

**National Nuclear Security Administration  
Sandia Site Office**

**Type B Accident Investigation**



**Employee Injured when Rocket Motor  
Unexpectedly Fired on October 9, 2008  
at the Sandia National Laboratories  
Technical Area III Sled Track**

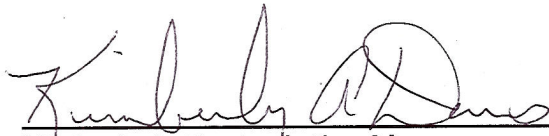
**November 2008**

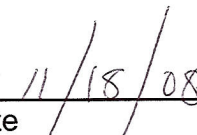
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## RELEASE AUTHORIZATION

On October 14, 2008, I appointed a Type B Accident Investigation Board (Board) to investigate the accident which occurred at the Sandia National Laboratories/New Mexico, Sled Track Facilities, Albuquerque, New Mexico on October 9, 2008. The Board's responsibilities have been completed with respect to this investigation. The analyses and the identification of the contributing causes, the root causes and the Judgments of Need resulting from this investigation were performed in accordance with DOE Order 225.1A, *Accident Investigations*.

I accept the report of the Board and authorize the release of this report for general distribution.

  
\_\_\_\_\_  
Kimberly A. Davis, Acting Manager  
Sandia Site Office

  
\_\_\_\_\_  
Date

This report is an independent product of the Type B Accident Investigation Board appointed by Kimberly A. Davis, Acting Manager, Sandia Site Office.

The Board was appointed to perform a Type B investigation of the accident and prepare an investigation report in accordance with DOE O 225.1A, *Accident Investigations*.

The discussion of the facts, as determined by the Board, and the views expressed in this report do not assume and are not intended to establish the existence of any duty at law on the part of the U.S. Government, its employees or agents, contractors, their employees or agents or subcontractors at any tier, or any other party.

This report neither determines nor implies liability.

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## ACRONYMS

ACLS	Advanced Cardiac Life Support
AF	Arming and Firing
CFR	Code of Federal Regulation
CO	Console Operator
CPR	Corporate Process Requirement
DOE	Department of Energy
EED	Electroexplosive Devices
EMT	Emergency Medical Technician
ERT	Emergency Response Team
ESD	Electrostatic Discharge
ES&H	Environmental, Safety & Health
FR	Facility Representative
GIF	Gamma Irradiation Facility
HA	Hazard Analysis
IN	Instrumentation Technician
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
IWP	Integrated Work Plan
JON	Judgments of Need
KAFB	Kirtland Air Force Base
LED	Light Emitting Diode
MOR	Management Operational Review
NNSA	National Nuclear Security Administration
OP	Operating Procedure
ORPS	Occurrence Reporting and Processing System
PHS	Primary Hazard Screening
PPE	Personal Protective Equipment
RBO	Risk-Based Oversight
RF	Radio Frequency
SA	Safety Assessment
SNL/NM	Sandia National Laboratories/New Mexico
SSO	Sandia Site Office
ST Mgr	Rocket Sled Track Complex Manager
TA-III	Technical Area III
TAT	Technical Assistance Team

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TE	Test Engineer
TMSP	Test and Maintenance Support Personnel
TMSS	Technical Management SolutionS, Inc.
TQP	Technical Qualification Program
TSOP	Test Specific Operating Procedure
UNMH	University of New Mexico Hospital
VQSEC	Validation and Qualification Sciences Experimental Complex

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## EXECUTIVE SUMMARY

On the afternoon of October 9, 2008, a sled track test was to be performed involving a sled that consisted of a test package connected to the front of a Super Zuni rocket motor. The purpose of the test was to record thermal battery output during the impact with the target.

At approximately 4:45 pm, one of the Arming and Firing Technicians (AF1), a TMSS employee, was installing a Light Emitting Diode (LED) module into a MDM25 connector on the top of the test package when the rocket motor unexpectedly fired. AF1 was hospitalized with a broken leg and first and second degree burns mostly to his hands and arms.

### Analysis

The direct cause of the injury was the inadvertent ignition of the Super Zuni rocket motor. If the requirements of the DOE Explosives Safety Manual had been properly

implemented, the rocket motor would not have ignited. The severity of the burn injury could have been reduced if the worker had been wearing a long sleeved cotton shirt as required by the Operating Procedure. The Sandia Integrated Safety Management System was not adequately implemented for this series of tests. Analysis of the hazards associated with this series of tests did not result in operating procedures and practices that precluded ignition of the rocket motor. Sufficient energy to fire the rocket was provided by an internal battery in the test package. Explicit controls were not provided to ensure that the energy in the test package could not ignite the rocket motor.

The Board concludes that this accident was preventable. Sandia did not provide sufficient oversight of the Sled Track Operations to ensure that requirements were appropriately implemented.

**Table ES-1. Conclusions and Judgments of Need**

Conclusions	Judgments of Need
<p>The Board concludes that the safety analyses used to support the MC4152 Thermal Battery Rocket Sled Testing were not performed in sufficient detail to adequately address all scenarios associated with this accident.</p>	<p>Sandia needs to develop and implement a plan to fulfill their responsibilities under 10 CFR 851, <i>Worker Protection</i> and the DOE M 440.1-1A, <i>Explosives Safety Manual</i> to control explosives hazards.</p>
<p>The Board concludes the test series setup did not provide for adequate grounding and bonding.</p>	
<p>The Board concludes that based on the work practices described in the OP and testimony of the workers, management did not adequately educate and train employees in the hazards and precautions required for handling explosives and materials used in conjunction with explosives operation.</p>	
<p>The Board concludes the OPs for this sled track test series were derived from the OPs from previous similar tests. Additional hazards analysis specific to this test series were not documented and used during the development of the OPs for this specific test series.</p>	
<p>The Board concludes the cited probability reduction in the SA from “Anticipated” to “Extremely Unlikely” was not supported by the identification of specific design features or engineered barriers to minimize the probability of the analyzed scenarios.</p>	
<p>The Board concludes that because the accident under review involves workers in close proximity to the rocket, the reduction in severity of the consequence would not be consistent with the qualitative analytical method described in the SA.</p>	
<p>The Board concludes that, based on an unmitigated scenario, the likelihood should be substantially higher than “Beyond Extremely Unlikely.” According to the HA, if the frequency had been assessed as “Anticipated” or “Unlikely,” this activity would have been within the Risk Rank of I or II and would have been carried forward for additional identification and discussion.</p>	



Conclusions	Judgments of Need
The Board concludes hazards specific to this test series were not fully analyzed and were informally discussed with the workers.	
The Board concludes that if implementation of the hazard assessment processes had more thoroughly identified hazards associated with this test series, required hazard controls could have been more clearly identified and followed by the workers.	
The Board concludes the controls were based on historical operations and not a detailed analysis of the rocket sled test series as required by ISM.	
The Board concludes that the actions of the workers involved with this test series did not demonstrate an understanding of conduct of operations principles.	Sandia management needs to ensure violations of explosives safety requirements and deviations from established practices are detected and corrected.
The Board concludes that identified practices represent a normalization of deviation from established explosives safety work practices.	
The Board concludes that SSO's efforts to improve Sandia's safety and health performance is an ongoing challenge.	SSO needs to evaluate the effectiveness of its RBO of explosives operations and facilities.

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## **1.0 BACKGROUND**

The organizations related to this accident were the National Nuclear Security Administration Sandia Site Office (NNSA/SSO), Sandia Corporation (Sandia) and Technical Management Solutions, Inc. (TMSS). A brief description of each organization is provided in this section.

### **1.1 NNSA/Sandia Site Office**

The NNSA/SSO provides oversight of Sandia's activities and implements the Department of Energy (DOE) contract with Sandia. In addition, the DOE/NNSA Service Center is available to provide support to the NNSA/SSO.

### **1.2 Sandia National Laboratories**

Sandia is a national security laboratory involved in a variety of research and development programs to help secure a peaceful and free world through technology. Sandia develops technologies to sustain, modernize, and protect the United States nuclear arsenal, prevent the spread of weapons of mass destruction, defend against terrorism, protect national infrastructures, ensure stable energy and water supplies, and provide new capabilities to the United States armed forces.

### **1.3 Sled Track Facility Description**

The Sled Track Test Site is a federally-funded basic research and development facility and operates under the programmatic direction of the DOE Headquarters. The Sled Track Test Site is one of numerous

federally-owned facilities situated on land owned by the DOE. The Sled Track Test Site is located on Kirtland Air Force Base (KAFB), Albuquerque, NM.

The Sled Track Complex supports the verification of design integrity, performance, and fusing functions of weapon systems through the simulation of high-speed impacts of weapon shapes, substructures, and components. Sandia National Laboratories, New Mexico (SNL/NM) test facilities such as the Sled Track Complex have been specifically designed for the validation of analytical modeling and the functional certification of weapons systems. The facility is also used to subject weapon parachute systems to aerodynamic loads to verify parachute design integrity and performance. In addition, Sandia Energy & Environment Programs use the Sled Track Complex to verify designs in transportation technology, reactor safety, and Defense Programs transportation systems.

Technical Area III (TA-III) is approximately 5 miles south of Technical Area I in the southwest portion of KAFB. Approximately 200 people work in the area, which is composed of 20 test facilities devoted to large-scale physical testing and simulation of a variety of natural and induced environments. Over 150 structures are located within TA-III, most of which are grouped in small units separated by extensive open spaces.

Operations at the Sled Track Complex include a variety of tests and test article preparation such as conducting rocket sled and rocket

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launcher tests, free-flight testing, and explosives testing. Each rocket sled test involves the acceleration of a rocket down a sled track. A test may involve impacting an object onto a target, or launching a parachute from an ejector accelerated along the track. Each explosive detonation is used to subject test articles to shock waves and propel missiles into test articles. Rocket launches are used to accelerate test objects along a beam on a carriage that is stopped at the end of the beam, releasing test objects into free flight at specific targets. In free-flight launches, test objects are launched directly into free flight from portable launch rails.

#### **1.4 Technical Management SolutionS, Inc.**

TMSS, Inc. has been working with various government agencies for over 20 years. They provide a wide range of support and service applications, consisting of:

- Project Management support
- Engineering support
- General Technologists
- System Program Administrators
- Maintenance Planners
- Technical Support Specialists
- Project Support Specialists
- Test and Maintenance Support Personnel (TMSP)

Under their contract with Sandia, TMSS provides maintenance and support of testing operations in various test facilities of SNL/NM to include the Rocket Sled Track Complex.

#### **1.5 Scope and Methodology**

The Accident Investigation Board (Board) was appointed on October 14, 2008 (See Appendix A) and began the investigation that day. The scope of the Board's investigation was to identify all relevant facts; analyze the facts to determine the direct, contributing, and root causes of the accident; develop conclusions; and determine Judgments of Need (JONs). (See Figure 1-4 below for an explanation of accident investigation terminology). The investigation was performed in accordance with DOE Order 225.1A, *Accident Investigation*, using the following methodology:

- The accident scene was inspected, physical evidence was collected, and photographs were taken of the scene.
- Facts relevant to the accident were gathered through interviews, reviews of documentation, and examination of the physical evidence.
- The facts were analyzed to identify the causal factors using barrier analysis, change analysis, event and causal factors analysis and root cause analysis.
- Conclusions and JONs were developed to guide the development of corrective actions that, if implemented, should prevent recurrence of similar accidents.

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### ***Accident Investigation Terminology***

A **causal factor** is an event or condition in the accident sequence that contributes to the unwanted result. There are three types of causal factors: **direct cause(s)**, which is the immediate event(s) or condition(s) that caused the accident; **root cause(s)**, which is the causal factor that, if corrected, would prevent recurrence of the accident; and the **contributing causal factors**, which are the causal factors that collectively with the other causes increase the likelihood of an accident but which did not cause the accident.

**Event and causal factors analysis** includes charting, which depicts the logical sequence of events and conditions (causal factors that allowed the accident to occur), and the use of deductive reasoning to determine the events or conditions that contributed to the accident.

**Barrier analysis** reviews the hazards, the targets (people or objects) of the hazards, and the controls or barriers that management systems put in place to separate the hazards from the targets. Barriers may be physical or administrative.

**Change analysis** is a systematic approach that examines planned or unplanned changes in a system that caused the undesirable results related to the accident.

**Figure 1-1. Accident Investigation Terminology**

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## **2.0 ACCIDENT DESCRIPTION AND CHRONOLOGY OF EVENTS**

### **2.1 Accident Description**

On the afternoon of October 9, 2008, a sled track test was to be performed involving a sled that consisted of a test package connected to the front of a Super Zuni rocket motor (See Figure 2-1). The test package consisted of two thermal batteries and a hardened data recorder known as the HiCapPen. The test package and the rocket motor were mounted on the west rail of the 10,000 foot sled track at Station 47 (a point 4,700 feet from the south end of the sled track). The objective was to launch the sled from Station 47 and impact a target located at Station 32 (a point 3,200 feet from the south end of the sled track). The purpose of the test was to record thermal battery output during the impact with the target.

At approximately 4:45 pm, one of the Arming and Firing Technicians (AF1), a TMSS employee, was installing a Light Emitting Diode (LED) module into a MDM25 connector on the top of the test package when the rocket motor unexpectedly fired and proceeded down the track (See Figures 2-3 and 2-4). AF1 was bending over the test package when the rocket fired. He was thrown onto the test track and was lying across both the east and west rails. There were 3 other sled track personnel in the vicinity. AF2 was standing near AF1 and west of the rails. An Instrumentation Technician (IN1) was standing east of the rails a few feet away and had

turned away from the test track to pick up his equipment. The Test Engineer (TE) was standing east of the rails several feet away. The rocket sled hit the target and came to a stop in the vicinity of Station 31.

When the smoke from the rocket exhaust cleared, AF2 saw that AF1 was injured, and instructed TE to call 911. AF2 and the TMSS fire crew moved AF1 from on top of the tracks onto the ground on the west side of the test track. TE called the Console Operator (CO) in Building 6741 and requested that the CO call 911.

AF2, IN1, and TE did not attempt first aid. They tried to make AF1 as comfortable as possible. They put a foam cushion behind AF1's head and some clothing material underneath his arms so he could rest his elbows. Because his arms were burned severely and AF1 could not lay them down or put them across his chest. AF1 rested his elbows and held his forearms up in the air. AF2 stated it was obvious that AF1's leg was broken and there wasn't anything AF2 could do.

AF2 was concerned that AF1 was going into shock. AF1's breathing accelerated and he kept asking for water to drink. AF2 gave AF1 sips of water to try to keep him calm.

AF1 was wearing TMSS's company attire consisting of safety boots, denim blue jeans, a denim short-sleeved shirt and baseball cap. After the accident AF2 stated that he saw black smoke marks and soot on AF1's clothing and the sleeves of AF1's shirt were tattered and torn.

**Table 2-1. Event Chronology Table**

Date	Time	Event
October 9, 2008	AM	At 11:00 a successful iteration of this sled track test series. The test crew included TE, CO, AF1, AF2, IN1 and IN2. IN2 installed the LED module for this test.
October 9, 2008	PM	AF1, AF2 and IN1 made connections to the wires leading to the thermal batteries and fire sets and performed a systems check to ensure they were working properly. The firing cable was shorted and grounded. AF2 took possession of the fire set key. The thermal battery fire set cable from the sled was disconnected.
October 9, 2008	PM	AF1 & AF2 team completed their rocket motor transport and pre-arming sequence, which involves installing the rocket motor on the sled track, connecting to the test sled, and shorting and grounding the coaxial cable that is connected to the rocket motor igniter.
October 9, 2008	PM	AF1 and AF2 contacted CO and informed him that they completed their tasks.
October 9, 2008	PM	CO announced on the radio that essential personnel may reenter the area to complete their tasks.
October 9, 2008	PM	TE and IN1 return to sled area. IN1 connected his instrumentation system and interface control box to the top of the sled and set the HiCapPen to a 5 minute delayed activation state.
October 9, 2008	PM	IN1 disconnected his equipment from the connector on the sled.
October 9, 2008	PM	IN1 requested AF1 to insert LED module into the connector mounted on the test unit. IN1 was not positioned to do the task and IN2 was not available.
October 9, 2008	PM	IN1 gave AF1 the LED module and screwdriver to tighten down the connector.
October 9, 2008	4:45 PM	AF1 bent over the rocket sled to insert the LED module.
October 9, 2008	PM	LED module made contact with connector housing the pin 4. AF2 heard a click.
October 9, 2008	Accident occurs	Rocket ignited and AF1 was injured.
October 9, 2008	PM	AF1 landed across the rails. TE, IN1 and AF2 heard loud sound and feel the heat from the rocket.
October 9, 2008	PM	AF2 instructed TE to call CO to call 911.

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October 9, 2008	PM	CO called 911.
October 9, 2008	PM	AF2 and TMSS fire crew helped move AF1 out of trough.
October 9, 2008	Accident+ 15 min	KAFB and SNL/NM emergency responders arrived on scene.
October 9, 2008	Accident+ 30 min	AF1 airlifted to the UNMH.
October 9, 2008	PM	IN1 and AF2 went to UNMH because of ringing in their ears. Waited three hours and left without treatment.
October 14, 2008		AF1 was hospitalized more than 5 days triggering a Type B investigation in accordance with DOE Order 225.1A, <i>Accident Investigation</i> .

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## **2.2 Emergency Response**

Nine minutes after receiving the 911 call, KAFB Fire Department and the SNL/NM Emergency Response Team (ERT) arrived at the accident scene. The emergency response crew included three Emergency Medical Technicians Paramedics (EMT-P). KAFB Fire Department reached the site first and treated AF1 for first/second degree burns and compound fracture of the right femur. Paramedics then started an intravenous saline and morphine and placed AF1 on a back board in preparation for airlift by helicopter. The ERT located a staging area and landing zone for the emergency helicopter. About 15 minutes after KAFB and SNL/NM ERT arrived, the helicopter arrived. AF1 was loaded into the helicopter and the helicopter left the scene en route to the University of New Mexico Hospital (UNMH). AF2 and IN1 were transported to UNMH complaining of ringing in their ears. TE refused transport and signed a refusal form for the paramedics.

The ERT began to clean up hazardous waste such as blood, remaining bandages, and blood-borne pathogen protective equipment. The accident scene was then isolated by a barrier of "Caution" tape by SNL/NM protective force personnel. The SNL/NM protective force maintained control of the accident scene until the Board took custody.

## **2.3 Description of Injuries**

AF1 received a compound fracture to the right femur, first and second

degree burns to both hands and arms, his face, and a 10 inch laceration on his right thigh. His right pants leg was torn and his clothing was charred. AF1 received two surgeries on his leg: the first surgery occurred on the evening of October 9, 2008 to repair his femur and the second surgery occurred on October 12, 2008 to clean up the fracture wound. His burns were treated and he was expected to recover fully.

IN1 and AF2 waited in the emergency room at UNMH for 3 hours without being seen by a medical professional. They decided to go home.

## **2.4 Emergency Preparedness**

The SNL/NM Emergency Medical Services Program includes five physicians in the Urgent Care Clinic and three paramedics in addition to six registered nurses and two medical assistants. The Urgent Care Clinic is equipped with two ambulances for immediate transport for patients requiring further care. There is a current contract with Albuquerque Ambulance for back-up transport of patients. The paramedics that responded to the incident were Advanced Cardiac Life Support (ACLS) certified and their certifications were current.

The attending physician at UNM Hospital indicated the patient care contributed to the effective treatment and made Emergency Room responsibilities considerably easier.



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## 2.5 Photographic Record of the Accident Scene

This section depicts the conditions at the accident scene.



Figure 2-1. Representative rocket motor and test package



Figure 2-2. Position of rocket and test package after accident

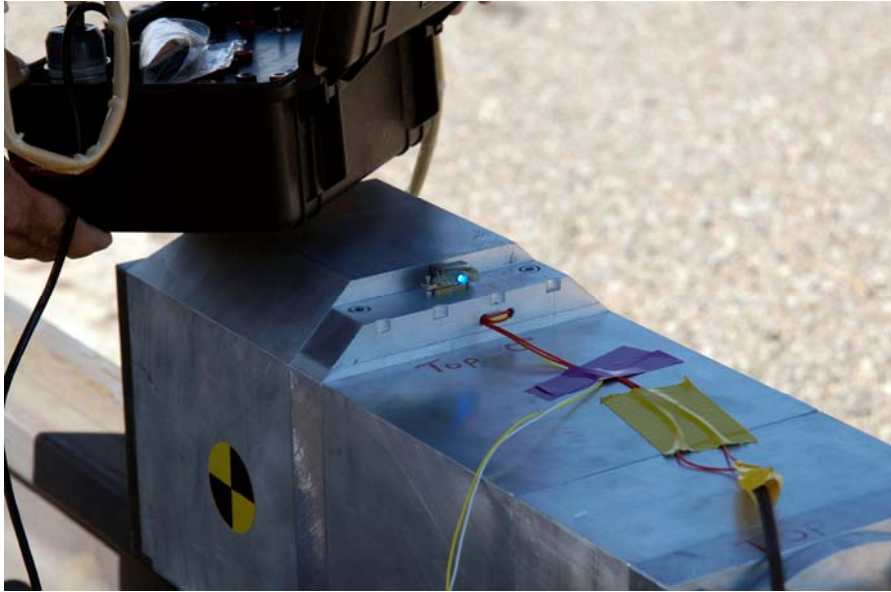


Figure 2-3. HiCapPen with LED module installed and illuminated

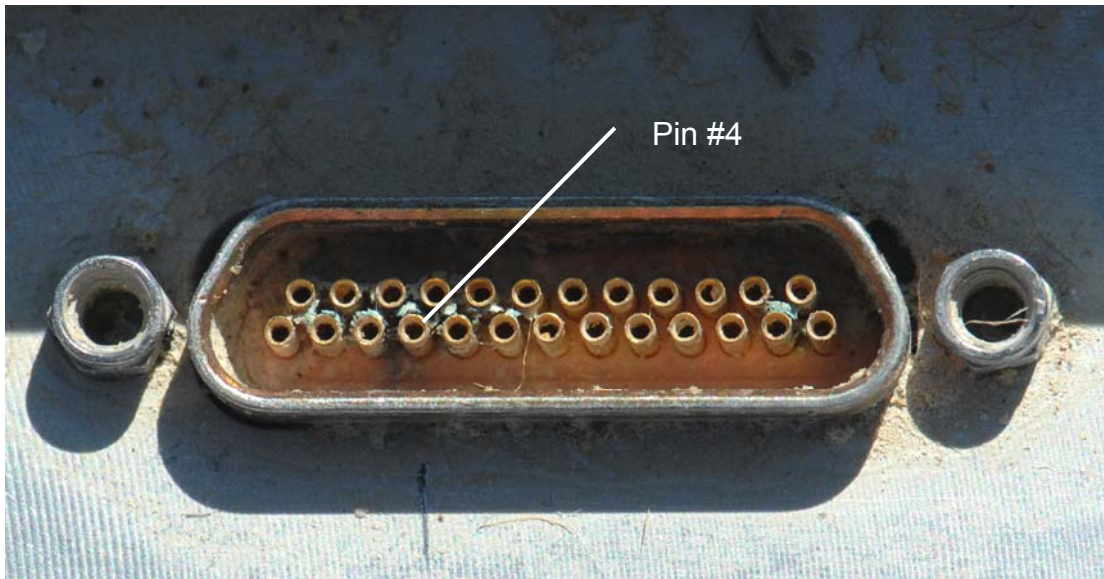


Figure 2-4. Post accident MDM25 connector



Figure 2-5. Post accident LED module with black electrical tape

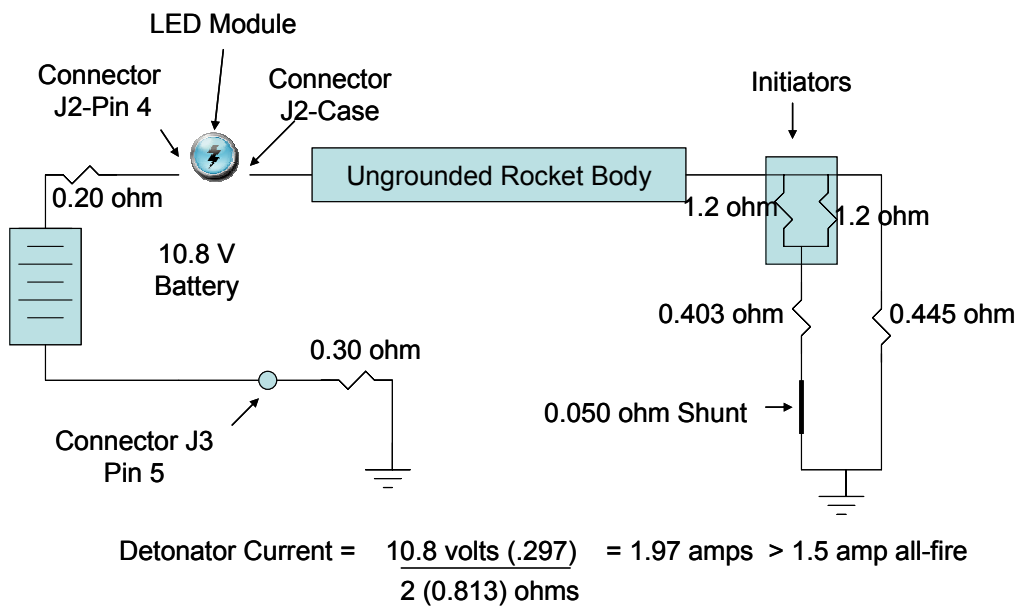


Figure 2-6. TAT Schematic Analysis



Figure 2-7. HiCapPen connection to sled track side box



Figure 2-8. Post accident sled track side box



Figure 2-9. Post accident wiring to sled track (note oxidation on track rails)

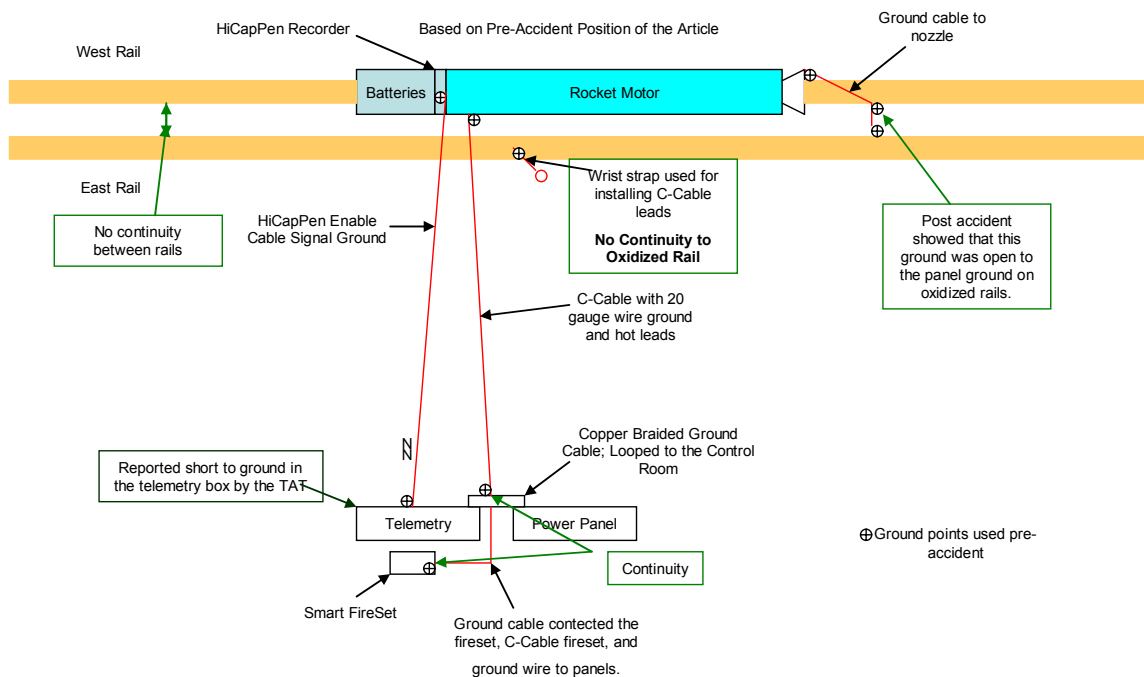


Figure 2-10. Pre-accident grounding connections (Board reconstruction)

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### **3.0 ACCIDENT ANALYSIS**

#### **3.1 Measurements, Photos and Physical Evidence at Accident Scene**

On October 9, 2008, the Sandia investigative readiness team took photographs of the accident scene. On October 10, 2008, Sandia took additional photographs and made electrical measurements at the accident scene. Preliminary measurements included the sled track rails, at the sled side boxes, and at the stop location on the sled track.

Starting October 14, 2008, the Board took additional photographs and electrical measurements at the accident scene and collected physical evidence such as wires, electrical cable, wire strippers, and a small screwdriver. All photographs and measurements were analyzed by the Board (See Section 2.5). A piece of physical evidence that was not found at the time was the LED module that AF1 was installing when the rocket ignited.

A search for the LED module was not initiated until the Board was assured that all other physical evidence and measurements had been taken. On October 30, 2008, a search team found the LED module (See Figure 2-5) approximately 250 feet north of Station 47 and approximately 60 feet east of the rocket sled track. Black electrical tape had been wrapped around the LED module (See Figure 2-5). The purpose of the tape was to shield the LED from sunlight in order to more effectively see the status of the LED

through the camera located north of Station 47. According to testimony from AF1, the presence of the electrical tape on the LED module did not make it difficult for him to install. The LED module was provided to the TAT for additional testing and analysis.

#### **3.2 Technical Assistance Team (TAT)**

Sandia formed a TAT to support the Board. The TAT members were selected from across SNL/NM to support the Board with technical advice and analysis. To minimize potential conflicts of interest, the personnel selected were not members of the organization that experienced the accident.

#### **3.3 Disassembly of Test Sled and Measurements**

On October 21, 2008, the Board met with TAT members to discuss a plan to disassemble the test sled package and to determine appropriate diagnostic tests. On October 21 and 22, 2008, the TAT, accompanied by Board members, took diagnostic and electrical measurements of the condition of the rocket at the stop location at Station 31 on the sled track. On October 21, the female MDM25 connector on top of the test package was examined and a black mark was observed near pin 4 that is connected to the HiCapPen battery. This is the connector where AF1 was attempting to insert the LED module (See Figure 2-4).

The test sled was towed back to the Station 47 firing location on October 22 and electrical measurements were taken with the test sled at

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Station 47. Photographs were taken of the measurements process in both locations. After all accident scene measurements were taken by the TAT on October 22, the test sled was towed to the end of the sled track, removed from the track, and transported to Building 6736 for disassembly and further diagnostic measurements in a more controlled environment.

On October 23 and 24, disassembly and diagnostic tests of the sled test package occurred in the presence of a Board member and photographs were taken of these activities. First, the spent rocket motor was unscrewed from the test sled. The exposed forward end of the rocket motor revealed that the interior electromagnetic barrier had been removed in order to expose the igniter wire as part of the test set up. The igniter wire was present but not connected to the igniter. AF2 said this is not uncommon after the rocket has been fired. Next, the test package (HiCapPen and thermal batteries) was removed from the sled and placed on a work table. The thermal batteries were separated from the HiCapPen and the wiring harness from the HiCapPen to the female MDM25 connector was removed and provided to the TAT for additional testing and analysis.

On October 24, the HiCapPen was connected to a laptop computer and an attempt was made to download the data from the HiCapPen memory. Because the HiCapPen had not armed, no data had been recorded.

During the week of October 27, the TAT took further measurements at

the accident scene and found an unexpected earth ground in the telemetry sled side box which later analysis showed contributed to the ignition of the rocket (See Figure 2-10).

### **3.4 TAT Assessment of Potential Causes of the Rocket Ignition**

Using the measurements gathered at the accident scene and information on the sled test package, fire set cable, and test sled side boxes, the TAT developed a circuit graphic for the test setup at the time of the accident (See Figure 2-6). The TAT also developed a schematic of the test package circuitry. The TAT analyzed this schematic for potential ignition sources within the test setup. In addition to the development of the circuit analysis, the TAT also analyzed other scenarios that could have ignited the rocket:

- rocket propellant self-initiation,
- radio frequency and electromagnetic energy induced current to the igniter circuitry (e.g., from radios, cell phones, electrical power lines, etc.),
- thermal battery initiation of the rocket motor,
- firing set initiation of the rocket motor, and
- electrostatic discharge (ESD) initiation of the rocket motor.

### **3.5 TAT Determination of Potential Causes of the Rocket Ignition**

On October 27, 2008, the TAT briefed the Board on the results of their measurements, data gathering, results of examination of the female

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MDM25 connector, and their determination of the cause as to why the rocket motor ignited.

Microscopic photography of the female MDM25 connector confirmed a black mark at the base of the pin connected to the HiCapPen battery (See Figure 2-4). Pin #4 on the female MDM25 connector, by design, was connected directly to the HiCapPen battery in order to energize the LED (See Figure 2-3). The output of the HiCapPen battery was 10.8 volts and the battery was not current limited. The TAT concluded that the energy source that caused the rocket ignition was a short at Pin #4 that occurred when

the male and female MDM25 connectors came in contact. From the TAT analysis of the circuit schematic (See Figure 2-6), they discovered a circuit configuration that would have caused the energy from the short to flow from the MDM25 female connector, through the test sled body, and through the rocket igniter.

The TAT did provide the Board with a formal report that is maintained in the official investigation files. Some of the topics discussed in the report were deemed Official Use Only and therefore are not included as part of this report.



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## **4.0 MANAGEMENT SYSTEMS EVALUATION**

### **4.1 DOE Oversight**

Starting in 2005, SSO adopted a new safety basis approach for non-nuclear facilities. This approach involved Risk-Based Oversight (RBO). RBO focuses a significant amount of effort on oversight of nuclear activities and less on industrial activities. This approach focuses on DOE's risk related to 1) exposure to the public; 2) releases to the environment; and 3) risk to DOE's mission. As a result, SNL/NM nuclear facilities receive extensive transactional oversight, as do industrial facilities that can release toxic gases and expose the public. Facilities such as the low hazard Neutron Generator Facility also have significant DOE oversight because of their ability to have a dramatic effect on DOE's mission on a routine basis.

For facilities/activities that do not fall into one of the three categories above, SSO relies on a systems based approach to drive performance improvement and compliance. Additional contractual mechanisms include Sandia's Contractor Assurance System (e.g. Performance Evaluation Plan, and fee determination, etc.). SSO and external audits from OA in 2005, and from HS-64 in 2008 continued to find problems with work control and ISMS implementation. Although the Lab has put much effort into improving work control and ISMS implementation, they have had limited success as indicated in Sandia's Performance Evaluation Report for the past three years.

*The Board concludes that SSO's efforts to improve Sandia's safety and health performance is an ongoing challenge.*

### **4.2 Explosives Safety Program Implementation**

Title 10 Code of Federal Regulation (CFR) 851.24 states that DOE contractors must have a structured approach to their worker safety and health program which at a minimum includes provisions for explosives safety. Contractors must comply with the applicable standards and provisions in 10 CFR 851, Appendix A.3, that states compliance with the DOE Manual (M) 440.1-1A, *DOE Explosives Safety Manual*, January 9, 2006, is mandatory. Sandia incorporated the requirements of DOE M 440.1-1A, *Explosives Safety Manual*, as well as additional requirements and practices for conducting explosives operations at SNL into the Corporate Process Requirement (CPR) 400.1.1.31, *SNL Environment, Safety, and Health (ES&H) Explosives Safety Manual*, dated November 9, 2007.

#### **4.2.1 Explosives Safety Analyses**

DOE M 440.1-1A, *Explosives Safety Manual*, Chapter II, item 2.1g requires that "Safety analyses of explosives facilities and operations shall be performed."

CPR400.1.1.31 *SNL ES&H Explosives Safety Manual*, Chapter II, item 1.7S states "The [Hazard Assessment] HA can either be a standalone document that explicitly follows the process outlined in this Manual and referenced within the [Primary Hazards Screening]

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PHS/HA, or it can be accomplished within the PHS/HA software as long as it satisfies the requirements outlined in this Manual.”

- PHS 9632456779-013, *The Primary Hazard Screening for the Area III Sled Track Complex*, dated April 14, 2008 and the Integrated Work Plan (IWP) for the MC4152 Thermal Battery Rocket Motor Sled Testing (IWP 1737 dated August 15, 2008) identified the worst case scenario of the rocket motor as “inadvertently ignites when personnel are nearby” without a specific breakdown of the hazards (reference section 4.3.2).

*The Board concludes that the safety analyses used to support the MC4152 Thermal Battery Rocket Sled Testing were not performed in sufficient detail to adequately address all scenarios associated with this accident.*

#### **4.2.2 Explosives Safety Compliance**

The following explosives safety requirements were not fully implemented:

- DOE M 440.1-1A, *Explosives Safety Manual*, Chapter II, item 13.3.5(4) requires “Test units containing low-firing-current actuators or detonators shall be clearly marked.”

The rocket motor test assembly was not marked as containing low-firing-current detonator (igniter).

- DOE M 440.1-1A, *Explosives Safety Manual*, Chapter II, item 6.0b states that “Stray energy, such as transients and other

forms of induced energy, can be imposed on circuits affecting [Electroexplosive Devices] EEDs from other subsystems by various methods. Examples are inductive or capacitive coupling; sneak ground circuits; defective components or wiring; errors in design, modification, or maintenance.”

The igniter was connected to the sled track side panel ground with a coaxial cable and an unexpected ground connection was discovered at the sled track side panel.

- DOE M 440.1-1A, *Explosives Safety Manual*, Chapter II, item 13.8.4a1 states that for electrical instruments used with non-initiating electrical circuits such as the HiCapPen “Each specific use of the instrument shall be analyzed to ensure no credible scenario exists whereby the normal test energy from the instrument can ignite explosives charges or initiators in the test.”

The ST Mgr stated that he suspected that there was a potential hazard due to the battery in the HiCapPen and he instructed an electrical engineer to assess the hazard. No documentation of this analysis was provided to the Board.

- DOE M 440.1-1A, *Explosives Safety Manual*, Chapter II, 7.1 states that “Positive steps must be taken to control or eliminate static electricity in areas where materials that are ignitable by static spark discharge are processed or handled. This includes spark-sensitive explosives, propellants, and pyrotechnics as well as solvent

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vapors, and flammable gases. Wires used as static ground conductors should be at least No. 10 AWG or equivalent.”

- CPR400.1.1.31, *SNL ES&H Explosives Safety Manual* Chapter II, 7.1S states that “Explosive materials and explosive devices require special care in handling and packaging because they can be set off by discharges of static electricity at levels commonly found in the work environment. In all cases, take special care to maintain the item and all of its electrically isolated parts in electrostatic equilibrium with their environment and anyone who may touch them.”

A 20 AWG wire pigtail, a coaxial cable, and a shorting plug were used to short the igniter. The shorting plug was grounded to the track side panel ground. The OPs did not specify any bonding or grounding instructions. The TE and technicians devised bonding and grounding methods based on their experience with Super Zuni rocket motors. The OPs did not specify when the IN workers were required to use wristbands.

Representatives of sled track management provided the TAT and the Board with a bonding and grounding graphic of how the test series was most likely setup at the time of the accident. The practice of clamping bonding straps to oxidized track rails did not provide an adequate common earthen ground.

*The Board concludes the test series setup did not provide adequate grounding and bonding.*

- CPR400.1.1.31, *SNL ES&H Explosives Safety Manual* Chapter II, 7.4Sa states “Use of wristbands during all operations involving static-sensitive explosive materials is mandatory. The functional check should be between the wearer contact point and the wristband attachment to ground. Functional checks shall be noted in the facility log.”

A wristband was not used by AF1 and IN1 during the instrumentation procedures for the HiCapPen preparation for this test. Evidence suggested that a wristband clamped to the East track may have been used during the shorting and grounding of the rocket motor. This wristband was connected to the oxidized East rail and measurements after the accident demonstrated no conductivity with the rail. Functional checks of the wristband bonding connections were not documented.

- DOE M 440.1-1A, *Explosives Safety Manual*, Chapter II, item 1.6 states “Before beginning explosives operations, managers shall educate and train employees in the hazards and precautions required for handling explosives and materials used in conjunction with explosives operation. This training should be a part of the employee training and qualification program specified in Chapter V.”

The OP requires personnel to take XPL-160, *Explosives Safety Course*. This course did not provide sufficient detail to ensure that personnel could effectively implement established explosives safety requirements and safe work practices.

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*The Board concludes that based on the work practices described in the OP and testimony of the workers, Sandia management did not adequately educate and train employees in the hazards and precautions required for handling explosives and materials used in conjunction with explosives operation.*

- CPR400.1.1.31, SNL ES&H *Explosives Safety Manual*, Chapter II, item 7.4Sc2 states that “Wristbands without resistors should be visually inspected prior to each use and conductivity verified to be less than 1,200,000 ohms at least once per year. Verification shall be recorded.”

The wristband (W011) connected on the east rail of the accident site was identified as being in fair physical condition during the last inspection on February 13, 2007. The grounding strap (G009) used at the side panel was documented as good physical condition during the last inspection on February 13, 2007.

- CPR400.1.1.31, SNL ES&H *Explosives Safety Manual*, Chapter II, item 7.1Sb3 requires workers to “Use tools that are non-sparking (nonferrous metal) and unpainted.”

IN1 gave a ferrous screwdriver to AF1. AF1 accepted the ferrous screwdriver to connect the LED module to the MDM25 connector.

- CPR400.1.1.31, SNL ES&H *Explosives Safety Manual*, Chapter I, item 8.4Sa6 states that “Maintain lightning protection and static grounding systems in accordance with Chapter X.”

No records related to the Sled Track grounding system maintenance, inspection, or verification of system integrity were provided in response to a request from the Board.

*The Board concludes that the above identified practices represent a normalization of deviation from established explosives safety work practices.*

### **4.3 Sandia’s Integrated Safety Management System**

CPR400.1.2, *Integrated Safety Management System (ISMS) Description*, January 11, 2008, documents the Sandia ISMS. The Board reviewed Sandia’s implementation of the five core functions. The Board found weaknesses associated with four of the five core functions.

#### **4.3.1 Core Function 1, Define the Scope of Work**

No specific issues were identified with respect to the definition of the work to be performed in the experimental series.

#### **4.3.2 Core Function 2, Analyze the Hazards**

The complicated relationship between the various qualitative hazard assessment methods used by Sandia made it challenging for line management to ensure that the hazards and associated controls for the MC4152 Sled Test Series were clearly communicated to the workers.

The following diagram is an excerpt from a diagram in the *Validation and Qualification Sciences Experimental Complex, Quality Assurance Plan and Work Controls Program*.

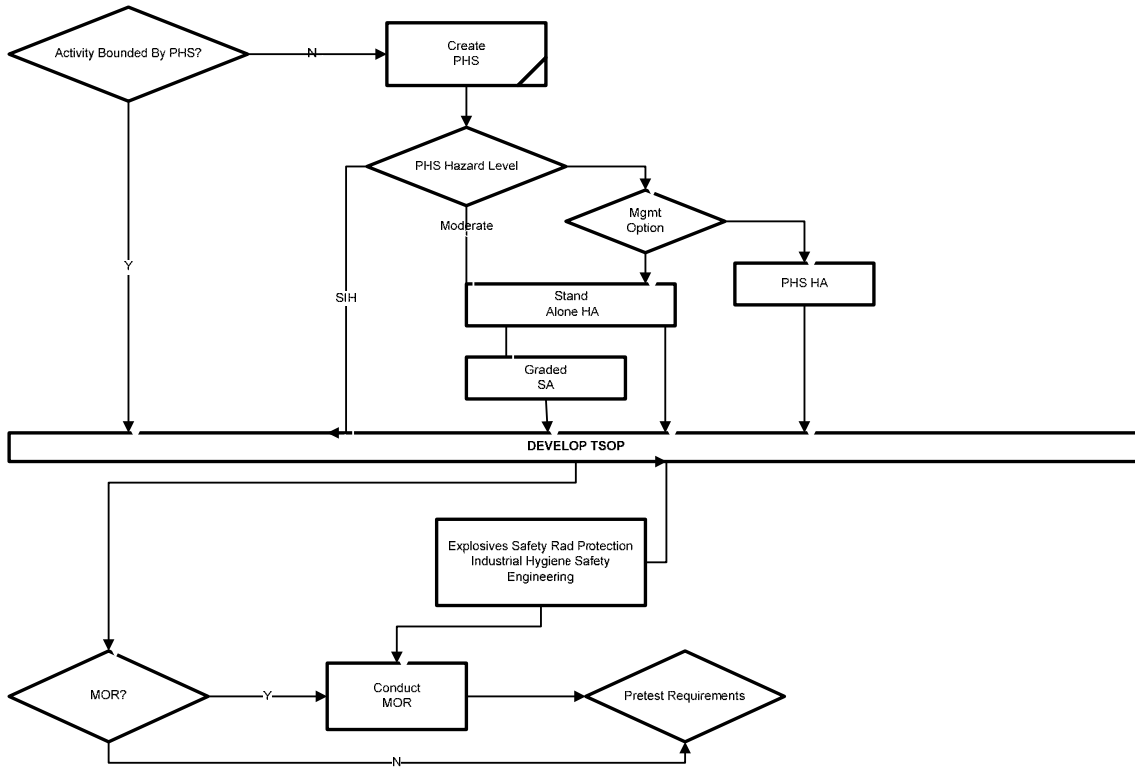


Figure 4-1. Validation and Qualification Sciences Experimental Complex, Quality Assurance Plan and Work Controls Program

The Primary Hazards Screening (PHS), Integrated Work Plan (IWP), Hazards Analysis (HA), Safety Assessment (SA), and Management Operational Review (MOR) identified inadvertent rocket firing as the worst case accident scenario; however, the only controls identified in these documents were the OPs. The OPs did not contain guidance to the workers on specifics such as grounding and bonding instructions, verifying continuity and resistivity of bonding and grounding systems, and when using wriststraps was required. The referenced documents did not include an analysis of the rocket sled test configuration. The need for electrical isolation of all batteries in the test package from the low energy

igniter in the rocket motor was not documented.

*The Board concludes the OPs for this sled track test series were derived from the OPs from previous similar tests. Additional hazards analysis specific to this test series were not documented and used during the development of the OPs for this specific test series.*

Sled Track management used the HA and SA to evaluate the risk of the Sled Track operations. Risk is categorized using qualitative methods to estimate the probability of occurrence and the severity of consequences of postulated accidents. Tables 1 and 2 below define parameters considered during qualitative risk analysis.

<b>Table 4-1 - Consequence Guidelines</b>	
<b>Consequence Level</b>	<b>Onsite (Workers)</b>
High (H)	Immediate worker fatality
Moderate (M)	Life-threatening injuries
Low (L)	Less than Life-threatening injuries
Negligible (N)	Minor medical treatment (such as cuts, bruises, contusions, and minor skin irritations)

<b>Table 4-2 - Frequency Guidelines</b>	
<b>Description</b>	<b>Frequency (per year)</b>
Anticipated (A)	$F \geq 1.0E-02$
Unlikely (U)	$1.0E-02 > F \geq 1.0E-04$
Extremely Unlikely (EU)	$1.0E-04 > F \geq 1.0E-06$
Beyond Extremely Unlikely (BEU)	$F < 1.0E-06$

The Board compared two similar accident scenarios in the hazard evaluation table of the SA-RSD-2006-0001, *Rocket Sled Track Complex Safety Assessment Safety Assessment (SA)*. In scenario STT-4, an explosion occurs near the sled track in the vicinity of the test package or rocket during test preparation and results in injury. The test package in this scenario may contain radioactive material and high explosives and the rocket motors contain propellant. In scenario STT-5, a normal test fails which causes fire and/or explosion at the sled track and result in injury.

The postulated causes of event STT-4 include an electrical short, leaking batteries, battery overheats, static electricity, equipment/vehicle fire, and equipment/vehicle collision. The causes of STT-5 include an electrical short, static electricity, electrical component failure, human error during preparation, sequence problem, design errors, hardware faults, etc. Both of these events were assessed to have an

unmitigated frequency level of “Anticipated,” and the unmitigated local physical consequence level for both events was determined to be “High.”

Preventive features are identified in the SA to reduce the probability of occurrence of the postulated scenarios. The preventive features for both accidents were “Conduct of Operations (Test Specific Operating Procedure (TSOP), Access Controls),” “Fire Protection Program,” and “Explosives Safety Program.” Crediting these identified controls, STT-4 probability is reduced to “Extremely Unlikely” and STT-5 is reduced to “Unlikely.” The difference in reduction in probability is not explained in the SA.

*The Board concludes the cited probability reduction in the SA from “Anticipated” to “Extremely Unlikely” was not supported by the identification of specific design features or engineered barriers to minimize the probability of the analyzed scenarios.*

Mitigative measures are identified in the SA to reduce the severity of the consequences associated with the STT-4 and STT-5 scenarios. Both scenarios list “Conduct of Operations (TSOP, Access Controls)” and “Emergency Preparedness Program” as mitigative features. STT-5 also cites a “Design Feature (building 6741 and 6742).” No explanation of the attributes of the design feature is provided for this in the SA.

The STT-4 consequence remained “High” and the STT-5 consequence was reduced to “Negligible.” The difference in the reduction of consequence between STT-4 and STT-5 is not explained in the SA. Because the hazard is an unanticipated explosion, the only mitigation that would result in a reduction from “High” to “Negligible” would be physical separation of the explosive and the human receptors.

*The Board concludes that because the accident under review involves workers in close proximity to the*

*rocket, the reduction in severity of the consequence would not be consistent with the qualitative analytical method described in the SA.*

PHS Number 9632456779-013, Area III Sled Track Complex, was written to encompass all the operations at the Sled Track. The PHS categorized the Sled Track operations as a “Moderate” hazard requiring the development of a HA. Sled track management considered the HA to be a bounding analysis and elected not to develop an activity-specific PHS for this test series.

VQSEC Operating Procedure, OP473407, 10019 Issue B, *Explosives Hazards Analysis*, is the HA for TA-III. Table 3 provides guidance for identifying risk bins for hazards based on unmitigated risk. Table 4 – Hazard Assessment for TA-III Sled Track Complex, contains the hazard analysis results for the sled track operations.

<b>Table 4-3 - Risk Bins for Onsite Receptors</b>				
<b>Frequency → Consequence ↓</b>	<b>Beyond Extremely Unlikely (BEU)</b>	<b>Extremely Unlikely (EU)</b>	<b>Unlikely (U)</b>	<b>Anticipated (A)</b>
High (H)	III	II	I	I
Moderate (M)	IV	III	II	I
Low (L)	IV	IV	III	II
Negligible (N)	IV	IV	IV	III

Note: Events classified as Risk Rank I or II, based on unmitigated risk, are carried forward for identification and discussion.

Operation	Mode of Failure	Effect	Frequency	Consequence Level	Risk Rank	Mitigating Features
Premature detonation of explosives while personnel are in the area.	Human error, such as inadvertent charging of fireset	Injury or death of employees due to overpressure and fragmentation	BEU	Moderate	IV	TWDs Engineering Controls Two-person rule Grounding Training Range limits Controlled Access Proper storage and handling Shielding

Risks are defined in terms of Risk Rank I, II, III, or IV. According to the procedure, hazards classified as Risk Rank I and II are those of “significant concern” and hazards classified as Risk Rank III and IV are of “less concern”.

Table 4 of the HA defines the operation being analyzed as “Premature detonation of explosives while personnel are in the area.” The mode of failure is defined as “Human error, such as inadvertent charging of fireset.” The effect is “Injury or death of employees due to overpressure and fragmentation.” The frequency level was determined to be “Beyond Extremely Unlikely” (less than  $1 \times 10^{-6}$ ) with a consequence level of “Moderate.”

Potential initiators of the rocket motor that were not included in this analysis include:

- electrostatic discharge (ESD);
- natural phenomena (e.g., lightning);

- use of ferrous tools (potential source of a spark);
- energy from test packages (e.g., HiCapPen); and
- radio frequency (RF) sources.

Several inconsistencies were noted between the HA and SA for the Sled Track Operations. The HA unmitigated frequency of “Beyond Extremely Unlikely” is not supported by either example from the SA. In the SA, the unmitigated frequency is “Anticipated” and the lowest mitigated frequency is “Extremely Unlikely.” Based on the SA, the unmitigated frequency in the HA should have been “Anticipated.” The HA unmitigated consequence was determined to be “Medium.” Both examples from the SA started with an unmitigated local physical consequence of “High.” Based on the values in the SA, the HA should have been an unmitigated Risk Rank I. Proper Risk Ranking in the HA would have resulted in the need for



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additional analysis of this test configuration.

*The Board concludes that, based on an unmitigated scenario, the likelihood should be substantially higher than “Beyond Extremely Unlikely.” According to the HA, if the frequency had been assessed as “Anticipated” or “Unlikely,” this activity would have been within the Risk Rank of I or II and would have been carried forward for additional identification and discussion.*

IWP 1737, MC4152 Thermal Battery Rocket Sled Testing, was developed to facilitate planning of this test series. The IWP references the PHS for the Sled Track, but does not reference the SA or HA. In the IWP Interview Questions and Answers, a “no” response was given for the following questions:

- IWP Question 31 Concerning TSOP and OPs – Have explosives safety issues been reviewed?
- IWP Question 32 Concerning TSOP and OPs – Have fire protection requirements been documented?
- IWP Question 33 Concerning TSOP and OPs – Have Lightning safety and static electricity issues been identified?
- IWP Question 34 Concerning TSOP and OPs - Have security issues been addressed?
- IWP Question 35 Concerning TSOP and OPs – Is an emergency plan in place?

- IWP question 36 Concerning TSOP and OPs – Is there adequate control of hazard area, including safety observers?
- IWP question 37 Concerning TSOP and OPs – Is there documented engineering basis to establish hazard area?

When asked, the IWP authors stated that they believed the IWP questions set was asking whether additional review of these areas was required.

Per the SA, prior to each test operation, the Rocket Sled Track Complex Manager (ST Mgr) performs a MOR to verify that ES&H and programmatic requirements are met. As part of this review, the ST Mgr, or his designee, determines that the requirements specified in the SA are properly implemented.

The MOR was part of the TSOP development process. Activity-specific OPs were intended to capture the required controls for the operation of the Sled Track and are discussed in Section 4.3.3 of this report.

The HA and SA both focused on all sled track operations and were not specific to the MC4152 Sled test series. The primary hazards associated with this activity were introduced into the facility by each individual test series. AF1 stated that he did not participate in the MOR, but had read and signed the OP MC4152. Based on interviews, it was determined that the hazard analysis for this sled track test series by the TE and the MOR of the test configuration was informal, verbal and undocumented. The MOR discussion of hazards associated

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with the test series was not documented in the notes in the final approved MOR.

*The Board concludes hazards specific to this test series were not fully analyzed and were informally discussed with the workers.*

The development and approval of the various hazards analyses associated with this series of tests did not demonstrate a level of technical inquisitiveness that could have increased the likelihood that the potential hazards associated with the test configuration were adequately identified and analyzed.

*The Board concludes that if implementation of the hazard assessment processes had more thoroughly identified hazards associated with this test series, required hazard controls could have been more clearly identified and followed by the workers.*

#### **4.3.3 Core Function 3, Develop/Implement Controls**

ISM requires controls to be developed and implemented based on the analysis of the hazards for an operation. The controls for this test series were captured in the OP473407-12349, *MC4152 Thermal Battery Rocket Sled Testing*. The OP was developed based on OPs from previous experiments; the connection between the hazard analysis methodologies and the OPs was not clearly demonstrated. This practice represents a normalization of deviation. Those involved with the development of the OP did not question the adequacy of the hazards analysis.

*The Board concludes the controls were based on historical operations and not a detailed analysis of the rocket sled test series as required by Integrated Safety Management.*

#### **4.3.4 Core Function 4, Perform Work Safely**

Several OPs were used to perform work at the Sled Track. The OPs reviewed did not contain detailed instructions (e.g., how to ground the test configuration, when wrist straps were required to be worn). The work was performed by AF1, AF2, and IN1 based on the experience of the workers and not necessarily the stated steps in the procedure.

A procedure was found in the control room and the CO had checked off most of his operational steps. A current OP was not found by the sled track and interviews confirmed that the sled side work was being performed based on each worker's training and experience. The procedure checklist was not being marked by AF and IN as required by the OP.

The same procedure was to be used by the CO and the workers that are physically located by the Sled Track. Communication between the CO and workers at the Sled Track was limited due to the logistics of the operation (e.g., physical separation and due to the restriction not to use the radio within 50 feet of the rocket). It was sled track management's stated expectation that a coordinated effort would be made to sign off procedure, but a process was not in place to sign off the procedure at multiple locations.

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*VQSEC Conduct of Operations, Chapter XVI Operations Procedures, Section 7 states that “Operators should have procedures with them and follow them in a step-by-step manner when the procedures contain sign-offs for the various activities.”*

OP473407-12349, MC4152 *Thermal Battery Rocket Sled Testing* stated that long sleeved shirts were required PPE for this activity. AF1 was wearing a short sleeved shirt at the time of the accident.

*The Board concludes that the actions of the workers involved with this test series did not demonstrate an understanding of conduct of operations principles.*

#### **4.3.5 Core Function 5, Feedback and Improvement**

Several SSO and Sandia assessment reports of sled track related activities were reviewed by the Board. The assessments were at a high level and concentrated on documentation and did not document observation of actual sled track operations. None of the reviewed assessment reports identified the hazards analysis and controls that failed during this accident. Corrective actions associated with the provided assessment reports were not provided to the Board.

Occurrence Reporting and Processing System (ORPS) report DP-ALO-KO-SNL-200-1993-0004, *Premature Rocket Sled Detonation, Resulting in Brush Fire*, describes a situation similar to the subject incident for this investigation. The event involved 25 Super Zuni rocket motors. The direct cause identified

in the ORPS report was that the fire set “was modified for the test in a manner that created an extreme sensitivity to spurious noise induced on the trigger circuit. This faulty design was directly responsible for the premature detonation of the payload which occurred when the second-stage rocket motor ignited.”

ORPS report DP-ALO-KO-SNL-2000-200—0002, *Employee Injured by Detonation at Explosive Components Facility*, involved an unexpected detonation. The ORPS report stated that the root cause was that the implementing procedure did not include a specific requirement to consider isolating all energy sources, including diagnostics, to the component being tested.

Several of the corrective actions from these two incidents could relate to this test sled incident, but the details of the corrective action implementation, closure and lessons learned were requested by the Board. The information was not provided to the Board.

A 2008 SSO Self Assessment identified SSO and Sandia feedback and improvement deficiencies. Weaknesses were noted associated with trending and analysis of data, issues management, and lessons learned program implementation.

*The Board concludes that line management missed opportunities to improve the effectiveness of management system implementation because of weaknesses in feedback and improvement.*

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## **5.0 CAUSAL FACTORS**

### **5.1 Direct Cause**

The direct cause of the accident was the inadvertent ignition of the Super Zuni rocket motor.

### **5.2 Root Cause**

Sandia did not fulfill their responsibilities under 10 CFR 851, *Worker Protection* and the DOE M 440.1-1A, *Explosives Safety Manual* to control explosives hazards as evidenced by the following:

- Hazards associated with this rocket sled test series were not accurately analyzed or fully controlled.
- The design of this rocket sled test series did not ensure that the test package was electrically isolated from the Super Zuni rocket motor.

- The test series set up did not provide adequate grounding, shorting and bonding.
- Sandia management did not adequately educate and train employees in the hazards and precautions required for handling explosives and materials used in conjunction with explosives operation.
- The actions of the workers involved with this test series did not demonstrate an understanding of explosives safety requirements or conduct of operations principles.

### **5.3 Contributing Causes**

Sandia management failed to detect violations of explosives safety requirements and deviations from established practices.

## 6.0 CONCLUSIONS AND JUDGMENTS OF NEED

JONs are the managerial controls and safety measures determined by the Board to be necessary to prevent or minimize the probability or severity of a recurrence. These JONs are linked directly to the causal factors,

which are derived from facts and analyses and form the basis for corrective action plans and which are the responsibility of line management. The following table, Table 6-1, contains the Board's conclusions and the JONs.

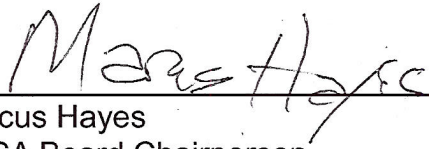
**Table 6-1. Conclusions and Judgments of Need**

Conclusions	Judgments of Need
The Board concludes that the safety analyses used to support the MC4152 Thermal Battery Rocket Sled Testing were not performed in sufficient detail to adequately address all scenarios associated with this accident.	Sandia needs to develop and implement a plan to fulfill their responsibilities under 10 CFR 851, <i>Worker Protection</i> and the DOE M 440.1-1A, <i>Explosives Safety Manual</i> to control explosives hazards.
The Board concludes the test series setup did not provide for adequate grounding and bonding.	
The Board concludes that based on the work practices described in the OP and testimony of the workers, management did not adequately educate and train employees in the hazards and precautions required for handling explosives and materials used in conjunction with explosives operation.	
The Board concludes the OPs for this sled track test series were derived from the OPs from previous similar tests. Additional hazards analysis specific to this test series were not documented and used during the development of the OPs for this specific test series.	
The Board concludes the cited probability reduction in the SA from "Anticipated" to "Extremely Unlikely" was not supported by the identification of specific design features or engineered barriers to minimize the probability of the analyzed scenarios.	
The Board concludes that because the accident under review involves workers in close proximity to the rocket, the reduction in severity of the consequence would not be	

Conclusions	Judgments of Need
consistent with the qualitative analytical method described in the SA.	
The Board concludes that, based on an unmitigated scenario, the likelihood should be substantially higher than “Beyond Extremely Unlikely.” According to the HA, if the frequency had been assessed as “Anticipated” or “Unlikely,” this activity would have been within the Risk Rank of I or II and would have been carried forward for additional identification and discussion.	
The Board concludes hazards specific to this test series were not fully analyzed and were informally discussed with the workers.	
The Board concludes that if implementation of the hazard assessment processes had more thoroughly identified hazards associated with this test series, required hazard controls could have been more clearly identified and followed by the workers.	
The Board concludes the controls were based on historical operations and not a detailed analysis of the rocket sled test series as required by ISM.	
The Board concludes that the actions of the workers involved with this test series did not demonstrate an understanding of conduct of operations principles.	Sandia management needs to ensure violations of explosives safety requirements and deviations from established practices are detected and corrected.
The Board concludes that identified practices represent a normalization of deviation from established explosives safety work practices.	
The Board concludes that SSO’s efforts to improve Sandia’s safety and health performance is an ongoing challenge.	SSO needs to evaluate the effectiveness of its RBO of explosives operations and facilities.

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7.0 BOARD SIGNATURES



Marcus Hayes  
NNSA Board Chairperson  
Service Center



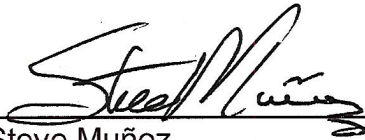
John E. Franchere, CSP  
NNSA Board Member  
Sandia Site Office



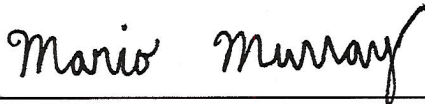
Kevin Carr  
NNSA Board Member  
Service Center



Lynn Maestas, MBA  
NNSA Board Member  
Service Center



Steve Muñoz  
NNSA Board Member  
Service Center



Mario Murray  
NNSA Board Member  
Service Center

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## 8.0 LIST OF BOARD MEMBERS, ADVISORS AND STAFF

### Board Members

Chairperson	Marcus Hayes, Occupational Safety and Health Manager, National Nuclear Security Administration Service Center
Analyst	John E. Franchere, Safety Engineer, Environment, Safety and Health Office, Sandia Site Office
Member	Kevin Carr, Explosives Safety Engineer, National Nuclear Security Administration Service Center
Member	Lynn Maestas, Physical Scientist, National Nuclear Security Administration Service Center
Member	Steve Muñoz, Electrical Engineer, National Nuclear Security Administration Service Center
Member	Mario Murray, Safety Engineer, National Nuclear Security Administration Service Center
Administrative Support	Denise Regalado, Administrative Analyst



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**APPENDIX A – APPOINTMENT OF TYPE B  
ACCIDENT INVESTIGATION BOARD**

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National Nuclear Security Administration  
Sandia Site Office  
P.O. Box 5400  
Albuquerque, New Mexico 87185-5400



OCT 14 2008

MEMORANDUM FOR: Marcus Hayes, National Nuclear Security Administration/  
Service Center (NNSA/SC)  
FROM: *Kimberly A. Davis*  
Kimberly A. Davis, Acting Manager  
SUBJECT: Type B Accident Investigation, Sandia National  
Laboratories/New Mexico, Sled Facilities

You are hereby appointed Chairperson of the Accident Investigation Board (Board) to investigate the accident which occurred at the Sandia National Laboratories/New Mexico, Sled Track Facilities, Albuquerque, New Mexico on October 9, 2008. I have determined this accident meets the requirements established for a Type B accident investigation in the Department of Energy (DOE) DOE Order 225.1A, ACCIDENT INVESTIGATIONS, dated September 29, 1997.

The Board will be comprised of the following members:

- John E. Franchere, NNSA/Sandia Site Office (SSO)
- Mario Murray, NNSA/SC
- Kevin Carr, NNSA/SC

I am requesting that Ralph Fevig from Sandia National Laboratories/New Mexico act as a technical liaison to the Board. The Board will be assisted by advisors and consultants and by other support personnel as determined by the chairperson.

Michele Reynolds, Site Office Counsel, will serve as the legal liaison. The scope of the Board's investigation is to include, but is not limited to, identifying all relevant facts; analyzing the facts to determine the direct, contributing, and root causes of the incident; developing conclusions; and determining judgments of need that, when implemented, should prevent the recurrence of the incident.

If additional resources are required to assist you in completing this task, please let me know and it will be provided. You and members of the Board are relieved of your other duties until this assignment is completed.

The Board is to provide my office with weekly reports on the status of the investigation but will not include any findings or arrive at any premature conclusions until an analysis of all the causal factors have been completed. Draft copies of the factual portion of the investigation report will be submitted to my office, for factual accuracy review prior to the report finalization. The final investigation report should

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Marcus Hayes

-2-

be provided to me by November 13, 2008. Any delay to this date shall be justified and forwarded to this office. Discussions of the investigation and copies of the draft report will be controlled until I authorize release of the final report. If you have any questions, please contact me at (505) 845-4392 or Dave Rast of my staff at (505) 845-5349.

cc:

G. Talbot, NA-17  
F. Russo, NA-1  
C. Lewis, HS-31  
K. Boardman, NNSA SC  
R. Sena, NNSA SC  
C. Soden, NNSA SC  
M. Hayes, NNSA SC  
K. Carr, NNSA SC  
M. Murray, NNSA SC  
B. Scott, SSO  
D. Brunell, SSO  
D. Rast, SSO  
M. Reynolds, SSO  
J. Franchere, SSO  
T. Hunter, SNL/NM  
M. Hazen, SNL/NM  
R. Fevig, SNL/NM

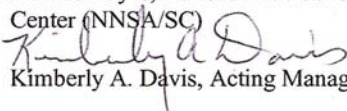


**National Nuclear Security Administration**

Sandia Site Office  
P.O. Box 5400  
Albuquerque, New Mexico 87185-5400



**NOV 12 2008**

MEMORANDUM FOR: Marcus Hayes, National Nuclear Security Administration/Service Center (NNSA/SC)  
FROM:   
Kimberly A. Davis, Acting Manager  
SUBJECT: Type B Accident Investigation, Sandia National Laboratories/New Mexico, Sled Track Facilities

As the appointed Chairperson of the Accident Investigation Board to investigate the accident which occurred at the Sandia National Laboratories/New Mexico, Sled Track Facilities, Albuquerque, New Mexico, on October 9, 2008, you have the authority to request additional personnel to assist you as subject matter experts.

The Sandia Site Office has approved your request for the following individuals to be added as Board members:

- Lynn Maestas, NNSA/SC
- Steve Munoz, NNSA/SC

If additional resources are required to assist you in completing this task, please let me know and it will be provided. The newly appointed Board members are relieved of their other duties until this assignment is completed.

The final investigation report should be provided to me by November 13, 2008. Any delay to this date shall be justified and forwarded to this office. Discussions of the investigation and copies of the draft report will be controlled until I authorize release of the final report. If you have any questions, please contact me at (505) 845-4392 or Dave Rast of my staff at (505) 845-5349.

cc:

G. Talbot, NA-17  
F. Russo, NA-1  
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K. Boardman, NNSA/SC  
R. Sena, NNSA/SC  
C. Soden, NNSA/SC  
K. Carr, NNSA/SC  
M. Murray, NNSA/SC  
B. Scott, SSO  
D. Brunell, SSO

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Marcus Hayes

-2-

D. Rast, SSO  
M. Reynolds, SSO  
J. Franchere, SSO  
T. Hunter, SNL/NM, MS-0101  
M. Hazen, SNL/NM, MS-0143  
R. Fevig, SNL/NM, MS-1094

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**APPENDIX B – BARRIER ANALYSIS**

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## Barrier Analysis

**Table B-1. Barrier Analysis Table**

Hazard: Rocket Motor Fires		Target: AF1	
What were the barriers?	How did each barrier perform?	Why did the barrier fail?	How did the barrier affect the accident?
Use of Non-ferrous Tools on a Low Energy, ESD Sensitive Article	No nonferrous tools identified at accident scene	AF1 was in position of a ferrous screwdriver and ferrous wire stripper at the time of the incident.  The presence of ferrous tools provided a second potential way to initiate this incident.	The analysis of the incident determined that the LED made contact with pin 4 and caused this incident.  Ferrous tools are a second potential initiator for a less than adequately grounded rocket and should not have been in use at the time of the incident.
Compliance with the DOE Explosive Safety Manual and SNL Established Explosive Safety Procedures	Weaknesses identified in implementation	Established Explosives Safety Procedures contain explicit requirements for working with explosives. Several of these requirements were not implemented in a manner that would prevent this accident.	More thorough implementation of the Explosives Safety Procedures would have prevented this accident (e.g., proper grounding, checking continuity of bonding and grounding systems, use of wrist straps, isolation, and limiting current from HiCapPen battery).
Work planning to ensure hazards are identified and controlled, and different jobs are coordinated	The complicated relationship between the various hazard assessment methodologies make it difficult for line management to ensure that the hazards and associated controls are clearly communicated to the worker.	The PHS, IWP, HA, and MOR identified inadvertent rocket firing as the worst case hazard scenario, however, the only controls identified in these documents were the OPs and specific hazards and controls of the test series were not identified.	If sled track management's implementation of the hazard assessment processes had more thoroughly identified hazards associated with this operation, required hazard controls would have been more clearly identified and followed by the worker.

SSO and SNL Management did not ensure requirements were followed and that systems were fully operational.	Management did not effectively assess sled track operations and was unaware of many deviations from SNL's ISM and established explosive safety procedures and practices.	More thorough implementation of the Explosives Safety Procedures would have prevented this accident.	Management did not detect the ineffective implementation of explosive safety procedures or ISM.
Operating Procedures and Checklist	Weaknesses identified in implementation	The MC4152 OP did not contain detailed steps to implement the SNL explosive safety manual (e.g., proper grounding, checking continuity of bonding and grounding systems, and use of wrist straps). The checklist was not used or fully completed (marked) up to the point of the accident by all of the involved workers.	Use of detailed explosive safety compliant checklist and procedures would have prevented the accident from occurring.
Personal Protective Equipment (PPE) - Long Sleeved Cotton Shirt	The PPE required by the OP was not implemented	The OP requires workers to wear long sleeve cotton shirts. This requirement was not rigorously enforced.	If AF1 had been wearing a long sleeved cotton shirt per the OP, the burns on his arms may not have been as severe.



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**APPENDIX C – CHANGE ANALYSIS**

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## Change Analysis

**Table C-1. Change Analysis Table**

<b>Accident Situation</b>	<b>Prior, Ideal, or Accident-Free Situation</b>	<b>Difference</b>	<b>Evaluation of Effect</b>
AF1 inserted LED	IN2 inserted LED for morning test. The OP calls for an IN tech to install the LED.	AF1 stated he did not have much experience using MDM25 connectors.	AF1's inexperience with MDM25 connectors may have increased the likelihood of grounding the connector bodies during the installation attempt.
Electrical tape was placed around the LED housing to shade the LED bulb so that it could be seen by the CO through the closed circuit monitors.	LED bulb was not shaded for the successful first test of the day.	The tape may have made it more difficult to line up the LED with the test unit.	AF1 stated that the presence of the electrical tape did not interfere with the installation and that the tape was on the LED when he received it.
Arming of HiCapPen changed – a 5 minute time delay was added to arming sequence	Arming of HiCapPen performed sled side was to fully armed mode.	Time delay added to HiCapPen arming sequence to allow time for personnel to move to safety before the HiCapPen fully armed.	This change was made to increase worker safety.
Method of establishing appropriate isolation between components did not preclude flow of electricity to igniter.	Ideal: Test sled configuration should isolate electrically sensitive components from battery supply	Ineffective isolation of components provided a path for energy to the igniter.	Rocket motor fired unexpectedly.
Grounding and bonding was not in accordance with the Explosives Safety Manual.	Grounding and bonding is adequate to mitigate ESD hazard.	Ineffective bonding and grounding was not in accordance with the Explosives Safety Manual.	Even though ESD did not cause this accident, the ESD sensitive rocket igniter could have been initiated by ESD due to ineffective bonding and grounding.

Accident Situation	Prior, Ideal, or Accident-Free Situation	Difference	Evaluation of Effect
OPs did not contain sufficient detail to ensure that the test configuration were the same for each test (e.g., bonding, grounding, electrical connections, isolation).	Hazardous work performed per OPs that are specific and developed based on activity-specific hazards analysis.	Variations in the way OPs are used in the field provide opportunities for variations in the way recognized hazards are controlled.	The potential for unexpected ignition of the rocket motor was not analyzed and effective controls were not devised to protect against inadvertent activation of the rocket motor.
Current from the HiCapPen battery flowed to the rocket motor igniter.	HiCapPen battery current is limited below firing current of rocket igniter.  HiCapPen current isolated from rocket igniter.	Rocket igniter exposed to energy source from HiCapPen.	Rocket motor fired unexpectedly.
Management accepted the results of previous hazard assessments during OP development	Prior situation: a long history of sled track operations without inadvertent rocket motor initiation.  Ideal situation: a hazard analysis is performed to determine how each test series/configuration impacts the worst case scenario.	The PHS, IWP, HA, SA, and MOR all identify that the worst case scenario for the test series was an inadvertent rocket motor ignition.	None of these processes addressed the specific hazards and controls that could prevent inadvertent rocket motor ignition.
Igniter wire was shunted at end of 106 ft fire cable.	Place shunt as close to igniter wire as possible to minimize line resistance through the shunt.	Placement of shunt at the end of 106 ft cable allowed sufficient current from the HiCapPen battery to flow through the igniter instead of the shunt.	Rocket motor fired unexpectedly.