vulnerability Assessment

(U) The LA5-2 candidate had many design features which were yet to be defined at the time of the assessment. With the design information available the following potential issues were identified which would need additional review and analysis. One, a forward warhead support and/or stiffener design would be required. (The updated design did not include a stiffener). The addition of a stiffener could impact the design of the capsule outer shell or could force the capsule to be shifted aft in order to accommodate these components. There appears to be sufficient design flexibility to accommodate some modification. It is believed that this would not be difficult to achieve either.

b(3)
DOE

6.4.11.4 (U) LA5-2 Candidate Feasibility Statement

(U) Analysis of the LA5-2 candidate design was accomplished utilizing a conceptual drawing and general mass property information only. While this may be closer to a "true" Phase 2 type of assessment it is still considerably less information than has been received for many of the other candidates and hence, has much larger uncertainties associated with the assessment conclusions. With these caveats in mind, the LA5-2 design was assessed to be feasible with modifications to the forward warhead support wedge.

b(3)
DOE

6.4.12 (U) LA5-3 STRUCTURAL ASSESSMENT SUMMARY

6.4.12.1 (U) LA5-3 Design Description

b(3) DOE DTRA

The AF&F mount is nearly identical to the W88/MK5 design

b(3) DOE DTRA

(U) This concept utilizes a CAT-F PAL use control.

b(3) DOE DTRA

Candidate mass properties (RB weight and CG location) are shown in Figure 6.2-2.

(U) The proposed CAT-F PAL use control is physically compatible with existing DoD hardware, although compatibility with all missile functional interfaces is in doubt. The concept has good aerodynamic stability margins.

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FIGURE 6.4.12-2

(U) NEP COMPARISON

b(3)
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FIGURE 6.4.12-3

(U) FORWARD WARHEAD SUPPORT

b(3)
DOE
DTRA

FIGURE 6.4.12-4

(U) AFT WARHED SUPPORT

6.4.12.2 (U) LA5-3 Normal Reentry Structural Assessment

(U) Analysis Approach

(U) The approach used to assess the LA5-3 concept was predicated on the design attributes of the forward warhead support wedge and the aft warhead support. (See Figure 6.4.12-1). The LA5-3 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, like LA5-7 and LA5-9, is a complex design that is basically flat as opposed to the normal concaved configuration. The flat part of this seal cover lays against the warhead, and since the seal cover bending load path is less stiff than the warhead axial load path, the majority of the pressure load on the seal cover is transmitted into the warhead and then into the aft warhead support. The pressure loading on the warhead support, due to the seal cover loading, is acceptable since it is less than the loading during reentry and occurs at a different time interval. (See Figure 6.4.12-1). The warhead attachment, the wedge, and the seal cover designs were assessed for the three critical MK5 V–γ trajectories (upper middle-UM, upper left-UL, and upper right-UR).

(U) Assessment Results

(U) The assessment of the LA5-3 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 has positive margins since the loading is transferred into the warhead and the aft warhead support.

[redacted]

6.4.12.3 (U) LA5-3 Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

b(3) DOE DTRA

(U) Structural Vulnerability Assessment

DOE DTRA b(3) b(3) DTRA b(3) DOE DTRA

6.4.12.4 (U) LA5-3 Candidate Feasibility Statement

(U) Analysis of the LA5-3 candidate design was accomplished utilizing a conceptual drawing and general mass property information. This is considerably less information than has been received for many of the other candidates and as such, has much larger uncertainties associated with the assessment conclusions. With these caveats in mind the LA5-3 design was assessed to be feasible with potential modifications to the aft mount and seal cover attachments when design dynamic properties are available.

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b(3)
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FIGURE 6.4.13-1

(U) LA5-4H FULL BODY PROFILE

b(3)
DOE
DTRA

(U) NEP COMPARISON

b(3)
DOE
DTRA

FIGURE 6.4.13-4

(U) AFT WARHEAD SUPPORT

6.4.13.2 (U) LA5-4 Normal Reentry Structural Assessment

(U) Analysis Approach

(U) The approach used to assess the LA5-4 concept was to compare the design attributes of the forward wedge support area and the aft warhead support to designs that have already be assessed. (See Figure 6.4.13-1). The LA5-4 concept has an aft warhead support design that is similar to the LA5-6 design. The LA5-6 design was extensively analyzed by finite element models. Since the LA5-4 design concept is similar to the above mentioned design, a comparison of the loads and mass properties was made to determine the feasibility of the LA5-4 design. The seal cover and the wedge area are similar to LA5-6 and were assessed based on that design. (See Figure 6.4.13-1). The warhead attachment, the wedge, and the seal cover designs were assessed for the three critical MK5 V–γ trajectories (upper middle-UM, upper left-UL, and upper right-UR) by comparison.

(U) Assessment Results

(U) It is recommended that the warhead interface ring base at the warhead/ring interface be increased in the axial direction to give the ring a better moment capability. If this change is incorporated into the design, then the assessment of the LA5-4 aft warhead support and the forward wedge support area will have margins equal to or greater than the W88/MK5 design. This assessment was based on a loads and mass properties comparison between LA5-4 and LA5-6. The seal cover has positive margins based on the assessment of LL5-1 configuration that had similar geometry.

6.4.13.3 (U) LA5-4 Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

[redacted] The LA5-4 candidate employs the same forward sleeve configuration as the LA5-6 candidate.

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b(3)
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(U) Structural Vulnerability Assessment

(U) For the LA5-4 candidate only the substrate stress response in the vicinity of the aft support under side-on impulse loading was examined for high frequency responses because evaluation of a similar design (LL5-1) has indicated that this environment most stressed this design configuration.

(U) The LA5-4 aft mount high-frequency responses were expected to be within material limits due to similarity in the design to LL5-3a, which was found to be acceptable (See section 6.4.3).

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(U) Low-frequency response analysis concentrated on the blast loading environment because, again it was found to be more critical than the cold or hot X-ray loadings.

(U) The approach to assess the blast response is illustrated by the flow diagram of Figure 6.4.3-5. This analysis was carried out using a warhead model established from LANL supplied warhead mass distribution and stiffness information. The calculated forward and the aft support stiffness of LL5-3a were used for the LA5-4 analysis because of design similarity.

b(3)
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DTRA

FIGURE 6.4.14-2

(U) NEP COMPARISON

b(3)

DOE
DTRA

FIGURE 6.4.14-3

(U) FORWARD WARHEAD SUPPORT

(b)(3)

DOE
DTRA

FIGURE 6.4.14-4

(U) AFT WARHEAD SUPPORT

b(3) DOE DTRA

(U) Structural Vulnerability Assessment

b(3) DOE DTRA

Selection of an adequately stiff wedge material was viewed as an issue for this component due to the potential shift of loading from the forward to the aft warhead mount. Also, the NEP has a longer forward reach than the W88 which results in a small gap between the NEP and the AF&F support. An adequate gap between the NEP front end and the AF&F would be required to prevent physical impact. Additional design and component stiffness information would be required to provide a more complete assessment.

6.4.14.4 (U) LA5-5 Candidate Feasibility Statement

(U) Analysis of the LA5-5 candidate design was accomplished utilizing a conceptual drawing and general mass property information. This is considerably less information than has been received for many of the other candidates and as such, has much larger uncertainties associated with the assessment conclusions. With these caveats in mind the LA5-5 design was assessed to be structurally feasible with modifications to the forward warhead support and possibly to the AF&F support ring.

(U) It should be noted though, that this candidate was outside the weight and center of gravity limits imposed by LMSC (see Figure 6.2-1). The added weight (i.e., higher ballistic coefficient) caused the reentry body to have a higher terminal velocity and greater total heating during normal reentry which violates MK5 heatshield criteria.

6.4.15 (U) LA5-6 STRUCTURAL ASSESSMENT SUMMARY

6.4.15.1 (U) LA5-6 Design Description

The AF&F mounting ring remains basically similar to the W88/MK5.

b(3) DOE DTRA

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.

(U) This design provides compatibility with DoD hardware including the modification of the AF&F. An alternate AF&F configuration using the existing AF&F would require that additional components be packaged in the RB to accommodate one of the new safety strong links. This configuration was not

b(3)
DOE
DTRA

FIGURE 6.4.15-1

(U) LA5-6 FULL BODY PROFILE

b(3)
DOE
DTRA

FIGURE 6.4.15-2
(U) NEP COMPARISON

FIGURE 6.4.15-3

(U) FORWARD WARHEAD SUPPORT

6.4.15.3 (U) LA5-6 Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

(U) For the proposed LA5-6 concept (see Figure 6.4.15-1) a stiffening sleeve was used to provide buckling strength for the aeroshell and to provide support to the warhead during structural vulnerability encounters.

DOE b(3)

DOE b(3)

b(3) DOE DTRA

DOE b(3)

(U) Structural Vulnerability Assessment

(U) The high-frequency responses for the LA5-6 design were investigated for a side-on impulse because evaluation of a similar design (LL5-1) had indicated that the side-on impulse was of most concern. Only the substrate stress response in the vicinity of the aft support was examined, again due to similarity of design. A local DYNA3D finite element model was developed to predict the local stress response in the aft support vicinity (see Figure 6.4.15-5). The results showed that the peak stresses developed at critical points in the substrate and in the connecting bolts and brackets were below the corresponding material allowables (i.e., yield strengths).

(U) With regard to low-frequency responses the candidate was evaluated for its and

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(U) HIGH FREQUENCY (IMPULSE) RESPONSE RESULTS FOR LA5-6

FIGURE 6.4.15-5

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performance under blast loading conditions because it was more critical than cold hot X-ray low-frequency loadings.

(U) The approach to assess the blast response was the same as that used for LA5-4 (see Figure 6.4.3-5). The centerpiece of the analysis was the low-order full-body model dynamic analysis. The required warhead forward and aft support stiffness data was determined from separate DIAL finite element analyses. The required warhead spring and mass constants were calculated using the stiffness and mass distribution information supplied by LANL.

(U) The results showed that the most critical responses occurred in the vicinity of the aft warhead support (see Figure 6.4.15-6). The highest stress occurred at the substrate outside surface located at the forward edge of the aft support on the hit side. The substrate stress exceeded the static material (aluminum) yield strength. Modification of the aft warhead mount to a wishbone-type design or increasing the mount thickness could alleviate the substrate yielding if it were found to be an issue in a later development phase.

(U) The DOE/DoD component relative deflection responses at known physical impact locations indicated that they were smaller than those in the W88/MK5 and therefore were not a concern

6.4.15.4 (U) LA5-6 Candidate Feasibility Statement

[redacted]

b(3)
DOE
DTRA

[redacted]

6.4.16 (U) LA5-7 STRUCTURAL ASSESSMENT SUMMARY

6.4.16.1 (U) LA5-7 Design Description

The AF&F mounting ring remains basically similar to the W88/MK5.

b(3)
DOE
DTRA

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.

(U) This design provides compatibility with the DoD including the modification of the AF&F. An alternate configuration using the existing AF&F would require that additional components be packaged in the RB to accommodate one of the new safety strong links. This configuration was not assessed due to insufficient data,

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b(3)
P.L. 86-36

FIGURE 6.4.16-1

(U) LA5-7 FULL BODY PROFILE

[redacted]

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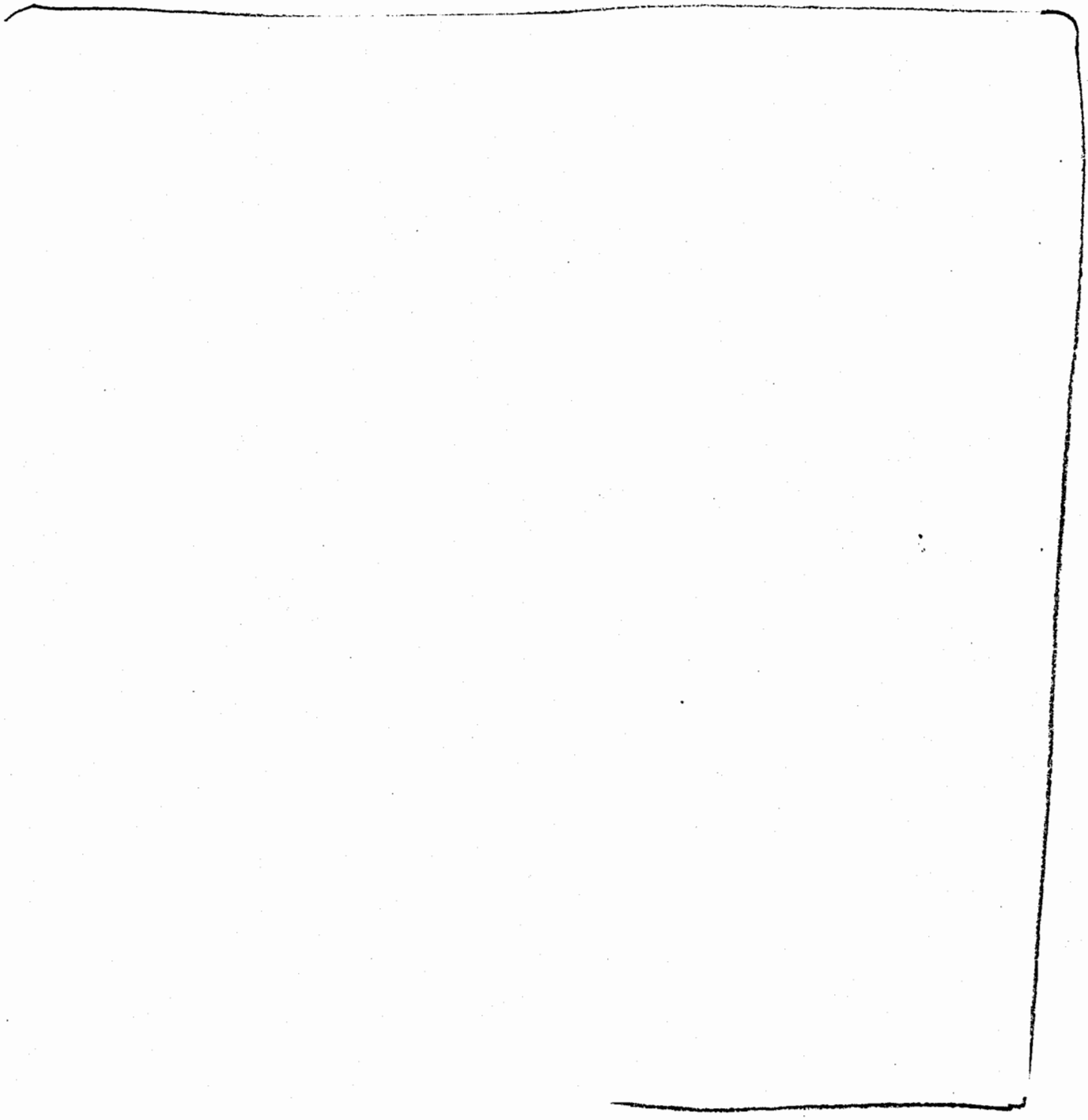

FIGURE 6.4.16-2

(U) NEP COMPARISON

DOE
DTRA 6(3)

(U) FORWARD WARHEAD SUPPORT

FIGURE 6.4.16-4

(U) AFT WARHEAD SUPPORT

although feasibility is likely. 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 is close to the aerodynamic stability limit. A slight increase in weight in the forward area would improve this condition. (See Figure 6.2-1).

6.4.16.2 (U) LA5-7 Normal Reentry Structural Assessment

(U) Analysis Approach

(U) The approach used to assess the LA5-7 concept was to compare the design attributes of the forward wedge support area and the aft warhead support to designs that have already been assessed (Figure 6.4.16-1). The LA5-7 concept has an aft warhead support design that is similar to the LA5-6 concept. The LA5-6 design was extensively analyzed by finite element models. Since the LA5-7 design concept is similar to the above mentioned design, a comparison of the loads and mass properties was made to determine the feasibility of the LA5-7 design. The wedge area is similar to the LA5-6 and was assessed based on that design. The seal cover design is a complex configuration that is basically flat as opposed to the normal concaved configuration. This seal cover is similar to one assessed on another program and was assessed based on that analysis (Figure 6.4.16-1). The warhead attachment, the wedge, and the seal cover designs were assessed for the three critical MK5 V–γ trajectories (upper middle-UM, upper left-UL, and upper right-UR) by comparison.

(U) Assessment Results

(U) The assessment of the LA5-7 aft warhead support designs and wedge area reflected margins equal to or greater than the W88/MK5 design. The seal cover has positive margins based on the assessment of a configuration that had similar geometry.

6.4.16.3 (U) LA5-7 Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

(U) For the proposed LA5-7 concept (see Figure 6.4.16-1) a stiffening sleeve was used to provide buckling strength for the aeroshell and to provide support to the warhead during structural vulnerability encounters. One issue associated with the sleeve was the response of the sleeve material to hot X-rays. Two sleeve configurations were examined just as for the LA5-6 candidate. See section 6.4.15.3 for a description of this work.

b(3)
DOE
DTRA

(U) Structural Vulnerability Assessment

(U) LA5-7 high-frequency responses were examined for the side-on impulse loading. Other candidate designs with similar configurations have shown that the impulse environment was most severe.

b(3)
DOE

(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) With regard to low-frequency responses the candidate was evaluated for its performance under blast loading conditions because it was more critical than cold and hot X-ray low-frequency loadings.

(U) The approach to assess the blast response was the same as that used for LA5-4 (see Figure 6.4.3-5). The centerpiece of the analysis was the low-order full-body

model dynamic analysis. The required warhead forward and aft support stiffness data was determined from separate DIAL finite element analyses. The required warhead spring and mass constants were calculated using the stiffness and mass distribution information supplied by LANL.

b(3)
DOE

(U) The DOE/DoD component relative deflection responses at known physical impact locations indicated that the relative lateral deflection along the AF&F and the aeroshell substrate gap interface was most critical. The deflection value is higher than that of W88/MK5, however, it is still below the allowable.

6.4.16.4 (U) LA5-7 Candidate Feasibility Statement

b(3)
DOE
DTRA

6.4.17 (U) LA5-8 STRUCTURAL ASSESSMENT SUMMARY

6.4.17.1 (U) LA5-8 Design Description

b(3) DOE DTRA

b(3) DOE DTRA

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.

(U) This concept appears to provide compatibility with the DoD hardware including the modification of the AF&F. An alternate AF&F configuration using the existing AF&F would require packaging of additional components in the RB to accommodate one of the additional safety strong links. This alternate configuration was not assessed, but feasibility is likely. A CAT-E PAL use control capability is feasible if utilized on this design and the concept is compatible with all the missile physical and functional interfaces.

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FIGURE 6.4.17-1

(U) LA5-8 FULL BODY PROFILE

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b(3)
DOE
DTRA

FIGURE 6.4.17-2

(U) NEP COMPARISON

b(3)
DOE
DTRA

FIGURE 6.4.17-3
(U) FORWARD WARHEAD SUPPORT

b(3)
DOE
DTRA

FIGURE 6.4.17-4

(U) AFT WARHEAD SUPPORT

6.4.17.2 (U) LA5-8 Normal Reentry Structural Assessment

(U) Analysis Approach

(U) The LA5-8 design was assessed by engineering judgment based on limited details of a 8 1/2 x 11 layout shown in the "Excerpts from the Fourth SLBM Phase 2 Study Group", dated 4 March 1993. The aft warhead attachment is similar to the MK5 IH attachment. The LA5-8 was assessed based on the MK5 IH design concept. The forward support is the same as the MK5 concept and the seal cover is the MK5 design.

(U) Assessment Results

(U) It was assumed that because of the similarity of this design to the W88/MK5 attachment designs that positive margins of safety can be obtained for the LA5-8 concept. One area in the design needing additional assessment is the aft cover of the NEP. This can be refined if this candidate is pursued.

6.4.17.3 (U) LA5-8 Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

(U) Based on the known materials included in the design, there are no material vulnerability concerns.

(U) Structural Vulnerability Assessment

(U) The LA5-8 candidate is a straightforward design concept. With the design information available it was noted that the aft warhead mount was similar to the MK5 IH mount and appears to be feasible. The forward warhead support or wedge, being similar in shape to the W88/MK5, likewise appeared to be feasible.

b(3)
DOE

(U) Additional information concerning the sequence of events associated with the NEP including the possible orientation of the various LA5-8 NEP components, during hostile environment encounters would need further assessment.

6.4.17.4 (U) LA5-8 Candidate Feasibility Statement

(U) Analysis of the LA5-8 candidate design was accomplished utilizing a conceptual drawing and general mass property information. This is considerably less information than has been received for many of the other candidates and as such, has much larger uncertainties associated with the assessment conclusions. With these caveats in mind the LA5-8 design was assessed to be feasible with modifications to the NEP case and aft cover to the case. In addition, information describing the operation (sequence of events) of the NEP would be needed if this candidate is to be further developed.

6.4.18 (U) LA5-9 STRUCTURAL ASSESSMENT SUMMARY

6.4.18.1 (U) LA5-9 Design Description

b(3)
DOE
DTRA

The AF&F mount appears to be of the same design as the W88/MK5.

b(3)
DOE
DTRA

b(3)
DOE
DITRA

FIGURE 6.4.18-1
(U) LA5-9 FULL BODY PROFILE

b(3)
DOE
DTRA

FIGURE 6.4.18-2

(U) NEP COMPARISON

b(3)
DOE
DTRA

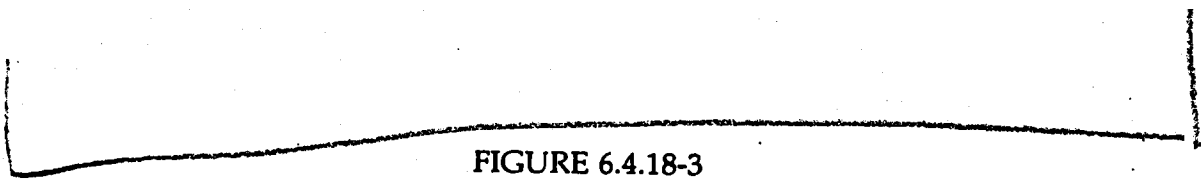

FIGURE 6.4.18-3

(U) FORWARD WARHEAD SUPPORT

b(3)
DOE
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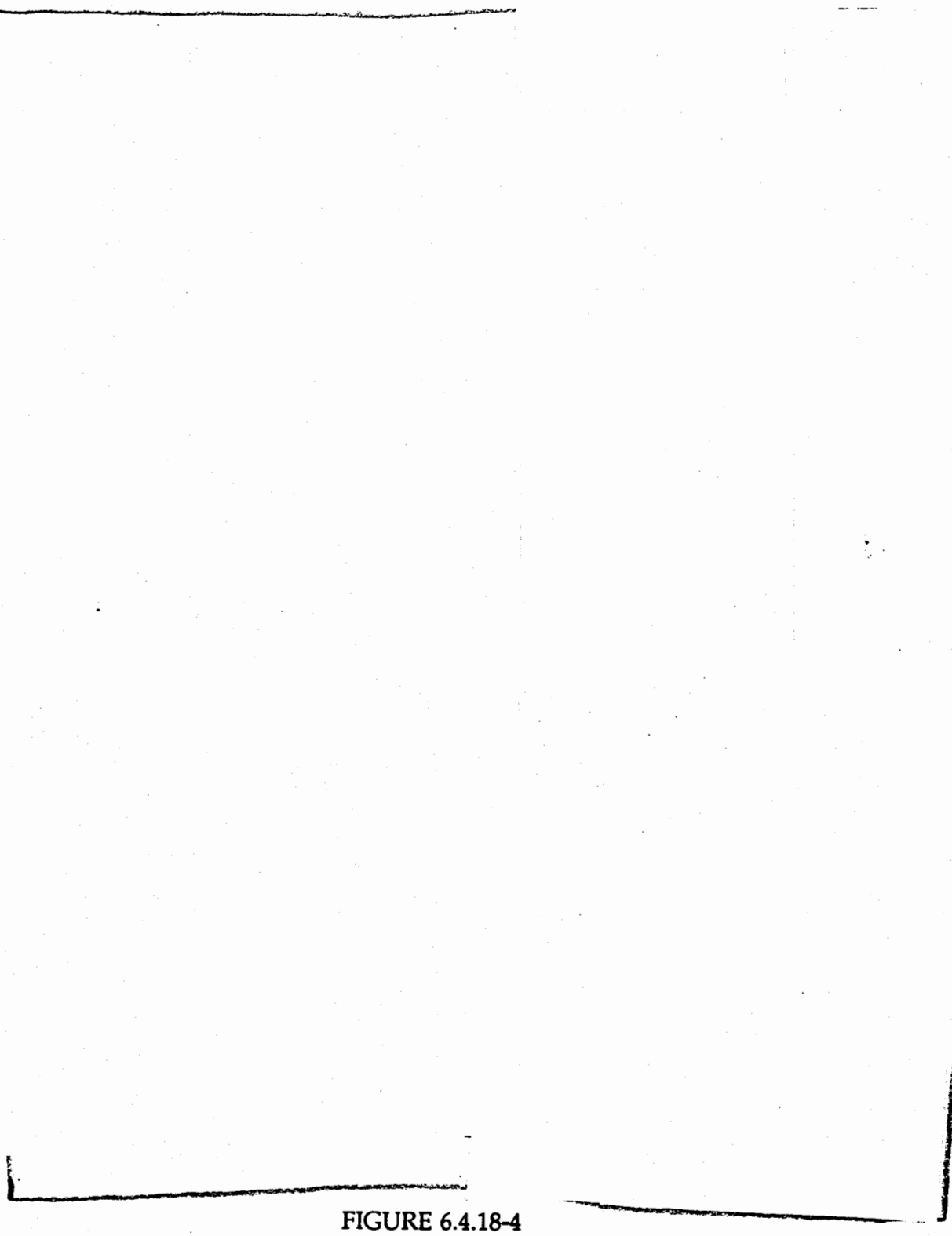

FIGURE 6.4.18-4

(U) AFT WARHEAD SUPPORT

b(3) DOE DTRA

b(3) DOE

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.

(U) This design provides compatibility with the DoD hardware including the modification of the AF&F. An alternate AF&F configuration using the existing AF&F would require that additional components be packaged in the RB to accommodate one of the new safety strong links. The configuration was not assessed, but feasibility appears likely. 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.

6.4.18.2 (U) LA5-9 Normal Reentry Structural Assessment

(U) Analysis Approach

(U) The approach used to assess the LA5-9 concept was predicated on the design attributes of the forward warhead support wedge and the aft warhead support. (See Figure 6.4.18-1). The LA5-9 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 is a complex design that is basically flat as opposed to the normal concaved

configuration. This seal cover is similar to one analyzed on another program and was assessed based on that analysis. (See Figure 6.4.18-1). The warhead attachment, the wedge, and the seal cover designs were assessed for the three critical MK5 V–γ trajectories (upper middle-UM, upper left-UL, and upper right-UR).

(U) Assessment Results

(U) The assessment of the LA5-9 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 has positive margins based on the assessment of a configuration that had similar geometry.

6.4.18.3 (U) LA5-9 Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

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DTRA

(U) Structural Vulnerability Assessment

(U) The LA5-9 candidate has a "wishbone" shape aft warhead support, and its foam wedge forward support is located further aft than that of the W88/MK5 (see Figure 6.4.18-3).

(U) Only the substrate stress response in the vicinity of the aft warhead support under side-on impulse loading was examined when high-frequency responses were evaluated. This approach was selected because evaluation of the W88/MK5, a similar design, had indicated that the impulse loading produced the most severe stress.

(U) A DYNA3D finite element model was developed to predict the local stress response in this vicinity (see Figure 6.4.18-5). The results showed that the peak

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FIGURE 6.4.18-5

(U) HIGH FREQUENCY IMPULSE RESPONSE RESULTS FOR LA5-9

b(3)

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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) The approach to assess low frequency 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 LANL.

(U) The results showed that the highest stresses occurred near the manufacturing joint area, however, their estimated magnitudes were still below allowable limits. The DOE/DoD component relative deflection responses at potential physical impact locations indicated that the relative lateral deflections between the warhead and the aeroshell substrate were the most critical. Additional analysis of the forward support deflection is recommended.

6.4.18.4 (U) LA5-9 Candidate Feasibility Statement

(U) Analysis of the LA5-9 candidate was accomplished with the following conclusion: the LA5-9 candidate design is feasible with possible modifications to the forward warhead support.

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 this highly optimized system. Those tradeoffs are discussed elsewhere in the report.

b(3)
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DTRA

(U) FIGURE 7.1-1

(b)
DOE
JOINT

(U) FIGURE 7.1-2

7.1.3 (U) AF&F AND ELECTRICAL SUPPORT SYSTEMS OPTIONS

(U) The AF&F and the other electrical support systems in the New Mexico Laboratories' proposed nuclear assembly packages for the MK4A address two specific Phase 2 Study issues, Use Control(UC) and Enhanced Nuclear Detonation Safety (ENDS). Specific implementation of UC and/or ENDS is addressed in the discussions and accompanying figures in the descriptions that follow for each candidate proposed.

[redacted] Three electrical configurations are proposed for the LA4 candidates on the D5 missile and two configurations on the C4 missile.

b(3)
DOE
DTRA

There are three electrical configurations proposed for the implementation of detonator enabling/safing for the LA4 candidates on the D5 missile and two configurations on the C4 missile.

(U) The first configuration proposed (C4 and D5) requires a complete rebuild of the MK4 AF&F. Most of the AF&F subsystems and components would be recovered during disassembly, tested, recertified, and reassembled into the new AF&F. The SALAD type device electrical system would be included in the expanded exclusion region inside the AF&F. A new, higher voltage thermal battery would replace the existing 500-volt battery to increase the fire set charge potential so that the existing fire set could fire slapper detonators. No additional electrical components are required inside the reentry body.

(U) The second configuration proposed (again C4 and D5) requires only minimal MK4 AF&F modification to replace the existing thermal battery with a higher voltage output unit. Additional components and systems are required within the

reentry body and the release assembly to provide appropriate power and control of the detonator enabling/safing system. An Environment Sensing Signal generating Device (ESSD) is required to generate and process unique signals that are used inside the reentry body to enable and trigger the SALAD type device.

(U) A third configuration is proposed for use on the D5 missile system only. Unique signals available at the MK5 platform interface (MK5 Data and Data Return) replace those signals generated by the ESSD assembly described in the configuration above. DoD hardware modifications are required to provide new cabling and connectors to and through the MK4 platform and the aft and seal covers.

7.1.4 (U) MK4 NUCLEAR SYSTEM DESCRIPTIONS

DOE DTRA b(3)

7.1.4.1.1 (U) *Origin/Basis*

b(3) DOE DTRA

7.1.4.1.2 (U) *General Description/Performance*

b(3) DOE DTRA

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b(3)
DOE

(U) FIGURE 7.1-4

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DOE
DTRA

UNCLASSIFIED

b(3) (
DOE
DTRA

(U) This system is calculated to be one-point safe. Multipoint safety evaluation, such as the exploding rocket bottle scenario, has not yet been performed.

7.1.4.2.1 (U) *Secondary Design*

b(3)
DOE
DTRA

(U) Nuclear System Engineering

b(3)
DOE
DTRA

(U) This warhead uses the same seal cover and AF&F which is currently in the MK4. The forward mount uses the same mounting holes but is slightly modified from the MK4 mount The aft mount is a foam mount similar to the MK4 aft mount. The gas transfer system is an Acorn.

7.1.4.2.2 (U) *Electrical Support System*

The electrical support systems for LA4-2 are identical, with one exception, to those proposed for LA4-1.

b(3)
DOE
DTRA

7.2.2 (U) NUCLEAR EXPLOSIVE PACKAGES

7.2.2.1 (U) LL4-1a (Baseline)

7.2.2.1.1 (U) *Warhead Description*

[redacted]

b(3)
DOE
DTRA

b(3)
DoE
DTRA

FIGURE 7.2-1
(U) SUMMARY OF LL4 CANDIDATES

The LL4-1a candidate provides fully modern safety features. It has been calculated to be conservatively one-point safe. Its ENDS protection includes DSSL.

b(3)
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DTRA

As noted above, the LL4-1a candidate provides IHE and a fire resistant pit (FRP). Its estimated INRAD values are shown in Table 7.2-1.

b(3) DOE DTRA

The LL4-1a candidate offers a CAT-E PAL option.

b(3) DOE DTRA

(U) The LL4-1a NEP emphasizes traditional warhead production technology, except for pit reuse. A facility to modify reused pits for use in new warheads is being developed in a cooperative effort between LLNL and the Pantex Plant. This development was motivated by the W89 program, but because of its generic utility, it has continued unabated even after the W89 program was canceled in July 1992. This effort is far less than would be required to establish a new plutonium fabrication facility. Pit reuse avoids the need for such a new facility. There are no identified issues that limit the longevity of a LL4-1a warhead. The NEP inside the MK4A has good vulnerability and hardening (V&H) characteristics.

TABLE 7.2-1

(U) SUMMARY VALUES FOR LLNL/SANDIA MK4A CANDIDATES

b(3) DOE DTRA

7.2.2.1.2 (U) *Nuclear Test Status*

b(3) DOE DTRA

7.2.2.1.3 (U) *Summary Of LL4-1a*

b(3) DOE DTRA

The LL4-1a is feasible, and because of its combination of good characteristics, it has been chosen as the baseline LLNL/Sandia MK4A warhead candidate.

7.2.2.2 (U) LL4-2a

7.2.2.2.1 (U) *Warhead Description*

b(3) DOE DTRA

There are no identified issues that would limit the longevity of a LL4-2a warhead. The LL4-2a NEP inside the MK4A RB has good V&H capabilities.

7.2.2.2.2 (U) *Nuclear Test Status*

b(3)
DOE
DTRA

7.2.2.2.3 (U) *Summary Of LL4-2a*

The LL4-2a candidate is feasible

b(3)
DOE
DTRA

7.2.2.3 (U) LL4-3a

7.2.2.3.1 (U) *Warhead Description*

b(3)
DOE
DTRA

INRAD values are shown in Table 7.2-1. Except for fabrication of a new pit, its producibility is good. However, because of its requirement for new pit fabrication, there is no near term prospect of its production in the DOE complex. There are no identified issues that would limit the longevity of a LL4-3a warhead. The LL4-3a NEP in the MK4A RB has good V&H capabilities.

7.2.2.3.2 (U) *Nuclear Test Status*

[redacted]

b(3) DOE DTRA

7.2.2.3.3 (U) *Summary Of LL4-3a*

(U) The LL4-3a candidate is the most robust and best performer of the LLNL/Sandia MK4A warhead designs. It also has the lowest INRAD. If new pits could be fabricated, it would be the LLNL/Sandia baseline design. However, because there is no near term prospect for its production, LL4-3a is an excursion that illustrates the benefits that come with a custom designed pit.

7.2.2.4 (U) LL4-1b, LL4-2b, and LL4-3b (New AF&F)

(U) Each of the above MK4A candidates has a "b" version with essentially the same NEP. These candidates are labeled LL4-1b, LL4-2b, and LL4-3b. In each "b" candidate the existing AF&F is replaced. This change offers the opportunity to place a second stronglink at the detonator, in addition to DSSL. This is done by replacing the booster pellets in the primary IHE with voids that will prevent initiation of the IHE, even if the detonators function properly.

b(3) DOE DTRA

The NEPs in the "b" candidates are the same as in the corresponding "a" candidates, except for the change in the booster pellets. Their development nuclear test requirements are the same as for the corresponding "a" candidates.

b(3) DOE DTRA

7.2.2.5 (U) MK4A NEP Summary

b(3) DOE DTRA

7.2.3 (U) WARHEAD COMPONENTS

7.2.3.1 (U) Electrical Systems

(U) There are three electrical systems available for the LL4:

1. A system that uses the W76 AF&F with its stronglinks and does not add any detonator safing;

2. A system that uses the W76 AF&F and adds detonator safing (DSSL) and a separate unique signal generator or auxiliary programmer;

3. A system that includes both DSSL and PEX Booster detonator safing. This system requires a new AF&F.

(U) Variants are possible within each of these themes as to how the unique signals are generated, the type of use control, etc.

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LL4-1a,2a,3a with DSSL and ESSG (C4 and D5)

b(3)
DOE

FIGURE 7.2-2
(U) ELECTRICAL SYSTEM BLOCK DIAGRAM FOR C4/D5 USING MC2912 AF&F

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11.4-1a.2a.3a with DSSL (Modified D5)

b(3)
DOE

FIGURE 7.2-3
(U) ELECTRICAL SYSTEM BLOCK DIAGRAM FOR MOD-D5 USING MC2912 AF&F

(U) All MK4 signals will be used as currently defined for the W76/MK4 at the field joint connector. The MK5 Data line could provide the unique signal information (including Intent) in the modified-D5 application. The proposed changes required to the MK4 adapter to obtain the in-flight unique signals for the modified-D5 application are shown in Figure 7.2-4. If the cable in the D5 adapter cannot be changed and the D5 data is not available, an ESSG would be used on D5 that would be similar to the ESSG used on C4 but optimized for D5 environments.

(U) The IFD for the W76/MK4 does not have sufficient number of pins for passing the unique signals required by DSSL. Replacing the 11-pin MK4 IFD insert with the 14-pin MK5 insert would correct this problem. This change will also require new cables to and from the IFD (i.e., on the RA and inside the RB). The additional conductors will be used to drive the DSSL directly from either an Environmental Sensing Signal Generator (ESSG) for the C4 and D5 application, or an auxiliary (in addition to the AF&F programmer) programmer for the modified-D5 application. The ESSG and auxiliary programmer will be mounted on the RA. The auxiliary programmer will receive the unique signal information from the MK5 Data line, which is available at the field joint connector with the changes to the MK4 adapter shown in Figure 7.2-4. The auxiliary programmer will use either the D5 unique signal information or a self-contained ESSG to generate the DSSL drive signal.

(U) Environmental-Sensing Signal Generator (ESSG)

(U) Portions of the environmental unique signal will be generated during powered flight and the remainder will be generated after RB separation from the RA. (The generation of the unique signal is addressed in more detail in Section 7.2.5.) While the post-separation portion of the unique signal must be generated by an ESSG on-board the RB, the powered-flight portion of the signal can be generated by an ESSG external to the RB. Locating this ESSG external to the RB allows the RB to be disconnected from the ESSG during shipping and storage, thus reducing the chance of inadvertent generation of the unique signal. The ESSGs will be based on technology similar to the W88 programmer (MC3811). The external ESSG will be located on the Release Assembly. Because it is not in the sealed volume, it will be hermetically sealed. The ESSG within the RB will be integral with the Seal Cover.

(U) The external ESSG should be located where it could be installed at the time that the RBA is installed to the missile. Figures 7.2-5 and 7.2-6 show potential locations for the ESSGs on the C4 and D5 RAs. The shipping container would be configured such that the RBA cannot be installed with the auxiliary ESSG attached. Safety could be improved further by the use of a Read-only Memory (ROM) key. This key would contain information necessary to generate the proper unique signal. The key would be configured as a simple connector. It would be installed on an ESSG connector during RBA mating to the missile and would be removed during demating.

(U) On the modified-D5, the unique signals would be supplied by the missile and the external ESSG would not be needed. However, the ESSG/programmer internal to the RB would always be present to allow the RB to be used on C4.

(U) The battery within the AF&F is not capable of driving DSSL. New batteries are required to operate the system with DSSL. One battery would be located on the RA. This battery would operate the ESSG (on C4 and unmodified D5 missiles) and advance the DSSL as the unique signal information was delivered to the internal programmer during powered flight. Another battery would be located in the RB, aft of the Seal Cover. This battery would power the programmer and ESSG within the RB and drive DSSL for the post-separation unique signal events. The on-board battery would be actuated by a signal from the external battery.

(U) The battery on the RA would be actuated by a G-Time sensor that would have a mechanical unlock mechanism. This mechanism is used to prevent premature actuation of the battery during transportation. The mechanism would be locked during transportation and unlocked immediately prior to installing the RBA onto the missile. The battery will use cobalt disulfide technology.

(U) The low voltage cable in the MK4 will have to be redesigned. The replacement cable will be a flat-flex cable. Two additional cables for the CAT-E PAL system are required. The cable from the seal cover to the aft cover will have to be replaced to accommodate the new auxiliary ESSG or programmer and battery.

(U) These candidates could also be produced without either DSSL or CAT-E PAL.

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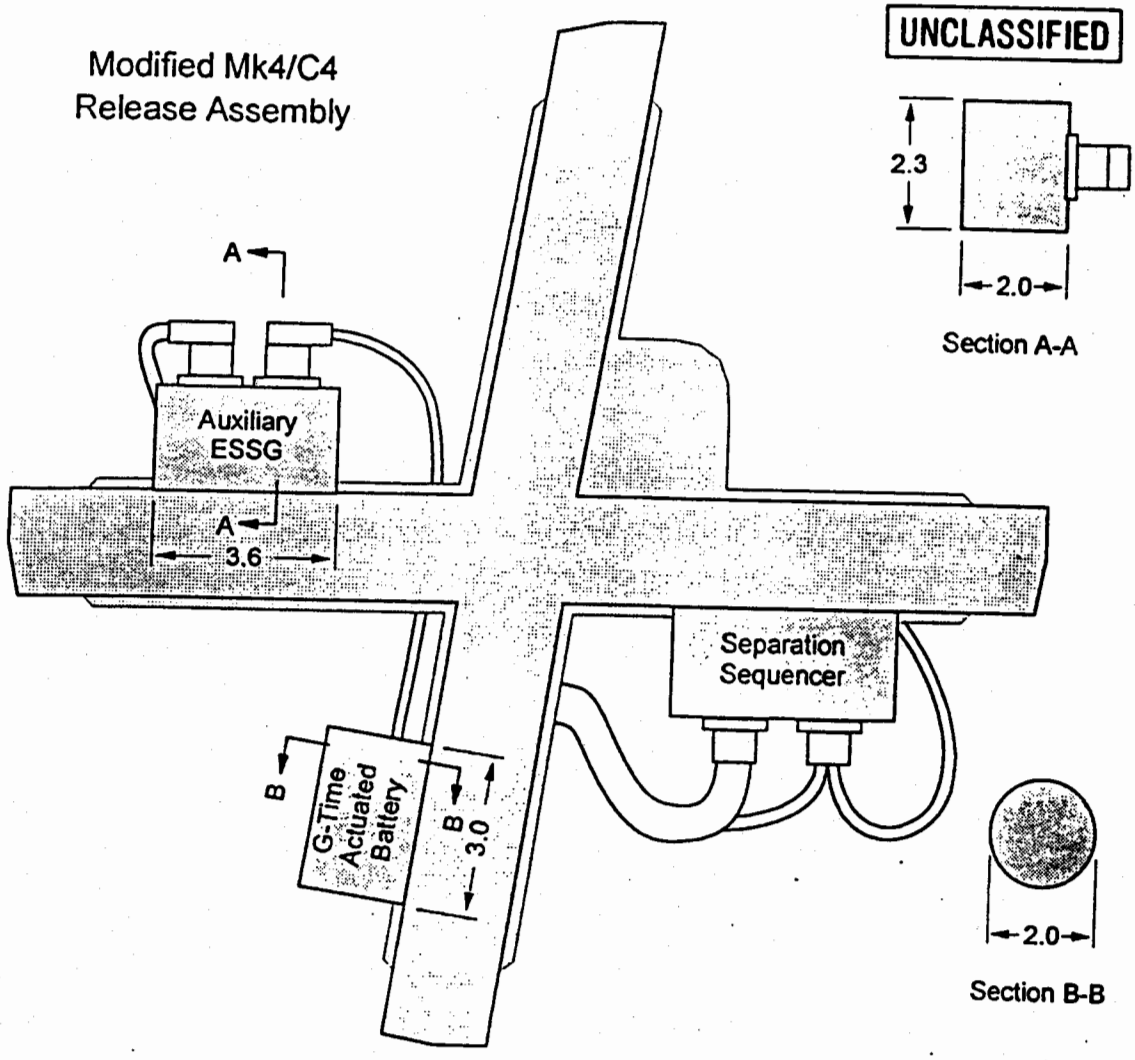

FIGURE 7.2-5
(U) ESSG MOUNTING ON C4 RA

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(U) The elimination of DSSL would delete the ESSG, the external programmer and the battery from the RAs and allow the use of the standard MK4 and MK5 RAs and adapter plate and cabling. The MK4A would not need the MK5 IFD insert and could use the MK4 IFD insert. The D5 MK5 Data Line would not be used.

(U) The elimination of CAT-E PAL would negate the need for the additional connector on the aft closure and seal cover and the associated cabling.

(U) The design could also be modified to incorporate Category D PAL. CAT-D PAL will require a programmer in the RB.

7.2.3.1.2 (U) *Based On New AF&F (LL4-1b, -2b, and -3b)*

(U) Block diagrams of the proposed electrical system for the MK4A using a new AF&F are shown in Figure 7.2-7 for the C4 and D5 applications and Figure 7.2-8 for the modified-D5 application. The majority of the new AF&F would be located in the same location as the old AF&F and would include a PEX system and the on-board ESSG. The only portion of the AF&F not located forward of the NEP is the fireset, which is integral with the Seal Cover. The packaging of the PEX Booster system into the new AF&F is shown in Figures 7.2-9 and 7.2-10. The PEX Booster concept and operation are described in detail in Section 5.2.5.3.

(U) The new AF&F will use technology similar to that used in the MK5 MC3719 AF&F. The ESSG/programmer in the new AF&F will use technology similar to that used in the W88 programmer (MC3811).

(U) The fireset will use capacitor discharge unit (CDU) technology similar to that used in the W87/MK21 (Peacekeeper). Because this design relies on DSSL and the PEX booster, no stronglinks are required in the fireset.

(U) The new MK4 AF&F will function much like the MK5 AF&F, and therefore require power during the entire flight of the RB. Two batteries are required; a low voltage-long life battery, and a short term negative-voltage battery. The new low voltage battery will be located in the front of the RB behind the impact fuze. The negative-voltage battery will be located in the rear of the AF&F, where the fireset was in the old AF&F.

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b(3)

FIGURE 7.2-8
(U) ELECTRICAL SYSTEM BLOCK DIAGRAM FOR MOD-D5 USING NEW AF&F

b(3) DOE DTRA

b(3) DOE DTRA

7.2.4 (U) PACKAGING AND MOUNTING

7.2.4.1 (U) Forward Mount

(U) The three LL4 NEPs have very similar configurations and dimensions which allows their mounts to be similar to one another.

The forward mount provides both axial and lateral support. Its interface with the body section and the AF&F are identical to the W76 forward support.

b(3) DOE DTRA

(U) Like the W76, the new forward mount attaches to the NEP with a tape joint. However, because of differences between the W76 and LL4 NEPs, the tape joint is in a significantly different location (Figure 7.2-11).

7.2.4.2 (U) Aft Warhead Support

b(3) DOE DTRA

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b(3)
DoE
DTRA

(U) SECTION OF FORWARD WARHEAD SUPPORT

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A section of the support is shown in Figure 7.2-12.

7.2.4.3 (U) Seal Cover

(U) The sealed volume of the RB is completed by the seal cover, which is bolted to the existing substructure flange located aft of the nuclear system. Designs that do not include DSSL would use seal covers similar to the W76 seal cover. Designs that include DSSL will require a programmer; this would be mounted to the inner surface of the seal cover.

7.2.4.4 (U) Shield

b(3) DoE DTRA

7.2.5 (U) SAFETY

(U) From an IND safety perspective, all of the LL4 NEPs are the same. Therefore, they all use the same IND safety themes. The LL4 candidates provide all the modern warhead safety features of enhanced nuclear detonation safety (ENDS), IHE, and FRP. The designs can also include the additional protection provided by a detonator safing stronglink (DSSL).

(U) The W76/MK4 is the benchmark from which we would make improvements in the IND safety for MK4A candidates. The W76 encloses its fireset and trigger circuit in an exclusion barrier assembled from stainless steel and aluminum components. The entry of electrical signals through the barrier is normally controlled by routing the signals through two stronglinks in series. One stronglink is the MC2854 Accelerometer; the other stronglink is the MC2897 Decelerometer. These types of stronglinks are referred to as Environmental Sensing Devices (ESDs). The detonator leads external to the NEP

FIGURE 7.2-12

(U) SECTION OF AFT WARHEAD SUPPORT

are enclosed by the AF&F, the reentry body section (that is constructed of aluminum covered with carbon phenolic heatshield), and the aft closure and seal cover (both of which are aluminum).

(U) The LL4 designs can improve two aspects of the W76 nuclear safety theme:

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(U) To provide positive protection even if the NEP becomes exposed in an accident, the LL4 candidates include a Detonator Safing Stronglink (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) The LL4 candidates that use a new AF&F add a second nuclear safety subsystem to the NEP by incorporating PEX Booster.

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These multiple event unique signals are carefully analyzed to verify that the probability of their inadvertent generation is much less than one in a million.

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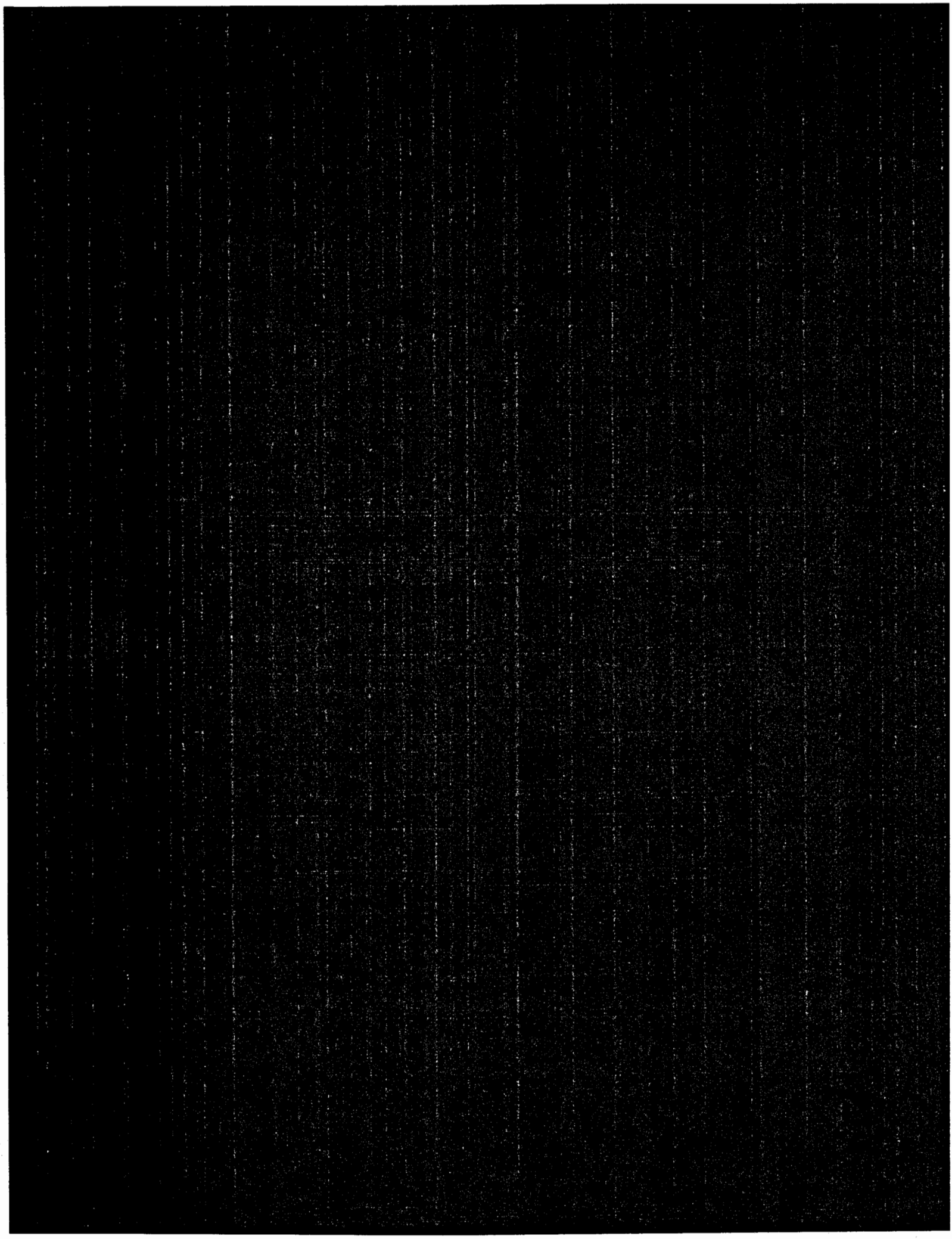

is authorized for use. This use of a human intent signal to prearm DSSL provides the optimal safety for this design. However, the C4 missile system does not have any unique signal capability and therefore is currently incompatible with this implementation. Therefore for LL4 warheads on C4, an Environmental Sensing Signal Generator would construct a unique signal by sensing a series of combinations of go/no-go environmental inputs, including acceleration and electrical signals from the missile.

b(3), DTRA

7.2.6 (U) USE CONTROL

(U) Each of the LL4 designs is compatible with Category E PAL, Category D PAL (which requires a programmer within the RB), and command disable. These options are discussed in detail in the Use Control section of this report (Section 10.2).

b(3) DTRA

b(3) DOE DTRA

7.2.8 (U) STOCKPILE AND PRODUCTION CONSIDERATIONS

(U) The LL4-1a and LL4-2a designs use standard production technology developed in previous programs. There is nothing in these designs that presents unusual production problems to the DOE complex, except for the modification of reused pits, and the development of a pit reuse production facility is underway and progressing well.

[redacted] b(3) DOE DTRA

(U) The baseline producibility comments also apply to LL4-3a, except for the pit. The pit production technology was once standard (like the W87), but with the shutdown of the Rocky Flats Plant, the DOE complex no longer has the capability to produce such pits in quantity, and there is no near-term prospect for such a capability. Thus, while LL4-3a is the best performer and has significantly lower INRAD, it cannot be produced in the present DOE complex.

7.2.8.1 (U) Use Of And Modifications To DoD Hardware

(U) This section identifies the modifications necessary to implement our candidate designs.

7.2.8.1.1 (U) *MC2912 AF&F*

(U) LL4-1a, LL4-2a, and LL4-3a can use the existing MC2912 AF&F. Tests at Sandia have shown that the existing AF&F does not have enough energy to fire slapper detonators (such as are used in DSSL). This can be resolved by changing out one of the AF&F batteries with a new higher voltage battery, or re-designing the detonators to not use slappers. Rework of the AF&Fs to exchange the battery has been studied and is straightforward requiring machining of a weld and removal of the AF&F can.

(U) The fuze settings in the existing AF&F are not optimal and changing these settings would improve the effectiveness of any of these candidates.

(U) LL4-1b, LL4-2b, and LL4-3b do not use the existing AF&F. A new AF&F is required for these candidates.

7.2.8.1.2 (U) *Aft Body Section*

(U) All of the LL4 designs use the existing MK4 Reentry Body aft sections with no modifications.

7.2.8.1.3 (U) *Nose Tip*

(U) All of the LL4 designs use the existing carbon-carbon nose tips with no modifications.

7.2.8.1.4 (U) *Forward Body Section*

(U) All of the LL4 designs require modification to the aluminum substrate of the forward body section. Ballast must be mounted in the forward end of the reentry body to keep the overall RB center of gravity within specification.[3] The ballast could be attached to the forward body section, incorporated into a new fuze shield, or incorporated into a new or repackaged AF&F (for LL4-Xb candidates). LMSC analysis shows that substantial ballast (~10 lb) can be attached to the anvil of the forward section in the void area between the forward body section and the contact fuze on the AF&F. This is the minimal amount of modification that would be required for any of the LL4 designs.

7.2.8.1.5 (U) Aft Closure

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7.2.8.1.6 (U) *Release Assemblies*

(U) All the LL4 designs are compatible with the existing MK4 release assemblies. The candidates that use the existing AF&F and do not include DSSL can use the existing release assemblies without any modification to the RAs. However, any of the designs with DSSL will require components mounted to the RAs, e.g., ESSG, battery, and battery actuator. These components weigh about 3.5 pounds with an ESSG and about 1.5 pounds without an ESSG. These weights have not been included in the RB weight but should be considered in calculating missile and RB range capabilities. The components that must be mounted on the RAs are described in Section 7.2.3.1.

(U) Changes to the MK4 to D5 adapter cable to provide human Intent unique signals to the MK4A are discussed in Section 7.2.3.1.

7.2.8.1.7 (U) *RB Internal Cabling And In-Flight Disconnect*

(U) All of our MK4A designs using the W76 electrical system (MC2912 AF&F, no DSSL) can use the existing MK4 (11-pin) IFD and cable.

(U) Any of the candidates with DSSL will require the use of the MK5 (14-pin) IFD connector. The connector will need a right-angle backshell inside the aft closure to provide clearance for the components in the aft compartment. These designs also will need a new cable between the IFD and the seal cover to support the electrical systems that are shown in the schematics in Section 7.2.3.1.

7.2.8.1.8 (U) *Antenna System*

(U) The existing antenna system (antennas, cables, splitters, etc.) may be used without any changes for the LL4 designs that use the existing MC2912 AF&F.

(U) We have only briefly assessed the compatibility of the existing MK4 antenna system with a new AF&F. The new AF&F is based on the radar technology from the W88. The MK5 radar operates at different frequencies than the MK4 antennas are designed for. Whether it would be better for the new radar to operate at the MK4 frequency (compatible with the MK4 RB RF system) or operate at the MK5 frequencies (compatible with the MK5 radar, but not compatible with the MK4 antenna cavities) has not been

evaluated. We believe that the existing windows would not need to be changed. The performance of the modified system would not be as precise as the MK5, but could be better than the MK4.

(U) We have attempted to avoid packaging interference of the war reserve designs with the existing W76 JTA antenna system. However, we have given priority to the war reserve design -- changes to some of the JTA RF system cable routing and component mounting may be necessary for some of these candidates.

7.2.8.2 (U) Shipping And Storage Container

(U) The LL4 designs are compatible with the existing MK4 shipping and storage container.

b(3) DOE DTRA

7.2.8.3 (U) Lifetime

(U) The comments relative to the lifetime of the LL5 candidates (Section 5.2.8.3) apply to the LL4 designs as well.

7.2.8.4 (U) Reliability

The reliability estimates for the LL4 candidates are shown in Table 7.2-2.

b(3) DOE DTRA

The estimates in the Table were calculated

using the differences in the unreliabilities of candidate components relative to the corresponding W76 components.[4]

TABLE 7.2-2
(U) RELIABILITY OF LL4 CANDIDATES

b(3)
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b(3)
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DTRA

7.3 (U) THE 10 QUESTIONS OF DoD INSTRUCTION 5030.55

1. (U) What nuclear devices in production or under development appear to meet the requirement? What are the advantages and disadvantages of each? If no qualified devices are under development or in production, what are the characteristics of conceivable warheads that would meet this requirement?

   (U) No devices are in production or under development that meet the requirements. One existing device can be adapted to the MK4 RB with space and volume available for hazard protection.

   (U) Conceivable warheads that would meet the requirement(s) must provide increased safety over existing SLBM warheads, survive specialized environments of strategic reentry systems, and package in existing RBs.

2. (U) Considering only the development of this particular warhead/bomb, and without regard to other programs that might be conducted concurrently, what is the estimated length of time required for development after DoD request commencement of a Phase 3 development engineering project?

   (U) For pit reuse candidates, 5 year Phase 3, plus 2-3 years Phase 4 and Phase 5 first production before delivery to the DoD. If plutonium fabrication is required, delivery to the DoD would begin in over 10 years.

3. (U) In the context of the overall atomic energy program, what time scales might be expected for development after Phase 3 authorization during the course of a normal program? What technical development problems would be involved if the time scales were significantly decreased?

   (U) Same as above.

   (U) Decreased time scales would increase risk of fielding a warhead with a design flaw that would prevent meeting performance, surety or reliability goals.

4. (U) What development problems can be foreseen that appear difficult to solve? Do any problems require development effort on a scale that is greater or less than normal?

b(3) DOE DTRA

Candidates without this type of pit would not require this new facility.

5. (U) What special training operational, or logistical problems are foreseen concerning the warhead that should be considered for Phase 3 development engineering?

(U) The inclusion of use control features will impact the Navy's current logistics and operations.

6. (U) What, if any, additional experimental or theoretical investigation is required to establish feasibility?

(U) Beyond-one-point-safety analysis has not been performed for any candidate during Phase 2. Selection of a candidate would mean additional theoretical and possibly experimental investigation would be required.

7. (U) What is the technical evaluation and/or recommendation made by the DOE representatives concerning nuclear testing prior to weaponizing the device for stockpile?

(U) None of the MK4A candidates can be developed without further nuclear testing. See Section 12.3 for a summary.

8. (U) What possible technical or economic advantages or nuclear materials savings would accrue from reasonable warhead/weapon system tradeoffs and changes in the requirements stated in the authorization for the Phase 2 feasibility study such as use of "natural" versus specified yields, alternative warhead or limited life

8. COMPATABILITY OF MK4A CANDIDATES W/WS

8. (U) COMPATIBILITY OF MK4A WARHEAD CANDIDATES WITH THE WEAPON SYSTEM

8.1 (U) INTRODUCTION

(U) In June of 1992, a MK4A Phase 2 (Design Feasibility) effort was kicked off using the groundrules of Table 6.1-1. As part of this effort LMSC 1) defined allowable mass/center combinations within which the DOE laboratories could create various alternative warhead concepts and 2) assessed the feasibility and compatibility of each candidate concept with the MK4 on the C4 and D5 missile systems.

(U) Section 8.2 will summarize the analysis which produced the boundaries seen in Figure 8.1-1. Each of the boundaries represents limitations imposed by a component of the overall missile system. Section 8.2 will also describe the principal limits imposed by the MK4 on C4 or D5.

8.2 (U) MASS PROPERTIES LIMITATIONS

(U) This section summarizes the MK4A RBA and C4 or D5 missile component limitations imposed on the design RB candidates. Each of the limiting boundaries shown in Figure 8.2-1 will be identified and the limiting mechanism called out. The MK4A limits are as follows:

- Release assembly structural limit during first stage ignition
- Reentry body aerodynamic stability (during reentry)
- Maintain current MK4 Interface Control Drawing (ICD) minimum weight limit

For MK4A, all missile related limits were driven by the D5 missile.

8.2.1 (U) POWERED FLIGHT

(U) Several missile events were investigated during the early portion of Phase 2, that is, during the time the design space was defined. The impact of these events on RBA performance was assessed and limits drawn. The environments of concern include the following: 1) a stowage shock event; 2) underwater launch;

b(3)
DOE
DTRA

FIGURE 8.2-1
(U) MK4A MASS PROPERTIES LIMITATIONS

3) first stage ignition and flight; 4) second stage ignition and flight; and 5) post boost flight and RB separation. Third stage ignition and flight were not seen as potential driving environments.

[redacted] Structural Mechanics evaluated several tactical MK4/D5 payload configurations with the objective of finding the limiting conditions to be imposed on the MK4A RBA on the D5 missile.

b(3)
DOE
DTRA

8.2.2 (U) DEPLOYMENT/SEPARATION MECHANICS

(U) During the design space definition process no limiting condition was identified for separation mechanics which would further reduce the design space of Figure 8.2-1. Reentry body separation velocities and spin rates all varied as expected as weight and CG combinations were evaluated, but again no limiting condition was found.

8.2.3 (U) AERODYNAMICS

(U) Reentry Aerodynamics assessed the MK4 RB's ability to maintain basic stability as weight and CG were varied. Aerodynamically, there was no concern and

therefore no limitation for the CG in the most forward possible position (i.e., towards the nosetip). The objective was to define the most aft CG position for possible MK4A candidate designs, while still maintaining a positive static margin and hence a stable RB for the current flight environment ranges.

(U) The analysis concentrated on the UL null range and the LL zero angle of attack deployments as the trajectories that would set the CG requirements. For null range deployment minimum static margin occurs during high altitude reentry, while for zero angle of attack minimum static margin occurs at low mach numbers at impact (as the mach number decreases, the center of pressure moves forward toward the center of gravity).

(U) The aerodynamic analysis employed a Monte Carlo procedure to probabilistically determine the static margin. Nine weight/CG configurations were analyzed to define the limits shown in Figure 8.2-1. For the MK4A candidates the stability limit was initially selected to be 0.1% static margin, similar to the MK4. Given the inherent uncertainties which came with extrapolating aerodynamic performance at increased RB weights, an uncertainty area was defined which accounted for these uncertainties and which provided the Design Laboratories with a design space which encouraged them to keep the CG as far forward as possible.

8.2.4 (U) THERMODYNAMICS

(U) One of the concerns that was investigated for the MK4A RB Phase 2 candidates was the heatshield and substrate temperature performance. Increasing the total RB weight will increase the RB ballistic coefficient and accordingly the reentry velocities. The increased velocities will in turn increase the heat rates and potentially the total heating on the body (increased velocities will also reduce the down time, therefore a trade-off is made with heat rate and time in the atmosphere).

(U) Three separate regions in the aeroshell have temperature limitation criteria. First, the aluminum substrate temperature; second, the temperature of the bond material between the substrate and the heatshield; and third, the heatshield temperature 50 mils from the bondline. These criteria are not a limitation for the

MK4A candidates for principally two reasons: 1) the aeroshell cone angle is lower for the MK4A; and 2) more importantly, the MK4A RB has no weather cloud specification as a design requirement.

8.2.5 (U) ADDITIONAL LIMITATIONS ANALYSES

(U) In order to increase confidence in the calculated limitations and to assure ourselves that as many as possible of the design drivers had been investigated several other reentry body and missile body analyses were performed. None of the analyses described in this section limit the design space except the ICD minimum weight limit, although other limits exist just outside of the limits shown in Figure 8.2-1.

(U) MK4A Nosetip Erosion

(U) Performance of the MK4 CMT nosetip was evaluated relative to the variations in reentry body weight and center of gravity. Approximately 20% additional weight could be accommodated before the nosetip overhang would be used up and a limit imposed. It should be noted that the increased weight would result in an increased ballistic coefficient (higher reentry velocities) and that the stagnation pressure seen by the nosetip would be larger than current flight test experience.

(U) MK4A Nosetip Thermal Strains

(U) As part of the MK4A Phase 2 study, analysis was performed to qualify the MK4A CMT graphite nosetip over the entire velocity-gamma (V–γ) map for a 20% increase in reentry weight. In this study, the finite element structural analysis results together with failure criterion were used to evaluate the structural reliability. This failure criterion is based on statistical theory and considers multi-axiality of stress states, surface and internal flaw equivalence, grain orientation (across the grain and with grain), volume of tensile stress, and temperature effects.

(U) The analytical results indicate the structural reliability (probability of survival) exceeds 0.999 over the entire V–γ map for both the MK4A (20% increase in reentry body weight) and the MK4 tactical (nominal weight).

(U) MK4A Thruster Pad Stress

(U) With the increased weights being considered for candidate MK4A RBs, the resulting stress levels in the RB thruster pads were investigated. For the design space weight increases, thruster pad stresses remained below critical levels and therefore, was not a limiting issue.

(U) MK4A Heatshield Char Sloughing

(U) One area which has on-going analysis is char loss or char sloughing. The MK4 forward heatshield wrap direction (forward-facing) is known to experience sudden loss of the char-layer during flight on severe reentry trajectories (Upper-Middle). In the extreme, loss of the insulation performance of the char could lead to excessive temperature to the RB forward structure. There are studies underway to better understand char loss and the potential for multiple char losses. As criteria for char loss are established, they will be applied to the Phase 2 warhead designs to determine if a weight increase constraint should be adjusted.

(U) MK4A Moments of Inertia Variations

(U) In order to increase confidence in the calculated limitations and to assure ourselves that as many as possible of the design drivers had been investigated, several other reentry body and missile body analyses were performed. None of the analyses described in this section limit the design space except the ICD minimum weight limit, although other limits exist just outside of the limits shown in Figure 8.2-1.

(U) C4/D5 Nose Fairing and Third Stage Clearances

(U) An RB clearance analysis was made to see if the proposed Phase 2 weight/CG limits could cause any RB contact with the nose fairing (N/F) or third stage (T/S) motor during any stowage or boost phase events. For Phase 2, a weight/CG upper limit was defined for allowable designs (limited by the reentry body separation bolts, (see Section 8.2.1). The largest RB motions for the tactical D5 missile payloads occurred during the first stage motor ignition transient.

(SFRD) The critical MK4A D5 missile payloads (7 and 8 body configurations) were evaluated because these produced the largest RB radial loads. For these MK4A payloads and mass properties, there was no contact between the RB and N/F or T/S motor.

8.2.6 (U) MASS PROPERTIES SUMMARY

(U) The design space defined by the above mentioned limiting phenomena and shown in Figure 8.2-2 constituted the boundaries for the Design Laboratories. As noted on the figure, some areas in the weight/CG space were not assessed, but concepts would be evaluated case by case. All MK4A designs were in the appropriate design space.

8.3 (U) ELECTRICAL COMPATIBILITY

(U) This section describes the electrical compatibility assessments performed on the MK4A candidates. These assessments are divided into two sections. Section 8.3.1 describes the functional interface compatibility assessment which evaluates compatibility between the MK4A candidates and the C4 and D5 missiles. This section also includes a physical interface compatibility assessment of electrical components associated with the MK4A candidates. Section 8.3.2 addresses compatibility between the MK4A RBA and the existing W76/MK4 normal, abnormal, and hostile electrical environments, all of which were incorporated into the WXX/MK4A STS. Descriptions of MK4A use control features and their associated impacts on the C4 and D5 missile systems are provided in Section 10.

8.3.1 (U) FUNCTIONAL AND PHYSICAL INTERFACE COMPATIBILITY ASSESSMENTS

(U) The functional and physical interface compatibility assessments were top level evaluations which examined the functional and physical interface requirements of each of the MK4A candidates. Functional block diagrams of each of the candidates electrical systems and design similarity between the existing MK4 interfaces and the MK4A were used as a basis for the assessment because complete electronic system definition for any of the MK4A candidates has yet to be completed.

(U) The Phase 2 groundrules require that no changes are to be made in the physical or functional interfaces to the C4 and D5 missiles, except for software changes in fire control.

LANL/Sandia Candidates

(U) The electrical systems for LA4-1 and LA4-2 are identical, except for the addition of use control features on LA4-2. The electrical systems of candidates LA4-1 and LA4-2 are presented in the three following configurations:

A. New AF&F with Integrated Safing (C4 and D5)

(U) Electrical configuration A is based on a new AF&F design. The additional safety features are integrated into the new AF&F design resulting in no change to existing missile or MK4 RB cabling or connectors. This system is fully compatible with both the C4 and D5 missiles since it only requires existing MK4 electrical signals for operation. Therefore, this electrical system configuration is feasible based on functional and physical interface compatibility.

B. Modified AF&F: ESSG on RA (C4 and D5)

(U) Electrical configuration B is based on a modified AF&F design. It utilizes an Environmental Sensing Signal Generator (ESSG), battery, and G-switch mounted on the release assembly which provides the unique signals. This system is fully compatible with the C4 and D5 missiles since it only requires the existing MK4 electrical signals for operation. Therefore, this electrical system is feasible based on functional interface compatibility.

(U) This configuration requires a new sixteen pin IFD connector to accommodate the additional signals from the ESSG. A new connector is required since the existing connectors only have 14 pins maximum. This connector change does violate the Phase 2 groundrules.

(U) This sixteen pin system could be modified with the addition of multiplexing/ demultiplexing components in order to utilize a fourteen pin IFD connector, but there are potential weight and CG penalties associated with this modification which have not been fully assessed.

C. Modified AF&F: Utilizes MK5 Data Signals (D5 Only)

(U) Electrical configuration C like configuration B is based on a modified AF&F. It utilizes the MK5 data/data return lines in place of the release assembly mounted ESSG components to provide inflight data. To provide these signals to the MK4 requires modification to the "MK5 to MK4" adapter cable on the D5 missile. This violates program groundrules and would require further assessment.

LLNL/Sandia Candidates

(U) The electrical systems for the LLNL/Sandia candidates are provided in two configurations; one which utilizes an ESSG to provide the unique signals and one which utilizes the MK5 data signals from the D5 missile. The LL4-1a, LL4-2a, and LL4-3a utilize the existing MK4 AF&F which requires a separate DSSL driver, and the LL4-1b, LL4-2b, and LL4-3b candidates utilize a new MK4 AF&F which contains an integrated DSSL driver.

A. Existing AF&F: ESSG on RA (C4 and D5)

(U) Electrical configuration A is based on the existing MK4 AF&F. It utilizes an ESSG, G-Time actuated battery, and a mechanical lock mounted on the release assembly. These components are required to provide the unique signals. This system is fully compatible with the C4 and D5 missiles since it only requires the existing MK4 electrical signals from the missile for operation. It requires a fourteen pin connector to accommodate the three extra signals from the ESSG. No issues have been identified with this configuration; therefore, this electrical system is feasible based on functional and physical interface compatibility.

B. Existing AF&F: Utilizes MK5 Data Signals (D5 Only)

(U) Electrical configuration B like configuration A is based on the existing MK4 AF&F. It utilizes the MK5 data/data return lines in place of the release assembly mounted ESSG components to provide inflight data. A mechanical lock and G-Time actuated battery are also mounted on the release assembly. It requires a fourteen pin IFD connector to accommodate both the MK5 signals and the additional signal from the G-Time switch. To provide these signals requires modification to the "MK5 to MK4" adapter cable on the D5 missile.

8.3.2 (U) ENVIRONMENT COMPATIBILITY ASSESSMENT

(U) The environment compatibility/feasibility assessment was conducted to evaluate the compatibility between the STS normal, abnormal and hostile environments of an electrical nature and the MK4A candidates.

8.3.2.1 (U) Normal and Abnormal Environment Assessment

(U) The only normal environment of an electrical nature in the MK4A (and MK4) STS is the electromagnetic radiation environment (EMR). This environment also becomes an abnormal environment in the event the RB protective RF shield becomes damaged. The EMR environment includes an average power specification which is an adaptation of the Hazards of Electromagnetic Radiation to Ordnance (HERO) specification (Mil-Std-1385B), a peak power specification, an environment for an RB connected to test equipment or disassembled, and a deperming/degaussing environment. The two concerns associated with EMR are (1) the inadvertent initiation of ordnance devices, and (2) damage to electronic circuitry.

(U) Generally, EMR protection involves the shielding integrity of the RB which consists of the aluminum substrate and aft closure in addition to all the grounding, bonding, and shielding practices implemented in the original W76/MK4 design. Since these components and practices remain unchanged for the MK4A, and the MK4 margins for the environments are quite large, all of the MK4A candidates are feasible with respect to EMR. Design feasibility for any safing components located outside the aeroshell is not an issue as long as the same level of hardness is

incorporated into package design, especially if these packages contain sensitive electronic components or ordnance devices. Consequently, achieving feasibility with regard to EMR for all the MK4A candidates is not a concern.

(U) Protection against the lightning environment is mainly influenced by the same design attributes mentioned in regard to EMR. In addition to the aforementioned design attributes, the lightning arrestor connector (LAC) provides electrical protection by its voltage breakdown characteristics as demonstrated during MK4 development. Consequently, if this connector is used and similar grounding, bonding and shielding design attributes are implemented during the incorporation of additional electrical components as part of the MK4A program, feasibility with regard to the lightning environment should not be a concern for any MK4A candidate.

8.3.2.2 (U) Hostile Environment Assessment

(U) Electromagnetic effects such as electromagnetic pulse (EMP) are substantially mitigated by the shielding integrity of the RB. Since there are large margins associated with these environments and the grounding, bonding and shielding attributes associated with the MK4 aeroshell are unchanged, there are no issues associated with achieving feasibility for any candidate.

8.4 (U) INDIVIDUAL CANDIDATE STRUCTURAL ASSESSMENTS

(U) The approach taken to assess the structural feasibility of the individual Phase 2 candidate designs is illustrated in Figure 6.4-1. As shown, when the candidate designs were received an initial screening occurred which evaluated whether the candidate design fit within the weight and CG design space described in Section 8.2 (see Figure 8.2-1). Included in the screening was a check to see if an adequate set of analyses information was provided (i.e., candidate drawing, mass properties, mass distribution and stiffness). Then two sets of analysis were performed, one covering the candidate response to the normal reentry environments of the MK4A STS and one covering the candidate response to the hostile environments of the MK4A STS. The normal reentry analysis was performed first because of its more rapid

turn-around time. Feedback was then made to the Design Laboratories through the Design Integration Technical Working Group (DITWG). This feedback included both normal and hostile/vulnerability inputs.

(U) The approach taken by the normal and hostile/vulnerability reentry assessments is provided below. Both normal reentry and hostile reentry analyses produced statements of feasibility which are summarized in Table 8.4-1.

TABLE 8.4-1
(U) SUMMARY OF MK4A CANDIDATE
STRUCTURAL FEASIBILITY STATEMENTS

UNCLASSIFIED

Candidate	Feasibility	Comments
• LL4-1A	• Feasible as Proposed	
• LL4-1B	• Feasible with Potential Mod.	• AF&F Support Ring
• LL4-2A	• Feasible as Proposed	
• LL4-2B	• Feasible with Potential Mod.	• AF&F Support Ring
• LL4-3A	• Feasible as Proposed	
• LL4-3B	• Feasible with Potential Mod.	• AF&F Support Ring
• LA4-1	• Feasible with Reservations	• Insufficient Data to Adequately Assess
• LA4-2	• Feasible with Reservations	• Insufficient Data to Adequately Assess

(U) Normal Reentry

(U) The approach utilized during the normal reentry assessment consisted of the information flow illustrated in Figure 6.4-1 which culminated with the structural assessment. Existing MK4 and MK5 ground and flight test data, extensive reentry body design experience, design similarity and finite element modeling of the candidates were the tools used for analysis. Table 6.4-2 shows the analytic approach taken which was a function of the candidate design data received and the similarity of the design to past experience.

(U) Two reentry body to NEP design areas were of most importance to the normal reentry assessment. The configuration of the forward warhead support (or wedge) and the aft warhead support (or mount). The method of attachment and the type of material utilized each contributed in determining the analysis approach chosen. All of the candidate designs had common components in these two areas which aided in completing all of the analysis associated with twenty six or more candidates within the time allotted.

(U) Hostile Environments Approach

(U) To expedite the feasibility assessment, LMSC made maximum use of the available MK4 and MK5 RB analytical models developed from the prior MK4 and MK5 programs. One model used was the DYNA3D MK4 full-body model. This model was used as appropriate during the assessment considering: 1) the required degree of accuracy, and 2) the possibility of establishing concept feasibility by analogy/similarity and by inference from previous analysis and test experience.

(U) In order to accommodate the assessment of the large number of candidates that have been generated during the Phase 2 program, LMSC utilized similarity in the candidate's forward and aft mounting design features to assemble them into two groups for the MK4A candidates. This grouping was done to more efficiently analyze the many proposed candidates. As successive candidates from these groups were analyzed the performance/response of the aeroshell due to the common design feature was better understood and this understanding was then applied to subsequent candidate assessments. This increased understanding also applied to

identifying the hostile environment which most stressed the candidates and their common design feature. Figure 8.4-1 illustrates the two candidate groups associated with the MK4A.

(U) The baseline designs for all six LL4-X candidates include an Advanced Heather gas transfer system, although two other gas systems were available for use. During the LMSC vulnerability assessment the baseline system was utilized in the full-up analyses for each of the candidates. LMSC evaluated the LL4-1a design to see if variations in the gas transfer system would significantly alter component response. It was found that, for the weight variations seen between the three gas systems, component responses were similar and therefore, the feasibility statement made for each of the baseline systems apply for all of the possible gas systems.

(U) MK4A Single Forward Support Group

(U) For the MK4A Single Forward Support Group both the forward and aft support designs were significantly different from those of the W76/MK4. Therefore, a coupled full-body DYNA3D analysis was performed for two representative concepts, LL4-1a and LL4-1b. All three hostile environments, cold X-ray impulse, hot X-ray TSR and blast, were analyzed. The feasibility of the remaining concepts in this group was assessed based on similarity to these two candidates.

(U) MK4A W76/MK4-Like Support Group

(U) For the MK4A W76/MK4-Like Support Group both the forward and aft support designs are similar to the W76/MK4 design. The only concept in this group was LA4-1.

(U) The analysis approach chosen for each candidate was dependent on the design data provided. Table 6.4-2 illustrates the various types of data (levels of design definition) that were received from the DOE Laboratories and the associated aeroshell structural analysis approach(s) that could be taken. As can be seen from the table the level of design detail covers the spectrum of finite element model (FEM) to a sketch or drawing. Once an approach was identified the objective, as stated earlier, was to assess the design response to the hostile environments defined in the respective STS documents and to provide a statement of feasibility.

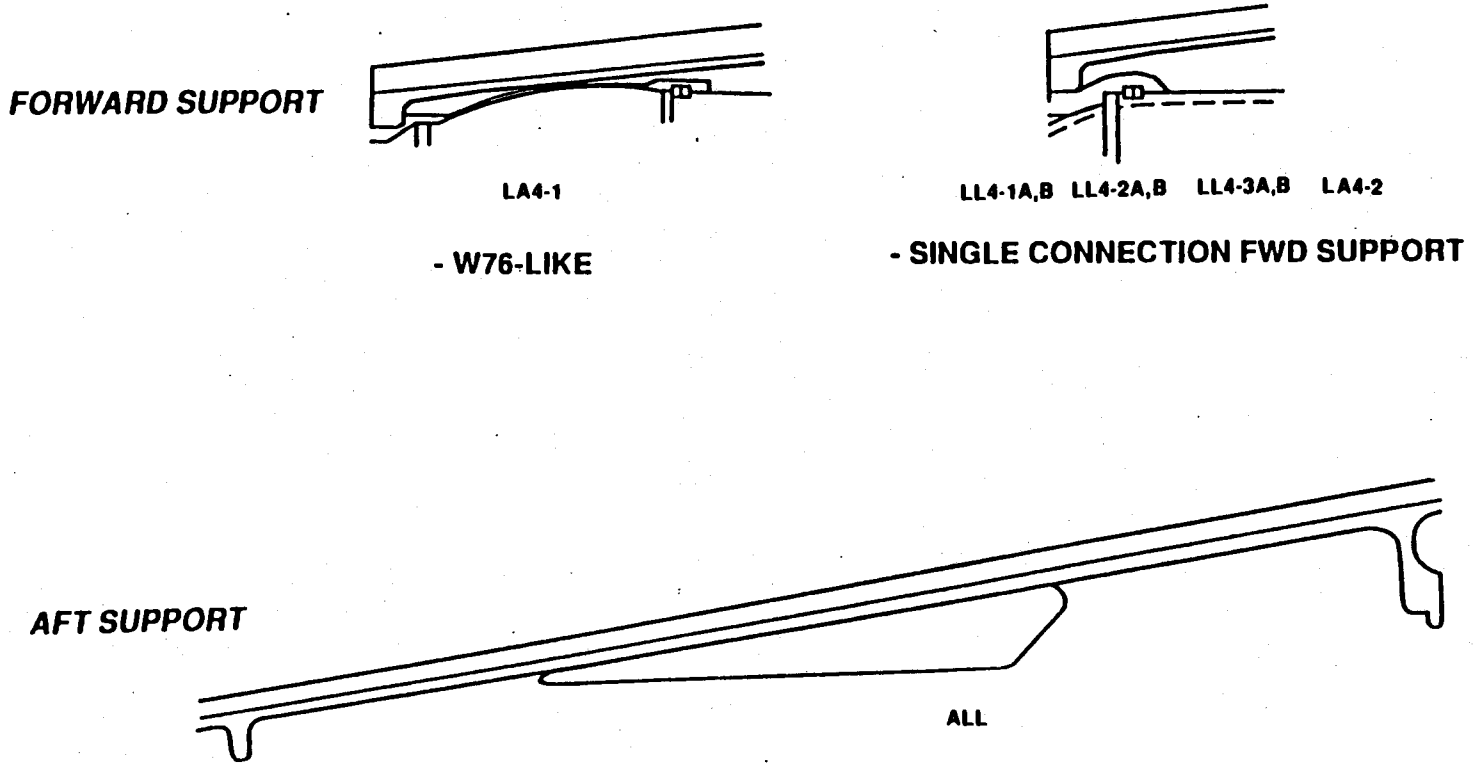

FIGURE 8.4-1
(U) MK4A GROUPS: SINGLE CONNECTION & W76-LIKE FORWARD MOUNTS

UNCLASSIFIED
UNCLASSIFIED

(U) The statements of feasibility were structured so as to cover the range of possible analytic conclusions, and are provided below:

1) the design is feasible as proposed or feasible with identified modifications,
2) the design is feasible with reservations,
3) the design is not feasible, or
4) insufficient data provided to adequately assess the candidate.

The second statement covers candidates where the identified design modification may not have a high level of confidence, or where the candidate requires a reduction in the hostile environment in order to be feasible, or where a reduction in candidate weight/center of gravity is required for candidate feasibility.

(U) Inherent in a Phase 2 study are uncertainties due to design maturity and uncertainties in modeling the performance of new design configurations. With this level of uncertainty, results which indicated yielding of component hardware were identified and design solutions recommended.

(U) Scope

b(3)
DoE
DTRA

(U) Structural vulnerability assessments of the reentry body aeroshell included the following: 1) evaluation of the relative deflection of DoD/DOE components (i.e., AF&F to aeroshell substrate, NEP to seal cover, and NEP to aeroshell substrate), 2) evaluation of forward warhead support stresses, 3) evaluation of aft warhead

support stresses, 4) evaluation of forward and aft substrate yielding and buckling at critical locations along the aeroshell, 5) evaluation of manufacturing joint region yielding and 6) evaluation of nosetip dynamic fracture. Each of the above mentioned responses can be caused by terminal air blast, side-on hot X-ray thermal structural response (TSR) and/or side-on impulse from cold X-ray encounters.

(U) Large relative deflections of the components inside the RB can cause physical impact and cable crushing during vulnerability encounters. Excessive stresses produced in the RB components can cause loss of structural integrity (i.e., yield or failure).

(U) In the following sections a summary of the vulnerability assessment made for each candidate will be presented, including a statement of feasibility regarding the candidate's material and structural responses to the MK4A hostile environments.

8.4.1 (U) LL4-1a STRUCTURAL ASSESSMENT SUMMARY

8.4.1.1 (U) LL4-1a Design Description

b(3)
DOE
DTRA

[redacted]

FIGURE 8.4.1-1

(U) LL4-1a FULL BODY PROFILE

b(2)

Date

Dra

b(3)
DOE
DTRA

FIGURE 8.4.1-2
(U) NEP COMPARISON

b(3)
DOE

FIGURE 8.4.1-3
(U) FORWARD WARHEAD SUPPORT

b(3)
DOE
DTRA

FIGURE 8.4.1-4
(U) AFT WARHEAD SUPPORT

b(3) DOE DTRA

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 W76/MK4. Candidate mass properties (RB weight and CG location) are shown in Figure 8.2-2.

(U) For either the MK4/D5 or MK4/C4 RB configuration some modification to the RBA would be required to accommodate the use of an additional nuclear safety strong link. An additional 1 to 3 components would need to be mounted on the RA to activate and power the additional strong link. The MK4 IFD needs to be replaced by a MK5-size IFD insert (to accommodate the additional pins required for the safety components). New RB and RA cable assemblies would need to be fabricated.

(U) LL4-1a requires some forward ballasting to meet the mass property design space limit. This task can be accomplished by either DoD or DOE.

b(3) DOE DTRA

b(3)
DOE
DTR

FIGURE 8.4.1-5
(U) FWD SHELL MODIFICATION

8.4.1.2 (U) LL4-1a Normal Reentry Structural Assessment

(U) Analysis Approach

(U) The LL4-1a concept was assessed early in the assessment period. The approach used to assess the LL4-1a concept was predicated on the design attributes of the forward warhead support and the aft warhead wedge support. (See Figure 8.4.1-1). The LL4-1a concept had a forward warhead support design similar to the MK4 tactical design. This area was assessed using existing MK4 capability curves. The aft warhead support wedge area was originally substantially different from the MK4 tactical design and was assessed using a Finite Element analysis. The seal cover design was similar to the MK4 tactical, although a programmer has been mounted to it. Given the similarity to MK4 the seal cover was assessed to be good by inspection. (See Figure 8.4.1-1). The warhead attach, the wedge, and the seal cover designs were assessed for the critical MK4 V–γ trajectories (upper middle-UM, max axial and max transverse).

(U) Assessment Results

(U) The assessment of the LL4-1a design reflected positive margins with the exception of the aft wedge which had a negative margin. This negative margin was caused by the smaller original wedge design that was located further forward than the MK4 tactical wedge. It was suggested and subsequently implemented that a longer wedge be included in the design and this was incorporated in the latest design.

8.4.1.3 (U) LL4-1a Hostile Reentry Structural Assessment

(U) As mentioned in the beginning of this section, the baseline designs for all six LL4-x candidates include an Advanced Heather gas transfer system, although Acorn and Heather gas systems were available for use. During the LMSC vulnerability assessment the baseline system was utilized in the full-up analyses for each of the candidates. LMSC evaluated the LL4-1a design to see if variations in the gas transfer system would significantly alter component response. It was found

that, for the weight variations seen between the three gas systems component responses were similar and therefore, the feasibility statement made for each of the baseline systems apply for all of the possible gas systems.

(U) Material Vulnerability Assessment

b(3)
DOE
DTR

(U) Structural Vulnerability Assessment

(U) The forward and aft warhead supports and the NEP of the LL4-1a concept were quite different from those of the MK4 baseline as seen in Figures 8.4.1-3 and 8.4.1-4. Issues important to structural vulnerability were the differences in the forward support Alvis joint connection (activated when the forward support is under tension during blast, TSR and impulse encounters), the aft support and the AF&F Support ring. For the aft support, the inner foam support in the W76/MK4 was eliminated due to a larger aft warhead radius. The outer foam wedge was used and is similar to the W76/MK4.

(U) A full-body finite element (DYNA3D) analysis was performed to assess the effects of blast, TSR and impulse forcings. The model used was the existing LMSC MK4 full-body DYNA3D model in which the model for the NEP and its support was replaced with a LLNL-supplied DYNA3D model for the LL4-1a NEP. Additional concentrated masses were added to the aeroshell model to simulate the ballast of 10 lbs. attached at the nose anvil (Figure 8.4.1-1). Also, modifications were

made to simulate the AF&F support ring. The interface accounts for sliding and gap opening, elasto-plastic behavior of metal parts and dynamic structural instability.

(U) The aft-on impulse and TSR load from the aft-on cold X-ray exposures were not analyzed, because, based on past MK4 test experience, their effect is felt mostly at the aft cover and is attenuated rapidly as it moves forward through the RB structure. Since the design in this region remains the same no analyses were needed.

(U) Assessment Results

(U) LL4-1a assessment results showed that the principal structural responses of peak stress, and deflection were acceptable for the blast, TSR and impulse forcings.

(U) Both low and high frequency responses for the critical aeroshell regions, as assessed by DYNA3D blast, TSR and impulse analyses, indicated that small increases occurred in the low-frequency response levels relative to W76/MK4 responses. These response increases, though, did not exceed the design allowables.

(U) Peak relative deflections seen at hardware interfaces were found to be driven by the blast environment. The most critical response was the relative axial deflection between the AF&F tip and the aeroshell substrate. Analysis showed that this deflection was less than the existing gap width and therefore, the design was considered acceptable. Cable crushing resulting from relative lateral deflections between the NEP and the inside surface of the substrate was also found to be less than the existing gap.

(U) Additionally, the peak stresses in the aeroshell substrate, forward support, Alvis joint and the aft foam support were all below allowables for blast, hot X-ray (TSR) and cold X-ray (impulse) loadings.

(U) Finally, the possibility of shell buckling was found not to be an issue with this candidate. This was confirmed for each loading by inspecting the deformation shape of the DYNA3D model at peak response times for any indication of buckling collapse.

8.4.1.4 (U) LL4-1a Candidate Feasibility Statement

(U) Analysis of the LL4-1a candidate was accomplished early in the assessment period and concluded that the design was feasible as proposed. During the assessment period modifications were made to the LL4-1a design by the DOE laboratories to improve its performance in normal, as well as hostile environments. These modifications included the addition of foam filler around the NEP, lengthening the aft warhead support and utilizing the W76/MK4-like preloads in the aft warhead support design. These updates have been reviewed with the result being that the LL4-1a candidate was assessed as feasible as proposed.

8.4.2 (U) LL4-1b STRUCTURAL ASSESSMENT SUMMARY

8.4.2.1 (U) LL4-1b Design Description

b(1)
DOE
DTRA

(U) This concept is almost identical to LL4-1a with the exception of the new AF&F. In order to accommodate the new AF&F the anvil on the inside front end of the substrate must be removed. See Figure 8.4.2-2. The new AF&F radar may not be compatible with the existing W76/MK4 antenna system and would require further evaluation. This design also utilizes a PEX Booster which is incorporated in the new AF&F.

(U) The NEP is identical to LL4-1a without exception. Thus the forward and aft warhead supports are identical to LL4-1a. The seal cover is also identical to LL4-1a.

(U) Use control capability and material concerns are identical to that of LL4-1a. Safety-related component and cabling issues are also identical to that of LL4-1a. The mass properties (RB weight and CG location) of this design are shown in Figure 8.2-2.

SECRET//REL TO USA, AUS, CAN, GBR, NZL

FIGURE 8.4.2-1

(U) LL4-1b FULL BODY PROFILE

b(3)
DOE
DTRA

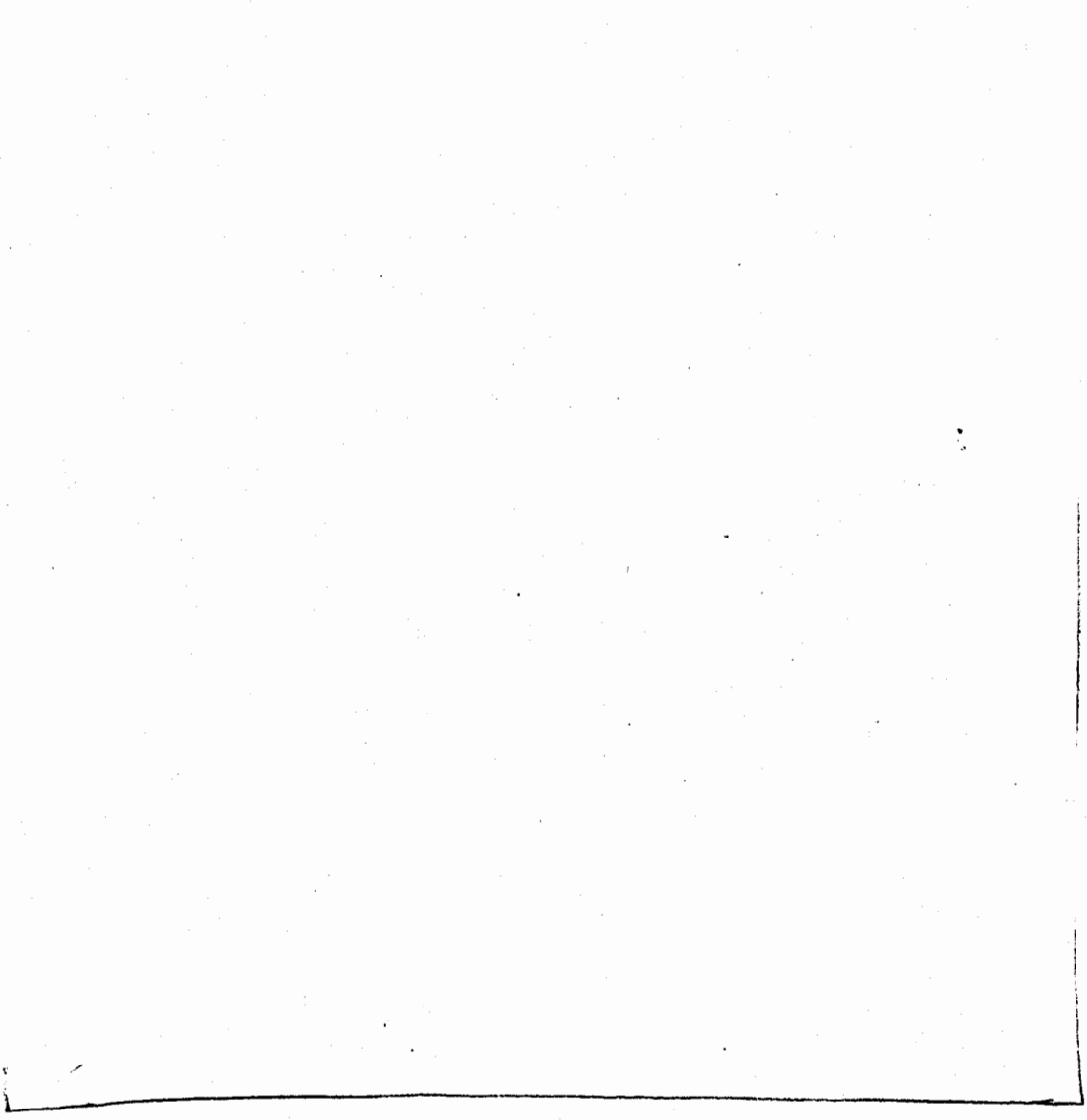

FIGURE 8.4.2-2
(U) NEP COMPARISON

b(3)
DOE
DTRA

(U) FORWARD WARHEAD SUPPORT

b(3)
DOE
DNA

FIGURE 8.4.2-4
(U) AFT WARHEAD SUPPORT

(U) Any ballasting required will be incorporated in the new AF&F. All DoD forward ballasting capability (see the LL4-1a assessment) has been replaced by the new AF&F (Figure 8.4.2-5).

(U) As in LL4-la, MK4/D5 and MK4/C4 RAs will also need to be modified to accommodate the added safety related components. Like LL4-1a, the proposed CAT-E PAL use control capability is feasible and the concept is compatible with all the missile physical and functional interfaces. Housing the additional safety components on the RA is feasible and will require structural modification to the RAs.

8.4.2.2 (U) LL4-1b Normal Reentry Structural Assessment

(U) Analysis Approach and Results

(U) LL4-1a and b, LL4-2a and b and LL4-3a and b candidates have been grouped because of their commonality in design and have been assessed as one configuration. See Section 8.4.1.2.

8.4.2.3 (U) LL4-1b Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

(U) The design differences of the LL4-1b and the LL4-1a do not affect this response. Therefore the conclusion for LL4-1b is the same as for LL4-1a which was acceptable. See Section 8.4.1.3..

(U) Structural Vulnerability Assessment

(U) The LL4-1b analysis used the same full-body finite element (DYNA3D) model of LL4-1a modified to reflect the additional 5.2 lbs of weight and the slightly forward CG position of the new AF&F in LL4-1b. The same critical regions and loadings were examined for LL4-1b as for LL4-1a. The results showed that the general responses were below allowables, although the most critical response, the substrate stress in the forward frustum, has small local yielding. Design feasibility should be attainable, as further studies would identify specific design solutions.

b(3)
DOE
DTRA

FIGURE 8.4.2-5
(U) AF&F COMPARISON

UNCLASSIFIED

[redacted]

UNCLASSIFIED

b(3)

FIGURE 8.4.3-1

(U) LL4-2a FULL BODY PROFILE

b(3)
DoE
DTRA

FIGURE 8.4.3-2
(U) NEP COMPARISON

UNCLASSIFIED

b(3)
DOE
DTRA

FIGURE 8.4.3-3
(U) FORWARD WARHEAD SUPPORT

UNCLASSIFIED

b(3)
DOE
DTRA

FIGURE 8.4.3-4
(U) AFT WARHEAD SUPPORT

of the connector on the aft closure its design remains very similar to the W76/MK4. Candidate mass properties (RB weight and CG location) of this design are shown in Figure 8.2-2.

(U) For either the MK4/D5 or MK4/C4 RB configuration some modification to the RBA would be required to accommodate the use of an additional nuclear safety strong link. An additional 1 to 3 safety-related components would need to be mounted on the RA to activate and power the additional strong link. The MK4 IFD needs to be replaced by a MK5-size IFD insert (to accommodate the additional pins required for the safety components). New RB and RA cable assemblies would need to be fabricated.

(U) Like LL4-1a, LL4-2a requires some forward ballasting to meet the mass properties limits mentioned in Section 8.2. This task can be accomplished by either DoD or DOE.

(U) This design is not fully compatible with existing DoD hardware and will require some changes to the existing AF&F shielding for forward ballasting and both the MK4/D5 and MK4/C4 RAs for mounting added safety components. The proposed CAT-E PAL use control capability is feasible and the concept is compatible with all the missile physical and functional interfaces. Housing the additional safety components on the RA is feasible and will require structural modification to the RAs. Forward ballasting will require changes to existing DoD and DOE hardware (see LL4-1a assessment).

8.4.3.2 (U) LL4-2a Normal Reentry Structural Assessment

(U) Analysis Approach and Results

(U) LL4-1a and b, LL4-2a and b, and LL4-3a and b candidates have been grouped because of their commonality in design and have been assessed as one configuration. See Section 8.4.1.2.

8.4.3.3 (U) LL4-2a Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

b(3)
DOE
DTRA

(U) Structural Vulnerability Assessment

(U) The structural response of the LL4-2a was expected to be similar to that of LL4-1a, as well. According to LLNL's information, the stiffness and mass distribution of LL4-1a should be used for the LL4-2a evaluations, even though the warhead contour is different at the forward end. In addition, the forward support stiffness/strength of LL4-1a can be duplicated in LL4-2a because sufficient space exists to arrive at such a design.

8.4.3.4 (U) LL4-2a Candidate Feasibility Statement

(U) The feasibility of LL4-2a (Figure 8.4.3-1) candidate design was assessed in reference to LL4-1a because of design similarity and the common stiffness and mass distribution data received. A longer forward mount was used in LL4-2a to reach the forward portion of the warhead because it was smaller than the LL4-1a design. This candidate was evaluated to be feasible as proposed.

8.4.4 (U) LL4-2b STRUCTURAL ASSESSMENT SUMMARY

8.4.4.1 (U) LL4-2b Design Description

b(3)
DOE
DTRA

b(3)
DOE
DTRA

FIGURE 8.4.4-1
(U) LL4-2b FULL BODY PROFILE

UNCLASSIFIED

b(3)
DOE
DTRA

FIGURE 8.4.4-2
(U) NEP COMPARISON

UNCLASSIFIED

UNCLASSIFIED

b(3)
DOE
DTRA

FIGURE 8.4.4-3
(U) FORWARD WARHEAD SUPPORT

UNCLASSIFIED

b(3)
DOE
DTRA

FIGURE 8.4.4-4
(U) AFT WARHEAD SUPPORT

UNCLASSIFIED

(U) This concept is almost identical to LL4-2a with the exception of the new AF&F. In order to accommodate the new AF&F the anvil on the inside front end of the substrate was removed. The new AF&F radar may not be compatible with the existing W76/MK4 antenna system and would require further evaluation. This design also utilizes a PEX Booster which is incorporated in the new AF&F.

(U) The NEP is identical to LL4-2a without exception. Thus the forward and aft warhead supports are identical to LL4-2a. The seal cover is also identical to LL4-2a.

(U) Use control capability and material concerns are identical to that of LL4-2a. Safety-related component and cabling issues are also identical to that of LL4-2a. The mass properties (RB weight and CG location) of this design are shown in Figure 8.2-2.

(U) Any ballasting required will be incorporated in the new AF&F. All DoD forward ballasting capability (see the LL4-1a assessment) has been replaced by the new AF&F.

(U) As in LL4-1a, MK4/D5 and MK4/C4 RAs will also need to be modified to accommodate the added safety related components. Like LL4-1a, the proposed CAT-E PAL use control capability is feasible and the concept is compatible with all the missile physical and functional interfaces. Housing the additional safety components on the RA is feasible and will require structural modification to the RAs.

8.4.4.2 (U) LL4-2b Normal Reentry Structural Assessment

(U) Analysis Approach and Results

(U) LL4-1a and b, LL4-2a and b, and LL4-3a and b candidates have been grouped because of their commonality in design and have been assessed as one configuration. See Section 8.4.1.2.

b(3)
DOE
DTRA

FIGURE 8.4.5-1
(U) LL4-3a FULL BODY PROFILE

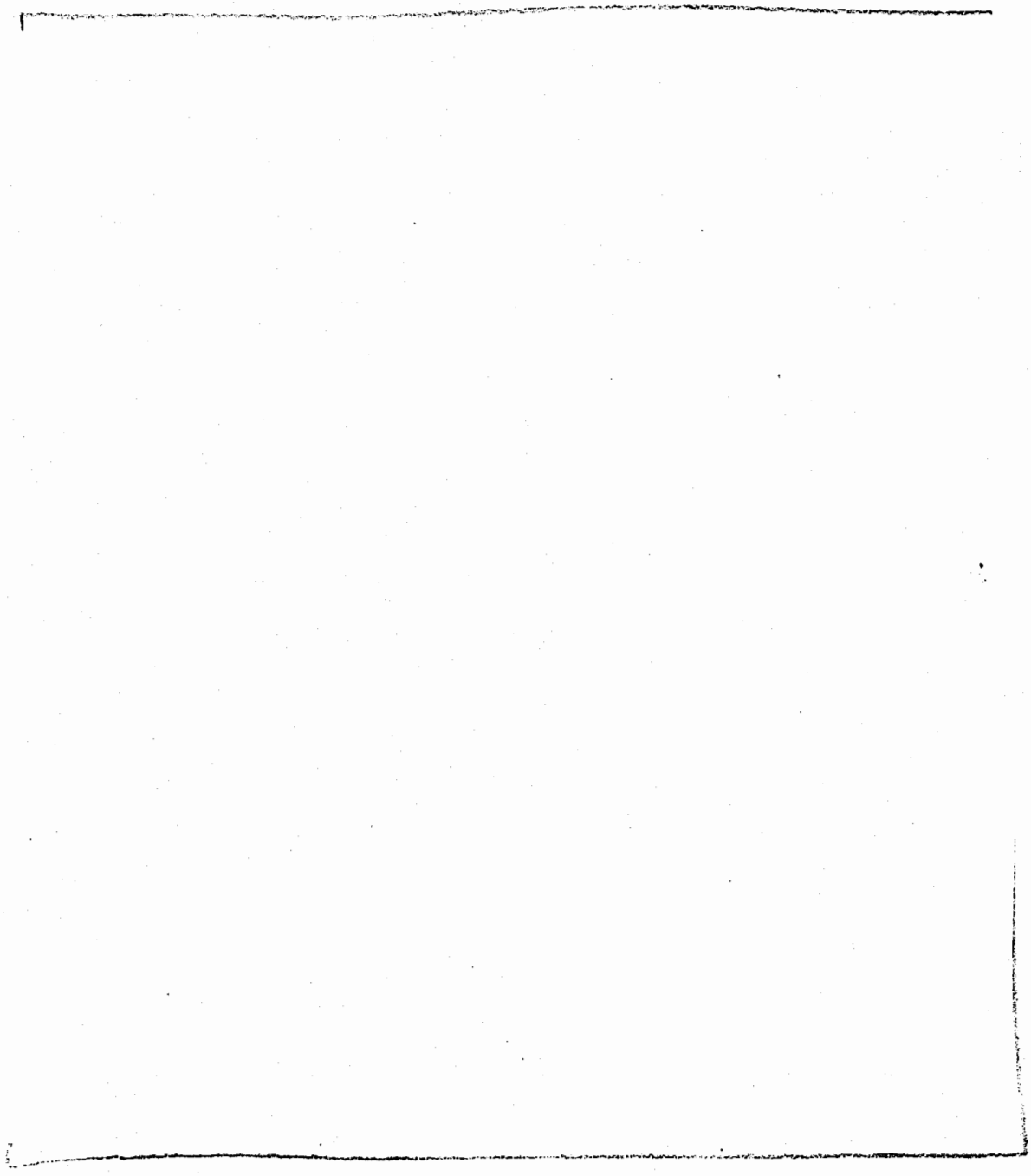

FIGURE 8.4.5-2
(U) NEP COMPARISON

b(3)
DOE
DTRA

FIGURE 8.4.5-4
(U) AFT WARHEAD SUPPORT

b(3) DOE DTRA

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. b(3) DTRA Other than the addition of the connector on the aft closure its design remains very similar to the W76/MK4. Candidate mass properties (RB weight and CG location) of this design are shown in Figure 8.2-2.

(U) For either the MK4/D5 or MK4/C4 RB configuration some modification to the RBA would be required to accommodate the use of an additional nuclear safety strong link. An additional 1 to 3 components would need to be mounted on the RA to activate and power the additional strong link. The MK4 IFD needs to be replaced by a MK5-size IFD insert to accommodate the additional pins required for the safety components. New RB and RA cable assemblies would need to be fabricated.

(U) Like LL4-1a, LL4-3a requires some forward ballasting to meet the mass properties limit described in Section 8.2. This task can be accomplished by either DoD or DOE.

b(3) DOE DTRA

Housing the additional safety components on the RA is feasible but will require structural modification to

the RAs.

b(3) DOE DTRA

8.4.5.2 (U) LL4-3a Normal Reentry Structural Assessment

(U) Analysis Approach and Results

(U) LL4-1a and b, LL4-2a and b, and LL4-3a and b candidates have been grouped because of their commonality in design and have been assessed as one configuration. See Section 8.4.1.2.

8.4.5.3 (U) LL4-3a Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

(U) Early time material responses will not be significantly affected by the design differences between the LL4-3a and the LL4-1a. Therefore, no additional material vulnerability concerns were identified.

(U) Structural Vulnerability Assessment

(U) The late-time structural response of this candidate was assessed to be similar to LL4-1a because the stiffness and mass distribution of LL4-1a NEP were provided for use in assessing the LL4-3a candidate. Therefore, by analogy to the feasible LL4-1a design, the LL4-3a design is also feasible as proposed.

8.4.5.4 (U) LL4-3a Candidate Feasibility Statement

(U) The feasibility of the LL4-3a candidate design was assessed in reference to the LL4-1a because of design similarity and the common stiffness and mass distribution data received. These two designs are identical except for some differences in warhead or NEP internals. The results of the assessment were a feasible as proposed evaluation.

8.4.6 (U) LL4-3b STRUCTURAL ASSESSMENT SUMMARY

8.4.6.1 (U) LL4-3b Design Description

b(3)
DOE
DTRA

(U) Note that this concept is almost identical to LL4-3a with the exception of the new AF&F. In order to accommodate the new AF&F the anvil on the inside front end of the substrate was removed. The new AF&F radar may not be compatible with the existing W76/MK4 antenna system and will require further assessment. This design also utilizes a PEX Booster which is incorporated in the new AF&F.

(U) The NEP is identical to LL4-3a without exception. Thus the forward and aft warhead supports are identical to LL4-3a. The seal cover is also identical to LL4-3a.

(U) Use control capability and material concerns are identical to that of LL4-3a. Safety-related component and cabling issues are also identical to that of LL4-3a. The mass properties (RB weight and CG location) of this design are shown in Figure 8.2-2.

(U) Any ballasting required will be incorporated in the new AF&F. All DoD forward ballasting capability (see the LL4-1a assessment) has been replaced by the new AF&F.

(U) This design may be not fully compatible with the existing DoD hardware depending on the radar selected. Like LL4-1b, the new AF&F radar compatibility with the existing W76/MK4 antenna system will need to be assessed when more detailed design information is available. As in LL4-3a, MK4/D5 and MK4/C4 RAs will need to be modified to accommodate the added safety related components. The forward aeroshell also needs to be modified to accommodate the new AF&F (the forward ballast would be incorporated into DOE components). Like LL4-3a, the proposed CAT-E PAL use control capability is feasible and the concept is compatible

(U) LL4-3b FULL BODY PROFILE

FIGURE 8.4.6-1

b(3)
DOE
DIRA

FIGURE 8.4.6-2
(U) NEP COMPARISON

b(3)
DOE
DTRA

FIGURE 8.4.6-3
(U) FORWARD WARHEAD SUPPORT

b(3)

DOE
DTRA

FIGURE 8.4.6-4
(U) AFT WARHEAD SUPPORT

8.4.7 (U) LA4-1 STRUCTURAL ASSESSMENT SUMMARY

8.4.7.1 (U) Design Description

b(3) DOE DTRA

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.

b(3) DTRA

b(3) DOE DTRA

8.4.7.2 (U) LA4-1 Normal Reentry Structural Assessment

(U) Analysis Approach

(U) The LA4-1 design was assessed by engineering judgment based on limited details of a 8 1/2 x 11 layout shown in the "Excerpts from the Fourth SLBM Phase 2 Study Group", dated 4 March 1993. The forward warhead attachment is that of the MK4 design and the aft wedge support and the seal cover designs are similar to the MK4 design.

FIGURE 8.4.7-1

(U) LA4-1 FULL BODY PROFILE

b(3)
DOE
DTRA

FIGURE 8.4.7-2
(U) NEP COMPARISON

b(3)
DOE
DTRA

FIGURE 8.4.7-3
(U) FORWARD WARHEAD SUPPORT

[redacted]

indicate that the design for the forward warhead attach, the aft wedge supp[illegible] and the seal cover would produce positive margins of safety.

8.4.7.3 (U) LA4-1 Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

b(3)
DOE
DTRA

(U) Structural Vulnerability Assessment

(U) The LA4-1 candidate has many design features which are similar to the W76/MK4. For this reason some of the sensitivity study analysis results which were performed using the MK4 aeroshell during the early portion of Phase 2 are applicable in assessing LA4-1. In these sensitivity studies the stiffness of the warhead and warhead attach points were varied, as was the weight of the NEP allowing the analyst to evaluate the effect of each variable on system performance. Given that the LA4-1 and W76/MK4 forward and aft warhead supports are nearly identical, and that the NEP change was not large, it was felt that the structural responses of the LA4-1 design would remain within the allowable limits.

8.4.7.4 (U) LA4-1 Candidate Feasibility Statement

(U) Analysis of the LA4-1 candidate design was accomplished utilizing a conceptual drawing and general mass property information. While this may be closer to a true Phase 2 type of assessment it is still considerably less information than has been received for many of the other candidates and has much larger uncertainties associated with the assessment conclusions. With these caveats in mind the LA4-1 design was assessed to be feasible due to its similarity to the W76/MK4.

8.4.8 (U) LA4-2 STRUCTURAL ASSESSMENT SUMMARY

8.4.8.1 (U) Design Description

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. b(3) DTRA

[redacted] Other than the addition of the connector on the aft closure its design remains very similar to the W76/MK4. b(3) DOE

[redacted] This task can be accomplished by either DoD or DOE.

(U) The proposed CAT-E PAL use control capability is feasible. Forward ballasting will require changes to existing DoD and DOE hardware. This task will entail modifying the anvil for mounting the ballast and a new DOE radiation shield to fit in the remaining volume.

8.4.8.2 (U) LA4-2 Normal Reentry Structural Assessment

(U) Analysis Approach

(U) The LA4-2 design was assessed by engineering judgment based on limited details of a 8 1/2 x 11 layout shown in the "Excerpts from the Fourth SLBM Phase 2 Study Group", dated 4 March 1993. The forward warhead attach and the seal cover are similar to the W76/MK4 design configuration. The aft wedge is thinner and

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[redacted]

[redacted]

FIGURE 8.4.8-1
(U) LA4-2 FULL BODY PROFILE

b(3)
10 USC 424

UNCLASSIFIED

b(3)
DOE
DTRA

FIGURE 8.4.8-4
(U) AFT WARHEAD SUPPORT

has approximately the same length as the W76/MK4, but has a forward slant at the wedge/warhead interface. This forward slant will require a gap at the wedge/warhead interface to allow for axial thermal expansion, otherwise the aeroshell will be locked at the forward warhead attach point and the wedge area, which will introduce large stresses in the aeroshell and forward wedge areas. Neither the gap nor the locked aeroshell are considered desirable conditions.

(U) Assessment Results

(U) The initial assessment of the LA4-2 based on the 8 1/2 x 11 layout would indicate that a design for the forward warhead attach area and the seal cover would produce positive margins of safety. The aft wedge design could result in high stresses in both the wedge and the aeroshell.

8.4.8.3 (U) LA4-2 Hostile Reentry Structural Assessment

(U) Material Vulnerability Assessment

b(2)
DOE
DTRA

(U) Structural Vulnerability Assessment

(U) The LA4-2 candidate has some design features which are similar to the LL4-1a, which was assessed to be feasible. Two structural design issues were noted in the assessment of the LA4-2 candidate. First, the aft warhead support was found to be thinner than the W76/MK4 support. Second, the forward warhead support appears to need strengthening in order to withstand the hostile environment encounters.

Both of these design differences involve a reduction in component size (relative to W76/MK4) which would require more analysis to determine actual structural responses.

8.4.8.4 (U) LA4-2 Candidate Feasibility Statement

(U) Analysis of the LA4-2 candidate design was accomplished utilizing a conceptual drawing and general mass property information. This is considerably less information than has been received for many of the other candidates and as such, has much larger uncertainties associated with the assessment conclusions. With these caveats in mind the LA4-2 design was assessed to be feasible with potential modifications to the forward warhead support. The slanted aft wedge design feature may need to be modified to reduce aeroshell stresses.

9. EFFECTIVENESS

presented to all working group members to review. This method added robustness to the study, by considering a greater number of analysis possibilities than if all members used the same assumptions.

9.1.3. (U) EFFECTIVENESS RESULTS SUMMARY

(U) The yields and weights of the W76/MK4, W88/MK5, and candidate warheads are shown in decreasing yield in Table 9-1 below, along with a comparative effectiveness ranking and rating.

9.1.3.1. (U) MK4A Effectiveness Summary

b(3). DOE DTRA

9.1.3.2. (U) MK5A Effectiveness Summary

b(3) DOE DTRA

TABLE 9-1
(U) SLBM PHASE 2 WARHEAD CANDIDATES AND EFFECTIVENESS RANKINGS

b(3)
DOE
DTAA

9.2. (U) GROUND RULES AND ASSUMPTIONS

(U) The SPETWG generally followed all the ground rules and assumptions contained in the Technical Objectives and Guidelines (TOG) for this study. The SPETWG also used the additional ground rules and assumptions in Sections 9.2.1.1 through 9.2.1.5.

9.2.1. (U) MISSILE CHARACTERISTICS AND CAPABILITIES

9.2.1.1. (U) Range / Payload Performance

(U) Figures 9-1, 9-2, and 9-3 show the range/payload assumptions used for this study and are based on data provided by LMSC. Figure 9-1 shows the range/payload capabilities for the W76/MK4 on the C4 missile. Figures 9-2 and 9-3 show the capabilities for the W76/MK4 and W88/MK5 respectively on the D5 missile. Using the weights of the candidates and the weight-to-range tradeoffs shown, the SPETWG determined the range/payload capabilities for MK4A candidates on both the C4 and D5 missiles and for MK5A candidates on the D5 missile.

9.2.1.2. (U) Weapon System Accuracy

The SPETWG used weapon accuracy values for D5 and C4 missiles based upon May 1993 TRIDENT CINCEVAL accuracy projections prepared by TASC. The D5 missile weapon system accuracy is shown as a function of range in Figure 9-4.

b(3) DOE DTRA

9.2.1.3. (U) Footprinting Capability

The footprint capabilities of each of the candidates used in developing effectiveness results are based on LMSC data.

b(3) DTRA

For example, with a payload

b(3) DOE DTRA

b(2)
DNE
DTRA

FIGURE 9-1
(U) C4/MK4 RANGE/PAYLOAD CONFIGURATIONS

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[redacted]

FIGURE 9-2

(U) D5/MK4 RANGE/PAYLOAD CONFIGURATIONS

b(3)
10 USC 130

UNCLASSIFIED

UNCLASSIFIED

[redacted]

(U) D5/MK5 RANGE/PAYLOAD CONFIGURATIONS

FIGURE 9-3

[redacted]

[redacted]

UNCLASSIFIED

UNCLASSIFIED

[redacted]

UNCLASSIFIED

FIGURE 9-4

(U) ACCURACY VERSUS RANGE FOR D5 MISSILE

UNCLASSIFIED

[redacted]

FIGURE 9-5

(U) ACCURACY VERSUS RANGE FOR C4 MISSILE

b(3) DOE DTRA

9.2.1.4. (U) Heights of Burst Fuzing Options

The SPETWG assumed that the HOBs of a MK4A would be changed from those of the W76/MK4.

b(3) DOE DTRA

9.2.1.5 (U) Reliability

In the force level effectiveness analysis, one study assumed a weapon system reliability (WSR) of 0.89 for all missiles, regardless of the type of warhead carried. Otherwise, the SPETWG did not consider reliability issues in the rest of their effectiveness assessments.

9.2.2. (U) FORCE UTILIZATION

9.2.2.1. (U) Force Levels and Missile Configurations

b(3) DTRA

The results from the other cases did not change the conclusions drawn from the 14 TRIDENT II (D5) case and are not presented in this report.

TABLE 9-2
(U) FORCE CONFIGURATIONS

b(3) DOE DTRA

9.2.2.2. (U) Operating Areas and SSBN Deployments

b(1) DTRA

The Aleutian Island chain and the Greenland-Iceland-United Kingdom gap formed effective northern barriers to these operating areas. Some of the assessments performed in this study used large fractions of these operating areas, and other assessments focused on those parts of the operating areas closest to the target base.

9.2.3. (U) TARGET BASES

(U) Each analyst in the SPETWG developed his own target bases, according to the scenarios he was analyzing. The target bases of the different analysts had many similarities and some differences. Each analyst developed a target base in Russia and a target base in China, but the Russian target bases, being harder and more diverse, had the most influence on the analyses.

One target base used in this study representative of the START II target base is

b(1) DTRA

b(1)
DTRA

9.2.3.1. (U) Treaty and Force Configuration Scenarios

(U) The base-case scenarios assumed that the START II treaty, negotiated by Presidents Bush and Yeltsin, would become effective. However, the SPETWG also assessed cases where only the START I agreement would become effective. The SPETWG performed no specific analyses in which they assumed that both START treaties would be rejected.

9.2.3.2. (U) Damage Mechanisms

(U) For many of the effectiveness comparisons, the single-shot probability of kill (SSPK) is the primary MOE considered. The damage mechanism assumed for SSPK is air blast overpressure causing severe structural damage to the facility, as defined by the DIA's Physical Vulnerability Handbook for Nuclear Weapons (OGA-2800-23-92). For this damage mechanism, an air burst is the appropriate fuze option, and each warhead candidate was evaluated using its most effective fuze option. For MK4A candidates, the radar fuze with optimum HOBs was used. For MK5A candidates, the radar-updated path length (RUPL) fuze with optimum HOBs was used

9.3. (U) APPROACH AND METHODOLOGY

9.3.1. (U) MEASURES OF EFFECTIVENESS

(U) The SPETWG defined nine different measures of effectiveness (MOEs) for MK4A and MK5A (Table 9-3), each of which addressed a specific aspect of effectiveness.

UNCLASSIFIED

TABLE 9-3

(U) MEASURES OF EFFECTIVENESS

DTRA

9.3.1.1. (U) MK4A Measures of Effectiveness

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

The SPETWG calculated the SSPK of each candidate against a target with a vulnerability number (VNTK) of 27P0.

b(3) DOE DTRA

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.

DTRA

UNCLASSIFIED

b(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*

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.

b(3)
DOE
DTRA

FIGURE 9-9
(U) MK4A AVERAGE SSPK

[redacted]

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

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

The SPETWG compared the numbers of DGZs (Designated Ground Zeros, or aimpoints) that would be required for each MK4A 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.

b3 DTRA

b(3) DOE DTRA

The SPETWG methodology associates with a given DGZ those target installations that are close enough to the DGZ that the minimum SSPK for 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 MOEs decreased monotonically as yield decreased, with a swing in numbers of DGZs required from the highest to the lowest candidate yield. Figure 9-13 shows the values of this MOE for each of the candidates.

b(3) DTRA

b(3) DOE DTRA

FIGURE 9-13
(U) MK4A NUMBER OF DGZS REQUIRED

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
DTRA

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*

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

UNCLASSIFIED

b(3) DOE DTRA

FIGURE 9-17
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*

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

UNCLASSIFIED

b(3)
DOE
DTRA

FIGURE 9-21
(U) MK5A FOOTPRINTING EFFICIENCY

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

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 [redacted] classified as Strategic Military, [redacted] categorized as Other Military, [redacted] categorized as National Leadership, and [redacted] categorized as War-Supporting Industry. The Strategic Military installations included only the numbers and types of ICBM silos permitted by the START II treaty.

b(1)
DTRA

b(3)
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[redacted] 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 [redacted] 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 [redacted] 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.

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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.

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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.

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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.

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

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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

(U) 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.

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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.

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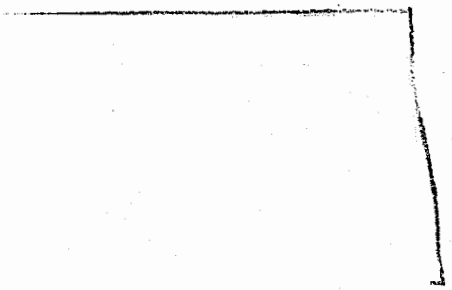
FIGURE 9-26a
(U) OVERALL MK4A EFFECTIVENESS RELATIVE TO W76



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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.

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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.

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

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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.

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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*

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).

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[redacted]

FIGURE 9-28

(U) EFFECTIVENESS OF MK4A CANDIDATES ON C4 VERSUS TARGET HARDNESS

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[redacted]

FIGURE 9-29

(U) EFFECTIVENESS OF MK4A CANDIDATES ON C4 VERSUS 27P0 TARGETS

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FIGURE 9-30
(U) EFFECTIVENESS OF MK4A CANDIDATES ON D5 VERSUS TARGET HARDNESS

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[redacted]

FIGURE 9-31

(U) EFFECTIVENESS OF MK4A CANDIDATES ON D5 VERSUS 46L8 TARGETS

9.4.2.1.2. (U) *MK5A*

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FIGURE 9-32
(U) EFFECTIVENESS OF MK5A CANDIDATES
ON D5 VERSUS TARGET HARDNESS

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FIGURE 9-33

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

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FIGURE 9-34

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

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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 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.

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FIGURE 9-35
(U) MK4A NORMALIZED FORCE ASSESSMENT RESULTS

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FIGURE 9-36
(U) FORCE LEVEL EFFECTIVENESS VERSUS MK4A CANDIDATES

9.4.2.2.3. (U) *MK5A*

(U) Figure 9-37 shows the normalized results of these four assessments for the MK5A candidates, along with a curve representing the average of these normalized values.

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FIGURE 9-37
(U) MK5A FORCE LEVEL ANALYSES SUMMARY

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Although the drop occurs at a rate that varies with the four studies, the general trend, indicated by the average, is consistent.

Figure 9-38 shows the effectiveness of MK5A candidates on a D5 missile for a 14 TRIDENT II (D5) SSBN force configuration.

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FIGURE 9-38
(U) FORCE LEVEL EFFECTIVENESS VERSUS MK5A FORCE SIZE

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9.4.2.2.4. (U) *MK5A Yield*

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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.

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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.

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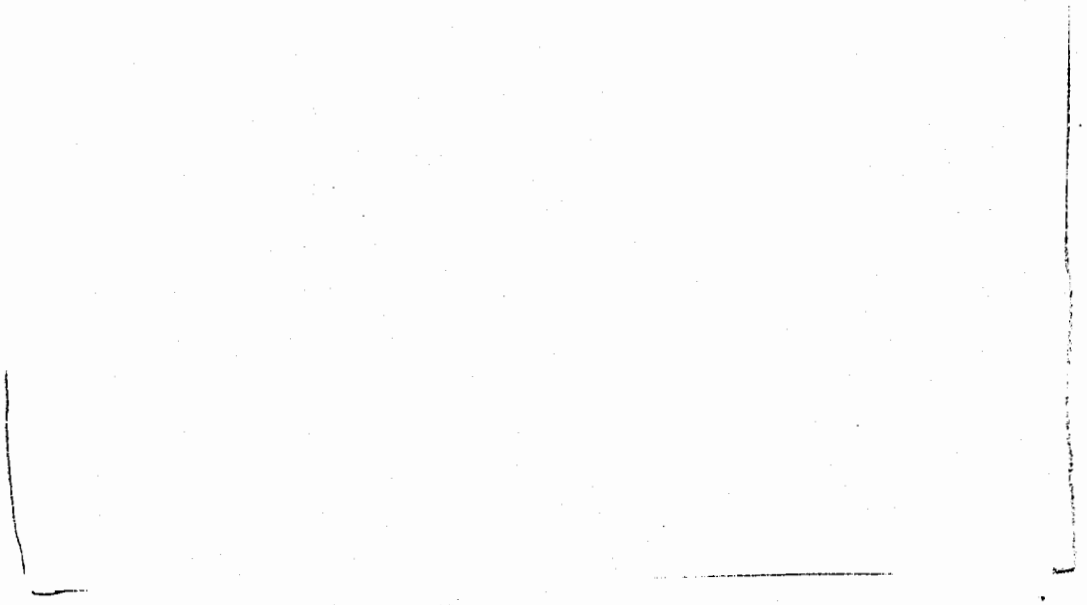

FIGURE 9-39
(U) YIELD FOR THE MK5A

9.5 (U) CONCLUSIONS

(U) The SPETWG assessments led to the following overall effectiveness conclusions.

9.5.1 (U) COMPARISONS OF MK4A CANDIDATES

The DOE weapons laboratories proposed eight candidates to replace the W76/MK4.

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The MK4 mission can also be accomplished with candidate LA5-2 on the D5 missile with approximately the same effectiveness as the baseline.

(U) The impact of missile range on the comparison of MK4 candidates should also be noted. The differences in weight of the MK4A candidates reduce full load (eight RBs) range of the C4 missile to a point where operational viability becomes a serious concern. This range is critical for the C4 missile whose deployment is on the TRIDENT submarine in the Pacific Ocean. The eight body range criterion, however, is not an effective discriminator among the candidates. Range of the C4 missile with only four RBs, a potential loading under START II rules, is large and the additional weight of the candidates is not an important discriminating factor. Range of the D5 missile, even with eight of the MK4A candidates, is not a significant issue for operations in either the Atlantic or the Pacific Ocean operating areas.

9.5.2. (U) COMPARISONS OF MK5A CANDIDATES

[redacted] Twenty-two candidates were proposed by the DOE weapons laboratories to replace the W88/MK5. While the W88/MK5 is more effective than any of the

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10. SURETY

10. (U) SURETY

10.1 (U) SAFETY ATTRIBUTE IMPLEMENTATION

10.1.1 (U) INTRODUCTION

(U) The scope of this study was to review the safety attributes of the Phase 2 candidates and to identify the issues and concerns associated with implementing modern safety features. The scope did not include determining the relative need for these features in the TRIDENT weapon system.

(U) Many of the proposed warhead candidates contain a number of safety features which can enhance nuclear safety and reduce the probability of Pu dispersal with minimal impact to the weapon system. These features are grouped into two basic categories: safety systems which are common to a number of candidates; and second, unique safety systems which are specific to a single candidate or small group of candidates. The features which are common to a number of candidates include; IHE, FRPs, robust exclusion barriers, and advanced detonator safing.

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(U) In Section 10.1.2, details of a number of safety features are discussed. Subsequently, candidate-specific ENDS themes, and an assessment of INRAD exposure levels are presented in Sections 10.1.3 and 10.1.3. In Section 10.1.5, Tables 10.1-2 to 10.1-5 detail the safety implementation scheme for all candidates, indicating the safety features incorporated and those which require excursions from the defined ground rules (e.g., impacts to missile system). The conclusions from this Safety Technical Working Group safety review are contained in Section 10.1.6.

(U) Recently, the possibility of plutonium scatter from nuclear weapons exposed to abnormal environments has received increasing attention. Plutonium dispersal safety features have been emphasized for all Phase 2 candidates.

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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.

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This evaluation has been partially completed, and no problems have yet been identified. See Section 10.1.2.1.3.

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10.1.2.1.1 (U) *LANL One Point Safety*

(U) All LANL MK4A and MK5A candidates are designed to be one point safe. Two-dimensional and three-dimensional analyses, along with some UGTs, have been used to evaluate the safety of the candidates.

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10.1.2.1.2 (U) *LLNL One Point Safety*

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10.1.2.1.3 (U) *LANL Beyond One-Point Nuclear Safety Analysis*

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10.1.2.2 (U) Fire Resistant Pit Design

(U) Plutonium containment requirements for the Phase 2 study have not been completely specified. STS requirements have been revised to specify a fuel fire of 1100°C for one hour at a Strategic Weapons Facility and potentially a much greater time when not at a Strategic Weapons Facility.

10.1.2.2.1 (U) *LLNL FRP Design Concepts*

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(U) The Design Laboratories have been developing fire resistant pit designs for the reduction of plutonium scatter in fire environments for well over a decade. The fire resistant pit designs have been fielded in the W84, B83 and W87, and the concepts for fire resistance have been continually improved leading to the current design standard developed into Phase 4 for the W89. The MK4A and MK5A candidates take advantage of these developments.

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(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.

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10.1.2.2.2 (U) *LANL FRP Design Concepts*

(U) Because the duration of fires while in DOE custody is yet to be determined, LANL has adopted the requirements of 1100°C for two hours as its requirement for fire resistance. Fire resistance reduces the chance and/or magnitude of Pu dispersal in accidental fires.

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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) *LLNL/Sandia Paste Extrudable Explosive (PEX) Booster*

(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.

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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.

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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.

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10.1.2.4.4 (U) *LANL Exclusion Barriers*

(U) To improve nuclear detonation safety in abnormal environments, detonator cables require improved shielding from possible abnormal electrical environments. The exclusion barriers should have the capability to withstand temperatures exceeding 1000°C, should provide for no line-of-sight to detonator cables, should maintain good electrical continuity between the AF&F and the warhead case, and should provide a strong mechanical mounting scheme between the AF&F and the NEP.

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(U) Los Alamos made a serious effort to design an exclusion region that would satisfy all requirements for ENDS. However, in the judgment of LANL and Sandia, only incremental improvements can be made toward ENDS, unless considerable modifications to the AF&F, RB, and warhead are made. See Section 5.1.4.3.3.

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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*

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.

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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.

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

(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

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FIGURE 10.1-1
(U) SUMMARY OF INRAD EXPOSURE PREDICTIONS FOR LANL PHASE 2 WARHEAD CANDIDATES
(PREDICTIONS BASED ON MK4/W76 EXPOSURE DATA)

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FIGURE 10.1-2
(U) SUMMARY OF INRAD EXPOSURE PREDICTIONS FOR LLNL PHASE 2
WARHEAD CANDIDATES
(PREDICTIONS BASED ON MK4/W76 EXPOSURE DATA)

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TABLE 10.1-2

(U) LANL/SANDIA MK5A CANDIDATE SAFETY IMPLEMENTATION

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TABLE 10.1-2 (Continued)

(U) LANL/SANDIA MK5A CANDIDATE SAFETY IMPLEMENTATION

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TABLE 10.1-4

(U) LLNL/SANDIA MK5A CANDIDATE SAFETY IMPLEMENTATION

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TABLE 10.1-4 (Continued)
(U) LLNL/SANDIA MK5A CANDIDATE SAFETY IMPLEMENTATION

TABLE 10.1-5
(U) LLNL/SANDIA MK4A CANDIDATE SAFETY IMPLEMENTATION

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.

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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:

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(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:

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(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.

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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

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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

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11. ENVIRONMENTAL EFFECTS ASSESSMENT

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) FINDINGS

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

12.3.1 (U) WITH UGT AND NEW PLUTONIUM PITS

(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)**:

MK4A on C4/D5:	LL4-3
	LA4-1
MK5A on D5:	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

SLBM Reentry System Alternatives

Objective:

Identify and quantify alternate reentry systems for use on the Trident II strategic weapons systems. Alternatives should consider maximum use of existing DOD hardware in order to minimize system cost. The alternatives should be evaluated with regard to the following attributes:

- SLBM weapon system safety
- Desensitization to aging effects
- Minimum need for refit
- Reliability
- Cost (initial and life cycle)
- Compatibility with existing DOD hardware

Maximum yields commensurate with the above attributes should be identified. Both existing physics packages and those reusing existing plutonium primaries should be emphasized to minimize the impact on limited DOE production capacity.

If the DOE agrees to participate in this study, the Study Group will convene at the earliest date convenient to all study participants. Within 90 days of the initiation of Phase 2, the Study Group will present its goals, strategy, and milestones for conducting the study to the Nuclear Weapons Council Standing Committee (NWCSC). The NWCSC will review the progress and status of the study as necessary but at least annually.

Sincerely,

Bob Barker

Robert B. Barker

Enclosure

cc:
CNO (OP-65)
CNO (OP-91B)
CNO (OP-02)
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.

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- (U) Meet the MC requirements while minimizing the dependence on underground nuclear tests and flight tests, both for development and stockpile surveillance.

- (U) Maximize compatibility with existing DOD hardware (including the AF&F) and facilities.

- (U) Optimize the producibility of the design consistent with potential limited weapon production capabilities.

2. (U) REENTRY BODY/WARHEAD TRADEOFFS

(U) 2.1 General. During the course of development, tradeoffs among competing reentry body/warhead characteristics shall be made with the guidance of the Project Officers Group to optimize overall system performance. Tradeoffs that could significantly alter the ability to meet the Military Characteristics set forth herein shall require prompt notification to the NWC.

2.2 Yield.

b(3) DOE DTRA

b(3) DOE DTRA

(U) 3.4.4 Arming. The warhead shall be designed to allow arming as late as practical in its planned flight trajectory.

(U) 3.4.5 Automatic Disarming Provisions. The warhead shall automatically disarm within 10 minutes if arming power is interrupted.

(U) 3.4.6 In the absence of arming and firing signals, the probability of nuclear detonation for normal and hostile environments specified in the STS shall not exceed:

(U) 3.4.6.1 One in 10^9 per warhead lifetime in the absence of warhead enabling stimuli*.

(U) 3.4.6.2 One in 10^6 per occurrence after application of initial enabling stimuli and in the absence of final enabling stimuli.

(U) 3.4.7 The probability of a nuclear detonation in the abnormal environments specified in the STS shall not exceed:

(U) 3.4.7.1 One in 10^6 per exposure or accident in the absence of warhead enabling stimuli.

(U) 3.4.7.2 One in 10^3 per occurrence after application of the initial enabling stimuli but prior to final warhead enabling stimuli.

(U) 3.4.8 HE Safety. The following are design requirements:

(U) 3.4.8.1 The warhead HE shall not ignite or detonate as a result of a free fall of the RBA from a distance specified in the STS.

(U) 3.4.8.2 The warhead HE shall not detonate when the RB is subjected to the fire environments described in the STS.

(U) 3.4.9 Criticality. Warhead arrays shall remain subcritical in all planned configurations and abnormal situations stated in the STS.

(U) 3.4.10 Warhead Monitoring. A positive means of monitoring WH disablement status shall be provided.

---

* (U) The enabling stimuli are generally unique signals or environments that operate safety subsystems. They are selected during weapon system development such that they will not be duplicated or simulated by abnormal environments.

MILITARY CHARACTERISTICS FOR THE WARHEAD FOR THE TRIDENT I AND II MK4A 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 MK4A Reentry Body (RB) used on the C4 and D5 Fleet Ballistic Missile Weapon Systems (TRIDENT I & II). This warhead will be a replacement for the existing W76 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.
- (U) Meet the MC requirements while minimizing the dependence on underground nuclear tests and flight tests, both for development and stockpile surveillance.
- (U) Maximize compatibility with existing DOD hardware and facilities.
- (U) Optimize the producibility of the design consistent with potential limited weapon production capabilities.

2. (U) REENTRY BODY/WARHEAD TRADEOFFS

(U) 2.1 General. During the course of development, tradeoffs among competing reentry body/warhead characteristics shall be made with the guidance of the Project Officers Group to optimize overall system performance. Tradeoffs that could significantly alter the ability to meet the Military Characteristics set forth herein shall require prompt notification to the NWC.

([redacted] 2.2 Yield.

b(3) DOE DTRA

[redacted] 2.3 Physical Characteristics.

b(3) DOE DTRA

3. (U) FUNCTIONAL CONSIDERATIONS

(SFRD) 3.1 Fuzing Options. The warhead shall be compatible with the fuzing options of air burst, near surface burst, and contact burst.

(U) 3.2 Environmental and Survivability Considerations

(U) 3.2.1 Normal Environments. The warhead shall be able to withstand the normal environments stated in the Stockpile-to-Target Sequence (STS) and meet the reliability stated in Paragraph 3.3 and the premature probabilities stated in Paragraph 3.4.6.

(U) 3.2.2 Hostile Environments. In addition to the normal environments, the warhead shall be capable of surviving the hostile environments stated in the STS and a) meet the premature requirements stated in Paragraph 3.4.6 and b) perform without severe degradation of the reliability stated in Paragraph 3.3.

(U) 3.2.3 Abnormal Environments. The warhead shall be able to withstand the abnormal environments stated in the STS and meet the premature probabilities stated in Paragraph 3.4.7.

(U) 3.2.4 Fratricide Environments. In addition to the normal environments, the warhead shall be capable of surviving the fratricide environment stated in the STS and perform without severe degradation of the reliability stated in Paragraph 3.3.

[redacted] 3.3 Reliability Considerations.

b(3) DOE DTRA

(U) 3.4 Safety Considerations. Nuclear weapons safety must be the maximum achievable consistent with operational requirements.

[redacted]

(U) 3.4.1 In the event of a detonation initiated at any single point in the high explosive system, the probability of achieving a nuclear yield greater than four pounds TNT equivalent shall not exceed one in 10^6. This characteristic shall be inherent in the design and achieved without the use of mechanical safing devices.

(U) 3.4.2. The potential for dispersal of hazardous materials shall be minimized by design and operational procedures.

(U) 3.4.2.1 The warhead design shall incorporate modern safety features which minimize plutonium dispersal in fire and other abnormal environments as defined in the STS.

(U) 3.4.3. Multiple independent safety subsystems shall be incorporated that will prevent arming of the warhead firing system in any manner other than the prescribed warhead arming sequence. A positive interruption in the sequence of events necessary to cause warhead firing system arming shall be provided and shall remain effective until the warhead senses a unique environment subsequent to launch. This interruption may be provided by the arming and fuzing subsystem.

(U) 3.4.4. Arming. The warhead shall be designed to allow arming as late as practical in its planned

(U) 3.4.6 In the absence of arming and firing signals, the probability of nuclear detonation for normal and hostile environments specified in the STS shall not exceed:

(U) 3.4.6.1 One in 10^9 per warhead lifetime in the absence of warhead enabling stimuli*.

(U) 3.4.6.2 One in 10^6 per occurrence after application of initial enabling stimuli and in the absence of final enabling stimuli.

(U) 3.4.7 The probability of a nuclear detonation in the abnormal environments specified in the STS shall not exceed:

(U) 3.4.7.1 One in 10^6 per exposure or accident in the absence of warhead enabling stimuli.

(U) 3.4.7.2 One in 10^3 per occurrence after application of the initial enabling stimuli but prior to final warhead enabling stimuli.

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* (U) The enabling stimuli are generally unique signals or environments that operate safety subsystems. They are selected during weapon system development such that they will not be

APP. C ACCIDENT RESISTANT CONTAINER

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APPENDIX C

ACCIDENT RESISTANT SHIPPING AND STORAGE CONTAINER (U)

Sandia National Laboratories
Livermore, California

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(U) Appendix C Accident-Resistant Shipping and Storage Container

(U) List of Acronyms and Abbreviations

b(3)
DOE

b(3)
DOE

(U) All of the MK4A candidates are compatible with the H1333A and H1333B MK4 RBA Shipping and Storage Containers. With an adapter, the MK4A designs are also compatible with the MK5 container. Therefore, we designed a single container which would accommodate either the MK5A or the MK4A.

(U) Because there are no formal accident resistance requirements for nuclear weapons, for the purpose of this study, we chose some criteria which we considered to be reasonable, as design goals. These design goals could be modified if a reason to do so arose. The design goals we chose are shown in Table C-1.

(U) Our main objectives in selecting these criteria was to assure:
the exclusion barrier(s) remained intact as long as possible for IND safety;
the fire resistance of the design would not be degraded by the accident (such as would occur if the FRP were punctured); and
the entire weapon would remain as one unit and would not be dispersed over a broad area.

(U) Because our candidates have relatively good thermal resistance (fire-resistant pits (FRP) and good thermal weaklinks against IND) but have relatively limited mechanical resistance (which can negate the FRP and bypass IND safety subsystems), we concentrated primarily on providing as much mechanical protection as possible within the footprint and height of the H1514 Container. Designing to fit within the footprint of the existing H1514 container helps maintain compatibility with operations in the storage magazines and service units. The height is limited by the DOE SSTs and SGTs.

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Figure C-2 is a sectional view of the container with a MK5 RBA. Figure C-3 identifies the major components and materials.

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(U) Figures C-6 through C-8 illustrate the clearance between the RBA and the inner surface of the container required to accommodate the RBA lifting and mating fixture ("Four Poster"). This clearance limits the thickness of accident mitigating materials that can be used.

(U) The accident-resistance capabilities of this container are significantly greater than those currently provided by the MK4 and MK5 Shipping and Storage Containers. However, the desire to keep the new container within the existing footprint limits the new container accident resistant capabilities to less than those of DOE's state-of-the-art H1501 Transportation Accident-resistant Container. The H1501 is shown in Figure C-9. The capabilities of the H1501 and the proposed MK5A accident resistance criteria are summarized in Figure C-10. The proposed MK5A criteria cover almost 90 per cent of aircraft accidents.

(U) A MK5A container with H1501 capabilities would be larger and heavier than the proposed design. Also, the H1501 is designed to carry warheads with their long axis oriented horizontally. Either the container would have to be redesigned to orient its long axis vertically or the MK5 and MK4 would have to be qualified for shipment with their long axes horizontal. Because of these considerations and our evaluation that the increased accident resistance was not sufficient to offset the associated drawbacks, we did not pursue the option of achieving the state-of-the-art in accident resistance. This assumes that these weapons will not be transported by air and therefore will not be exposed to the risk of an aircraft crash environment (high speed impact followed by a long duration fuel fire). If the weapon is to be transported by aircraft, then we would strongly recommend the development and use of an H1501A-like container to provide maximum protection in the event of an accident.

TABLE C-1

(U) PROPOSED ACCIDENT-RESISTANT SHIPPING CONTAINER DESIGN GOALS

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b(3)
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TABLE C-2

(U) DIMENSIONS OF STATE-OF-THE-ART ACCIDENT RESISTANT CONTAINER

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(U) Preliminary structural analysis indicates that the container meets the puncture and impact criteria. The area of most concern for impact is the bolted connection between the upper and lower pieces. This joint will require much more detailed design, analysis, and test to be qualified for these environments. The analysis also indicates that an 0.090 inch thick 304 stainless steel skin is adequate for these criteria. Thicker skin may not be beneficial--the skin would be stronger, but this increase would be offset by higher impact energies in the impact and puncture tests due to the increased weight of the skin.

(U) Preliminary thermal analysis of the proposed accident-resistant container indicates approximately a 10°F temperature rise from the ambient temperature to the outside surface of the RB during normal environments. In an abnormal thermal environment (1850°F fuel fire) the warhead IHE will not reach 319°F (the temperature at which it begins to react exothermically) for at least 50 minutes.

b(3)
DoE
DIRA

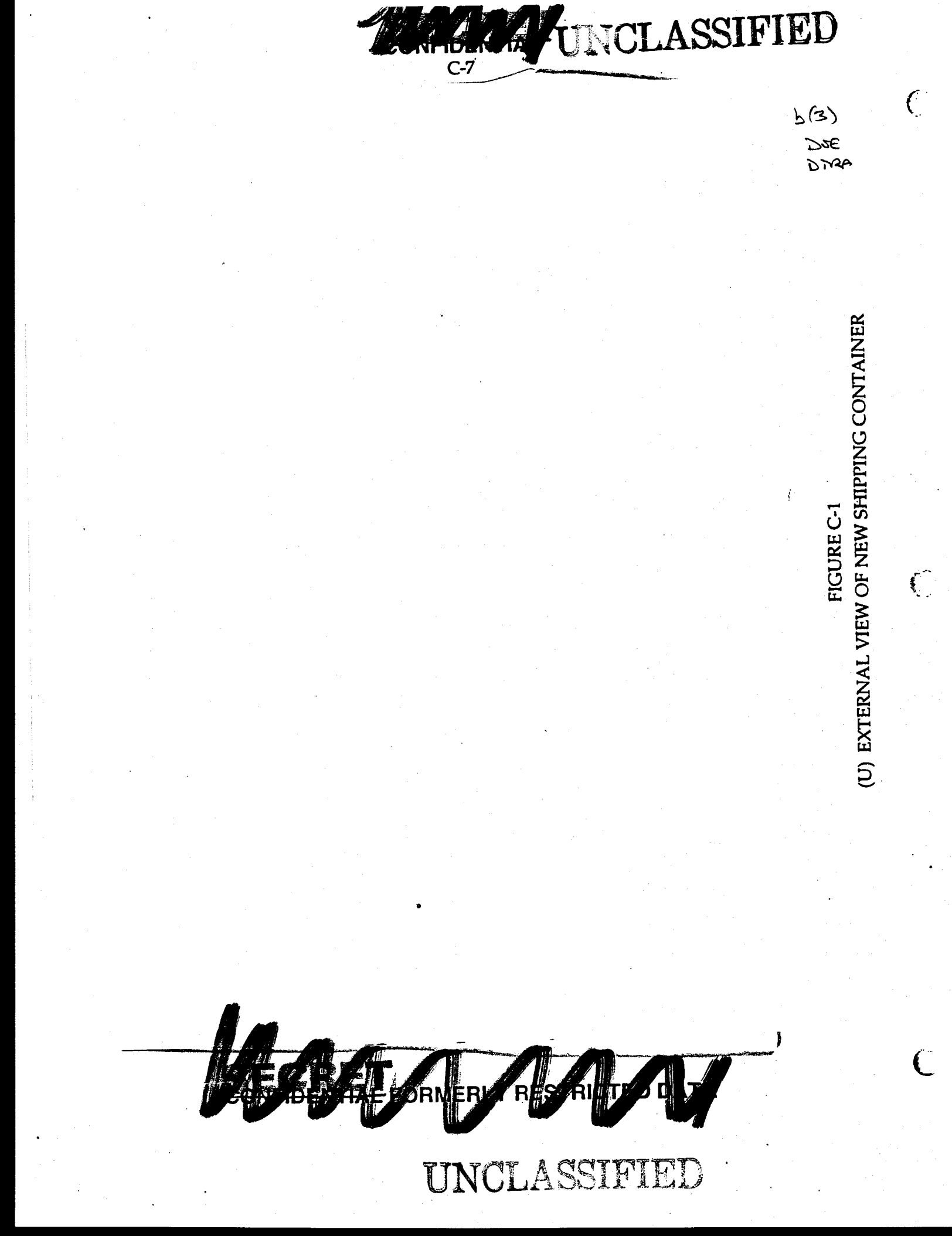

FIGURE C-1
(U) EXTERNAL VIEW OF NEW SHIPPING CONTAINER

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(U) SECTION VIEW OF NEW SHIPPING CONTAINER

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b(3)
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(U) SHIPPING CONTAINER MATERIALS AND COMPONENTS

[redacted]

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FIGURE C-4
(U) SECTION VIEW REMOVING SINGLE LID

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(U) SECTION VIEW REMOVING DOUBLE LID

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b(3)
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FIGURE C-6
(U) SECTION VIEW WITH FOUR POSTER

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b(3)
DOE
DTRA

FIGURE C-7
(U) SECTION VIEW WITH TIPPED RBA

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Side View (Castors Extended)

End View (Castors Retracted)

FIGURE C-9
(U) H1501 TRANSPORTATION ACCIDENT RESISTANT CONTAINER

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DNRA

FIGURE C-10
(U) PROTECTION LEVEL FOR ACCIDENT-RESISTANT CONTAINERS

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