DEFENSE NUCLEAR FACILITIES SAFETY BOARD

October 13, 1993

MEMORANDUM FOR: G.W. Cunningham, Technical Director

COPIES: Board Members

FROM: James J. McConnell
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SUBJECT: Nuclear Explosives Safety Study: Arming & Firing and Timing & Control (A&F/T&C) System for Lawrence Livermore National Laboratory Devices at the Nevada Test Site.

1. Purpose: This memorandum describes the initial results of the review of the arming & firing and timing & control system for nuclear tests at the Nevada Test Site (NTS). This information was obtained through the review of various documents and a trip to NTS conducted by Derek Barboza of the DNFSB staff during the period of July 28-30,1993. There are two attachments to this report. Attachment I provides a brief overview of the A&F/T&C system and Attachment II discusses the various phases involved in an underground test.

2. Background:

   a. A nuclear explosive safety study group (NESSG) completed the "Nuclear Explosive Safety (NES) Study of the Lawrence Livermore National Lab (LLNL) Arming & Firing (A&F) and Timing & Control (T&C) System and Operations at the Nevada Test Site" in October 1992. The group consisted of members from DOE/HQ, DOE/NV, DOE/SF, DOE/AL, Los Alamos National Lab (LANL), LLNL, and Sandia National Lab (SNL). The NESSG concluded that the T&F system used by LLNL meets the criteria of DOE Order 5610.11, Nuclear Explosive Safety.

   b. The SNL member, however, submitted a minority report stating that the A&F/T&C system violates each of the five safety standards listed in DOE Order 5610. 1 1:

      1. There shall be positive measures to prevent nuclear explosives involved in accidents or incidents from producing a nuclear yield.

      2. There shall be positive measures to prevent deliberate prearming, arming, or f~nng of a nuclear explosive except when directed by competent authority.

3. There shall be positive measures to prevent the inadvertent prearming, arming, launching, firing or releasing of a nuclear explosive in all normal and credible abnormal environments.

4. There shall be positive measures to ensure adequate security of nuclear explosives pursuant to the DOE safeguard and security requirements.

5. There shall be positive measures to prevent accidental, inadvertent, and deliberate unauthorized dispersal of plutonium to the environment. "

3. Summary:

a. Minority Report:

1. DOE determined that the concerns of the minority opinion were not valid. This decision was based on the experience of DOE personnel. No technical justification for the determination was documented.

2. With respect to Standard 1, the SNL member expresses concerns that design deficiencies of the LLNL system could create potential vulnerabilities in the event of accidents. The DNFSB staff believes that there is some validity to these concerns. For example, the arming and firing system does not included engineered safety features to isolate firing signals from the detonators. Electrical currents and voltages available in a accident or incident (such as a short circuit) could trigger the detonators. The LLNL system utilizes a low voltage trigger that can trigger an armed device with tens of volts from uphole, unlike the LANL system, which requires much higher voltages.

3. With respect to Standard 3, the SNL member expresses concerns that abnormal environments could create short circuits that inadvertently prearm or arm the device. Various apparently credible scenarios, such as an airplane crash, pipe string drops, and crane accidents (other than drops) were not considered during the NESS. Omitting analysis of credible abnormal environments that could affect nuclear explosive safety is a violation of Standard 3.

4. With respect to Standard 5, the same conditions that could result in violations to Standard 1 could result in a violation of Standard 5.

5. Standards 2 and 4 are related to safeguards and security and have not been reviewed by the DNFSB staff.

b. NESS Process:

1. Formal procedures do not exist to close out recommendations made by the NESSGs. A 1988 Master Study on the LANL A&F/T&C systems provided four recommendations to improve explosive safety. These recommendations were closed out between DOE/NV and LANL and did not receive additional input from the NESSG on the adequacy of the closeout justification. Furthermore, one recommendation, an updated lightning study, has not yet been completed.

2. It appears that documented analysis of abnormal events (AEs) is incomplete and inadequate. Sufficient technical justification for the determination of credibility is not provided. Furthermore, the scope of abnormal events is limited to the immediate vicinity of the explosive. It excludes other potentially important environments, such as the Red Shack and the cable bundles, that could create a potential threat to nuclear explosive safety. The Red Shack serves as the uphole terminal for electrical A&F/T&C cables and other cables. It receives microwave energy from the command center and provides electrical energy to the devise. The Red Shack is described in more detail in Attachment I.

4. Discussion:

a. Minority Report:

1. The SNL minority position states that the LLNL A&F/T&C system violates the five safety standards of DOE Order 5610.11. The minority position states the following reasons for the violation.

   Standard 1 is not met because of design deficiencies that create potential threats in the event of accidents.

   Standard 2 is not met because of inadequate control of access to critical system components.

   Standard 3 is not met because several AEs create the possibility to arm or prearm a device as well as expose the same deficiencies as with Standard 1.

   Standard 4 may not be met because of inadequate security at surface ground zero prior to device delivery.

   Standard 5 is not met because of violations to Standards 1, 2 and 3.

2. DOE personnel responded to the minority position by stating that they did not believe that it was valid. This decision was based strictly on the experience of the DOE personnel. Technical justification for the decision was not documented.

3. The DNFSB staff believes that the concerns expressed by the SNL member of the NESSG contain some validity. With respect to Standard 1, engineering safeguards normally provided on a fielded weapon are not included with test devices. These safeguards and the associated electrical signals (which can not be credibly generated in an accident) are not replaced by engineered devices serving the same function. In addition, LLNL utilizes a low voltage trigger that will trigger an armed device with tens of volts from uphole. This low voltage is passed through a dc-dc converter downhole which outputs a high voltage to trigger an armed device. It should be noted that the LANL A&F/T&C system does not utilize a low voltage trigger, but requires sustained high voltage directly from the Red Shack to trigger the device. Such a voltage profile would not credibly be available in an accident situation.

4. The abnormal environments covered by the NESS are derived from "Nuclear Explosive Abnormal Environments at the Nevada Test Site" which was prepared by DOE/NV in May 1992. This document does not evaluate the effects of an AE, but attempts to identify the AE conditions which require further evaluation. With respect to Standard 3, it appears that the scope of the review of abnormal events, which is determined from the AE document, is inadequate. For example, airplane crashes, pipe string drops, and crane accidents (other than drops) were not analyzed. Therefore, it can not be determined that certain abnormal events combined with apparently incomplete isolation of the arming and firing cables from other cables do not pose a threat to nuclear explosive safety.

5. Potential accidents or abnormal events that could create an inadvertent explosion could result in the dispersal of plutonium. The design deficiencies that potentially make the system vulnerable to producing nuclear yield in an accident situation, as well as the deficient scope and analysis of abnormal environments (the violations to Standards 1 and 3) could also result in a violation of Standard 5.

6. The minority position on Standards 2 and 4 is related to safeguards and security and was not reviewed by the DNFSB staff.

b. NESS Process:

1. Formal procedures do not exist to close out recommendations made by the NESSGs. For example, an NESSG made four recommendations in the "Nuclear Explosive Safety Master Study of the LANL Timing and Firing of Nuclear Explosives at the Nevada Test Site" in June 1988. The first three included performing further analysis on various components and presenting this analysis to the NESSG. These recommendations were closed out by

DOE and LANL without input from the NESSG. The fourth recommendation involved performing a joint LANL/SNL/LLNL investigation into lightning effects. LANL stated in a letter to DOE/NV that this would be performed, but could not provide a schedule for completion. This study has not yet been completed.

2. The document titled "Nuclear Explosive Abnormal Environments at the Nevada Test Site" attempts to determine the credibility of various abnormal environments. It is intended to be an input document for the Master Safety Studies and attempts to identify single abnormal events and credible trigger events that produce combinations of these single events.

3. The technical justification for the determinations in the AE document appears to be inadequate. For example, an airplane crash was determined to be incredible based on the single administrative control that restricts air travel over the NTS. A 1987 Master Study of Security at the NTS, however, deemed that an airplane crash was credible.

4. Also, the scope of the AE document is limited to the effects of abnormal events in the immediate vicinity of the explosive, and excludes other potentially important environments. These include accidents involving the Red Shack, which provides the arming and firing signals to the device, as well as the cable bundles, which transmit power from the Red Shack to the device.

5. Furthermore, while this document is intended to be an input document for future safety studies, it heavily references past safety studies. It is unclear whether it is an analysis of abnormal events or a summary of past safety study evaluations.

5. Future Staff Actions: The following reviews should be completed by the DNFSB Staff prior to DOE's resumption of testing, if possible:

a. The staff should review the cable specifications and testing programs to analyze the quality of the cables and their performance in abnormal environments against any commercial standards related to cable testing, isolation, and environmental qualification of critical components.

b. The staff should review any efforts that represent an increase in the scope of the abnormal environments analyses that support the NESS process.

c. The staff should conduct a review of certain A&F/T&C procedures such as cable lockouts and dry runs, to assess the adequacy of these administrative controls and the potential for human error.

d. Several documents should be reviewed upon publication including the "Electrical Phenomena Master Study" and the "Risk Assessment of the Arming and Firing System at the Nevada Test Site" (LLNL). The former document should supply information on the lightning hazard at NTS. The latter document should supply a quantitative risk assessment of the hazards at NTS.

e. The Master Study of the LANL A&F/T&C system is scheduled to be completed in 1994 and should be observed.

ATTACHMENT I
System Overview

The system to test a nuclear device can be divided into the following three areas: the downhole area, the Red Shack, and the control room. The downhole area is where the device is located and contains the arming and firing components as well as various measurement instrumentation. The Red Shack is a trailer which houses the electronics that provide the power to detonate the device. The control room is where the command signals originate to detonate the device. The signals are sent to the Red Shack by a microwave link.

The arming and firing components include exploding bridgewire detonators (EBWs), capacitor discharge units (CDUs) (also known as firesets or X-units), neutron generators, and dc-dc power converters. The process of arming and firing a device consists of charging the CDU to a specific voltage level and then releasing the stored energy of the CDU into the EBWs. This is accomplished by sending a trigger signal to the CDU. The dc-dc converters are used to transform a low voltage (in the order of tens of volts) to a high voltage (in the order of kilovolts) which is required to charge and trigger the CDU.

The LLNL A&F/T&C system utilizes a low voltage trigger such that a voltage in the order of tens of volts is sent from the Red Shack to a downhole dc-dc converter that outputs a high voltage to trigger the device. The LANL system utilizes a high voltage trigger such that the trigger signal from the Red Shack is in the order of kilovolts.

The power supplied to the A&F components downhole originates at the Red Shack. The device which supplies this power is the Zero Rack. The Zero Rack is controlled by the Zero Power Control Unit which prevents power from being transmitted from the Zero Rack to the arming circuits until a power relay signal is received from the control room. In addition to the power relay signal, a ten digit code must be sent to enable the control room to send the arming and firing signals. This ten digit code is set in the Red Shack by two people during prearming. Once the code is set, the personnel at the Red Shack move to the control room where they enable the system by sending the ten digit code. Sending an incorrect code disables the system.

In order for an accidental explosion to occur, electrical energy must be applied to the detonators. This can be achieved by applying energy directly to the detonators or by applying energy to the CDU and then discharging it to the detonators. Direct electrical energy to the detonators can come from either a short circuit or a lightning strike. Electrical energy to arm and fire the detonators can come from inadvertently sending the arm and fire signals, short circuits, or lightning.

ATTACHMENT II
Test Schedule and Key Events

1. Pre-delivery: The trailer park, where the Red Shack is located, and the emplacement tower is assembled approximately two to three months prior to delivery of the device. Various tests, such as pre-compatibility checklist, compatibility checklist, and dry runs, are performed to verify system operation. Equipment is listed by model and serial number. Cable integrity tests are performed. Cables are connected to the Red Shack and voltage levels are set. The uphole ends of the cables are then locked out in the Red Shack.

2. Delivery: The device is delivered to the emplacement tower. The Red Shack then comes under two-person control just prior to connecting the A&F circuitry to the device. Various tests are performed prior to emplacement. For an LLNL experiment, this includes the hot dry run (HDR) where the detonators are locked out and the detonator cables are connected to detonator simulators. Two person control is in effect to attach the detonator cables to the detonator simulators. The A&F cables are unlocked and attached to the Zero Rack. The test concludes with the control room simulating an actual shot. If the detonator cables are attached to the device instead of the load simulators, and the HDR continues, an explosion would occur. LANL does not perform a HDR and the uphole ends of the cables remain locked out until shot morning. LANL begins to lower the device the same day that it is delivered. LLNL takes several days.

3. Emplacement: Following the HDR (for LLNL shots only), the A&F cables are again locked out at the Red Shack. The emplacement phase lasts approximately one to two weeks. During this phase, signal dry runs (SDRs) are performed. During these tests, the uphole ends of the A&F cables remain locked out. Power from the Zero Rack is connected to load simulators to verify operation of the system.

4. Stemming: Stemming is the act of preparing the hole for detonation. Once the device is stemmed, the device is in the proper configuration to be detonated and the threat to nuclear explosive safety is minimal. The timing for stemming operation is on the order of several days.

The total time between device delivery and the completion of stemming is on the order of three weeks.