TYPE B ACCIDENT INVESTIGATION

OF THE

JANUARY 28, 2003

FALL AND INJURY AT THE

STANFORD LINEAR ACCELERATOR CENTER

February 2003

Stanford Site Office

U.S. Department of Energy

DISCLAIMER

This report is an independent product of the Type B Accident Investigation Board appointed by John S. Muhlestein, Director, Stanford Site Office (DOE/SC), U.S. Department of Energy.

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

The discussion of facts, as determined by the Board, and the views expressed in the report are not necessarily those of the Department of Energy and do not assume and are not intended to establish the existence of any legal causation, liability, or 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.

RELEASE AUTHORIZATION

On 5 February 2003, I appointed a Type B Accident Investigation Board to investigate the January 28, 2003 fall and personal injury at the Stanford Synchrotron Radiation Laboratory at the Stanford Linear Accelerator Center. The responsibilities of the Board have been satisfied with respect to this investigation. The analysis, identification of contributing and root causes, and judgments of need reached during the investigation were performed in conformance with Department of Energy Order 225.1A, *Accident Investigations*.

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

John S. Muhlestein

Director, Stanford Site Office (DOE/SC)

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PROLOGUE

On January 28, 2003, an employee sustained head injuries as the result of a ladder fall at a power supply location at the Stanford Synchrotron Radiation Laboratory (SSRL) at the Stanford Linear Accelerator Center (SLAC).

The Type B Accident Investigation Board found that SLAC line managers responsible for work conducted at that facility were not sufficiently engaged in work monitoring and follow-up activities to ensure that work was planned, hazards were analyzed and controls developed and implemented. Analysis and trending of previous ladder-related accidents at the site indicated a need to improve line management oversight, work planning and controls and perform hazard evaluations to assure that appropriate safety requirements were implemented prior to performing work.

DOE oversight on follow-up actions to the 1999 Integrated Safety Management System (ISMS) Phase II Verification Report was also inadequate to ensure that SLAC line management was being held accountable for safety and that a process was in place to ensure that the Laboratory had developed criteria to determine when a task-specific hazard analysis needed to be completed and procedures to ensure effective implementation of the process. Furthermore, adequate DOE resources were not available to perform effective line ES&H oversight of work activities at SLAC.

The Stanford Site Office (SSO) and SLAC will ensure that the integrated safety management systems approach to work planning, hazard analysis, hazard controls, work authorization and feedback and improvement is fully implemented prior to performing work activities at the site. The SSO has worked successfully with the Laboratory through performance-based management and oversight processes to identify safety management system implementation weaknesses requiring attention by DOE and the Laboratory, including development of an effective line management self-assessment program. The SSO will continue to work closely with SLAC senior management to facilitate and enhance the high level of communication, trust and teamwork that has served as the foundation for implementing continuous improvement which has contributed to the overall excellent safety record of the Laboratory.

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TABLES, FIGURES, AND EXHIBITS

ACRONYMS AND INITIALISMS

AD	Associate Director
AME	Accelerator Maintenance East
ASD	Accelerator Systems Division
CFR	Code of Federal Regulations
ESD	Electronics and Software Engineering Department
DOE	U.S. Department of Energy
EMS	Emergency Medical Services
ES&H	Environment, Safety, and Health
ESHM	Environment, Safety, and Health Manual
ISMS	Integrated Safety Management System
MSG	Mechanical Services Group
NNSA	National Nuclear Security Administration
OAK	Oakland Operations Office, U.S. Department of Energy
OCR	Operations Control Room
OMP	Occupational Medicine Physician
ORPS	Occurrence Reporting and Processing System
OSC	Operating Safety Committee
OSHA	Occupational Safety and Health Administration
PCD	Power Conversion Department
PPE	Personal Protective Equipment
PSOG	Power Systems Operations Group
RD	Research Division
RFHVPS	Radio Frequency High Voltage Power Supply
SC	Office of Science
SEM	Site Engineering and Maintenance
SLAC	Stanford Linear Accelerator Center
SPEAR	Stanford Positron-Electron Asymmetric Ring
SSO	Stanford Site Office, U.S. Department of Energy
SSRL	Stanford Synchrotron Radiation Laboratory
VVT	Variable Voltage Transformer
WSS	Work Smart Standards

EXECUTIVE SUMMARY

The Accident

On January 28, 2003, at approximately 9:30 A.M., a Systems Engineer at the Stanford Linear Accelerator Center (SLAC) received serious head injuries requiring hospitalization after falling from a ladder in Building 514.

On February 5, 2003, the Director of the Department of Energy's Stanford Site Office appointed a Type B Accident Investigation Board to analyze causal factors, identify root causes, and determine Judgments of Need related to the accident to preclude similar accidents in the future. The Board arrived onsite and began the investigation on February 6, 2003, and completed the investigation on February 24, 2003.

Background

SLAC is a national basic-research facility located in Menlo Park, California, and operates under the programmatic direction of the DOE Headquarters' Office of Science. The SLAC program centers on experimental and theoretical research in elementary particle physics using electron beams and a broad program of research in atomic and solid state physics, chemistry, biology and medicine using synchrotron radiation. Total SLAC staff numbers approximately 1,200, of which 150 are Ph.D. physicists. Each year approximately 3,000 scientists from academic and industrial concerns in 20 countries are active in the high-energy physics and synchrotron radiation program. The DOE Stanford Site Office, under the Office of Science, oversees site contractor activities. Stanford University operates the site under contract to the DOE.

Results and Analysis

The accident resulted from a number of deficiencies in the SLAC work control process, and general informality in execution of the integrated safety management program. Deficiencies were evident in all line management organizations including the DOE Office of Science (SC), the DOE Stanford Site Office (SSO), the SLAC, and the Stanford Synchrotron Radiation Laboratory (SSRL), responsible for the troubleshooting activities conducted the day of the accident.

During nitrogen leak troubleshooting activities in Building 514, SLAC line managers' unstructured approach to work did not ensure that safety and health requirements were translated into work controls, did not take those actions necessary to enforce compliance with fundamental safety requirements during the work, nor did they otherwise define their safety and health expectations for the activity prior to the start of work. If a hazard analysis had been developed to address the troubleshooting tasks and all identified controls had been implemented, unsafe work practices would have been recognized and the injury prevented. This inattention to safety and health requirements was indicative of a work environment where occupational safety and health policies, programs and procedures for worker safety and health were not routinely implemented or effectively enforced.

The weaknesses in the integrated safety management program enabled the Systems Engineer to commence troubleshooting activities in Building 514 without a defined scope of work. No task-specific hazard analysis was conducted therefore implementation of work controls was not effective. The absence of formal line management awareness and authorization permitted the engineer to continue those troubleshooting activities.

Conclusion

The Board concluded that this accident was preventable. The direct cause of the accident was a loss of footing while the Systems Engineer was stepping from the ladder to an elevated surface. The Board identified significant weaknesses in the implementation of integrated safety management system policy pertaining to nitrogen leak troubleshooting activities performed the day of the accident. These weaknesses impacted the effectiveness of worker safety and health protection including the processes for translating safety policy into implementing procedures, implementing line management's integrated safety management responsibilities, and personnel training and qualification.

SSRL line managers responsible for work conducted in Building 514 on the day of the accident were not sufficiently engaged in work monitoring and follow-up activities to ensure that work was planned, hazards were analyzed, and controls were developed and implemented. Since SLAC did not establish formal criteria for determining when task-specific hazard analysis should be performed and documented, no hazard analysis was conducted for troubleshooting activities. Instead, SSRL line management accepted an informal, expert-based approach to performing troubleshooting activities and controlling the associated hazards.

Over a period of five years, SLAC experienced four precursor occurrences involving ladders that resulted in severe personnel injuries. In addition, during annual briefings to the SLAC Operating Safety Committee on the status of safety at the site, staff of the SLAC Safety, Health, and Assurance Department has reported fall protection as a top safety and health concern. Analysis of these previous incidents indicated a need to significantly improve line management oversight, work planning and controls, and the performance of hazard evaluations to assure that appropriate safety requirements were implemented prior to performing work. Initiatives by SLAC to address the causes of the previous incidents and to prevent recurrence were not effective.

DOE oversight of ISMS at multiple levels was ineffective in identifying weaknesses in integrated safety management and ensuring that corrective actions and improvements from previous incidents and assessments were effectively implemented.

Judgments of Need	Conclusions
SLAC needs to develop and implement processes for work planning and control that: • defines the scope of work • establishes a criteria for performing task-specific hazards analyses • develops procedures for implementing task-specific hazard analyses • authorizes work • provides feedback to and from the workers • ensures line management are actively engaged in the process for controlling hazards.	SLAC has not demonstrated that the ISM core functions are being effectively implemented in the areas of work planning, task-specific-hazards analysis and implementing hazard controls to conduct work safely. Line management failed to develop an integrated approach for conducting task-specific hazard analyses. The Board concluded that because the scope of work was not defined, task-specific hazards were not analyzed and controls to protect employees were not developed by line management. A task-specific hazard analysis process was not implemented on January 28, 2003, that identified and assessed the task-specific hazards involved with the nitrogen leak troubleshooting activity in Building 514.
SLAC needs to develop effective employee performance evaluation standards to promote line management accountability for Safety. SSO needs to develop and implement an ongoing process to assess the effectiveness of SLAC's process for: • holding line management accountable to ensure adequate enforcement of safety requirements • addressing safety as part of the work planning and line management responsibilities for safety are implemented.	Line management failed to adequately address safety as part of planning for troubleshooting activities and failed to enforce compliance with fundamental safety requirements during those work activities. SSRL line management failed to adequately address safety as part of planning for troubleshooting activities and failed to enforce compliance with existing safety requirements during those tasks. The Board concluded that the occupational safety and health policies, programs, and procedures for worker safety and health were not routinely implemented or enforced in Building 514. Management responsible for the building and the work tasks did not identify and control the hazardous work environment in Building 514.

Judgments of Need	Conclusions
SLAC needs to develop and implement a procedure for accident scene management that meets the requirements of DOE Order 225.1A, Accident Investigations.	The Board concluded that the procedures used for accident scene management required by DOE Order 225.1A, were neither adequate, timely and/or effective. Although the procedural deficiencies indicated above did not affect the ultimate outcome of the investigation, they did impact its efficiency.
No Judgment of Need	The Board concluded that the results of the limited engineering evaluation indicate the Systems Engineer could have moved from the ladder while attempting to access the top of the VVT section of the old RFHVPS or the Systems Engineer encountered circumstances that caused him to move off the ladder. In either case the Systems Engineer would have fallen.
The Office of Science and SSO need to develop and implement an effective oversight program to ensure effective implementation of ISMS. SLAC needs to develop and implement an integrated process that effectively identifies the issues, tracks and trends the effectiveness of corrective actions, and reports results in ISMS terms to senior management for attention.	The Board concluded that DOE and SLAC oversight at multiple levels was inadequate to ensure effective implementation of ISMS as it pertains to troubleshooting activities the day of the accident. The Board concluded that the deficiencies in implementing ISMS at SSRL contributed to an unsafe work environment in Building 514 on the day of the accident.

1 INTRODUCTION

1.1 BACKGROUND

On January 28, 2003, at approximately 9:30 A.M. a Stanford Linear Accelerator Center (SLAC) employee (referred to as the Systems Engineer) fell and sustained serious head injuries. Emergency Medical Services (EMS) personnel were immediately summoned, and arrived on scene in four minutes. EMS stabilized the engineer and transported him to Stanford University Hospital where he was hospitalized for multiple head traumas.

On February 5, 2003, the Director, Department of Energy (DOE) Stanford Site Office, appointed a Type B Accident Investigation Board to investigate this accident in accordance with DOE Order 225.1A, *Accident Investigations*. A copy of the appointment memorandum appears in Appendix A.

1.2 FACILITY DESCRIPTION

SLAC is a national basic-research facility operated by Stanford University under contract to the DOE. The Center is one of a handful of laboratories worldwide that stands at the forefront of research in the study of the basic constituents of matter and the forces that act between them. The SLAC program centers on experimental and theoretical research in elementary particle physics using electron beams and a broad program of research in atomic and solid state physics, chemistry, biology and medicine using synchrotron radiation. Its total staff numbers approximately 1,200, 150 of which are Ph.D. physicists. Each year roughly 3,000 (users) scientists from academic and industrial organizations in 20 countries are active in the high-energy physics and synchrotron-radiation program and produce 900 papers for journal publication.

SLAC occupies 426 acres of Stanford-owned land in Menlo Park, California. The SLAC property was first provided on a fifty-year lease to the Atomic Energy Commission in 1962. The land is part of Stanford's academic reserve west of the University's main campus and the City of Palo Alto. The main instrument of research is the 3.2 kilometer-long linear accelerator (LINAC) that generates high-intensity beams of electrons and positrons. A smaller storage ring, the Stanford Positron-Electron Asymmetric Ring (SPEAR), has its own smaller LINAC and a booster ring for injecting accelerated beams of electrons. SPEAR is fully dedicated to synchrotron radiation research by the Stanford Synchrotron Radiation Laboratory (SSRL). SSRL is a national user facility that provides synchrotron radiation, a name given to x-rays or light produced by electrons circulating in a storage ring at nearly the speed of light. These extremely bright x-rays can be used to investigate objects of atomic and molecular size, and to perform basic and applied studies on the structure of matter. The facility is used by researchers from industry, government laboratories and universities in many areas, including the fields of biology, chemistry, geology, materials science, electrical engineering, chemical engineering, physics, astronomy, and medicine. SPEAR 3 is the planned upgrade to the currently operating SPEAR Accelerator facility. SSRL is one of five divisions at SLAC. The other divisions are: the Technical Division, the Research Division, the Business Services Division, and the Environmental Safety and Health Division.

1.3 SCOPE, PURPOSE, AND METHODOLOGY

The Board began its investigation on February 5, 2003, completed the investigation on February 24, 2003 and submitted its final report to the Director, Stanford Site Office on February 24, 2003. The scope of the Board's investigation was to review and analyze the circumstances surrounding the accident to determine its cause. The Board also evaluated the adequacy of safety management systems as they related to the accident.

The purposes of this investigation were to determine the causes of the accident including deficiencies, if any, in safety management systems and to assist DOE in understanding lessons learned to reduce the potential for similar accidents.

The Board conducted its investigation using the following methodology:

- Facts relevant to the accident were gathered though interviews, document and evidence reviews, and examination of physical evidence.
- Event and causal factor charting, along with barrier analysis and change analysis techniques, were used to analyze the facts and identify the cause(s) of the accident.
- Based on the analysis of information gathered, judgments of need for corrective actions to prevent reoccurrence were developed.

Accident Investigation Terminology

A **causal factor** is an event or condition in the accident sequence that produces or contributes to the occurrence of the accident. There are three types of causal factors:

1. *Direct cause*, the immediate event(s) or condition(s) that caused the accident
2. *Root cause(s)*, the causal factor(s) that, if corrected, would prevent recurrence of the same accident or similar accidents
3. *Contributing causes*, factors that collectively with other causes increase the likelihood of an accident, but that individually did not cause the accident.

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

Barrier analysis reviews 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, such as equipment design or protective clothing, or elements of management, such as training and supervision.

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

2 THE ACCIDENT

2.1 BACKGROUND AND ACCIDENT DESCRIPTION

2.1.1 Accident Overview

On the morning of Tuesday, January 28, 2003, a SLAC Systems Engineer working for SSRL sustained serious head injuries in a fall accident that required extended hospitalization. The Systems Engineer was attempting to access the top of a Radio Frequency High Voltage Power Supply (RFHVPS) enclosure located in Building 514 to check for and repair nitrogen gas leaks that were believed to be the cause of an excessive loss of nitrogen blanketing gas. There were no eyewitnesses to the accident.

On Wednesday, February 5, 2003, the Director, Stanford Site Office, appointed a Type B Accident Investigation Board to determine the cause of the accident in accordance with DOE Order 225.1A, *Accident Investigation*, and to analyze the causal factors, identify root causes and determine Judgments of Need to prevent recurrence of this accident.

2.1.2 Background

SSRL is a division of SLAC devoted to research using synchrotron radiation, the electromagnetic radiation emitted when charged particles travel in curved paths. The klystron tubes used to provide the added energy to the electron beam are powered by Radio Frequency High Voltage Power Supplies (RFHVPS). These power supplies are of two designs with a new design replacing the old one. The old design incorporates three distinct enclosures: A disconnect (switchgear) enclosure, a variable voltage transformer (VVT) that is used to vary the AC voltage input to a step-up transformer and rectifier enclosure (the last enclosure). The three enclosures are side-by-side. The new design (to be used for SPEAR 3) uses only two enclosures; a disconnect and solid-state controller enclosure and a step-up transformer and rectifier enclosure. The step-up transformer and rectifier enclosures for both the old and the new designs are filled with oil for cooling and insulation. A blanketing gas (nitrogen) is used to prevent the entrance of moisture into the space above the oil. Both the old and new designs have an input voltage of 12.47kv AC and a variable output voltage up to 90kv DC.

Problems related to excessive nitrogen blanketing gas leakage for both RFHVPS were identified before the accident. Troubleshooting efforts ensued to identify the source of the leakage. On Thursday, January 23, 2003 previous to the accident, the Systems Engineer and a technician had accessed the top of the enclosure to test for leaks in the gasketed areas and tighten the access covers. Some leaks were identified around access covers in the top of the old step-up transformer and rectifier enclosure. The same ladder was used on the day of the accident.

Building 514 is a fenced and covered concrete pad area that houses two RFHVPS units. A weather cover extends approximately 10 feet above an 8-foot high chain link fence on all four sides, terminating in a sloped roof. Prior to the accident, one side of the chain link fence and weather cover were removed to allow the demolition (removal) of an old RFHVPS and the installation of a new unit. The RFHVPSs are installed on raised concrete pads within the building. One of the old RFHVPSs was removed in July 2002. Part of the new RFHVPS had been placed on the raised concrete pad and welded in place on Tuesday, January 14, 2003. No electrical connections were made to the new RFHVPS. The building floor has a raised curb at the outer edge that acts as a containment in case of oil leakage from an RFHVPS. During construction activities, orange "construction fencing" (also called "bird netting") was used to replace the chain link fence and weather cover on the open side. Building 514 is posted as a "Hard Hat Required" area and as a High Voltage area (See Exhibit 2-1, Building 514).

Exhibit 2-1 Building 514

When originally installed, the old design of RFHVPS could develop a problem that could cause the variable voltage transformer (VVT) to overheat and violently disassemble, posing a "shrapnel" hazard to personnel if nearby. For that reason the RFHVPSs were fenced to keep personnel at a safe distance. The cause of this problem was identified and effective corrective actions were implemented to prevent this situation from recurring. Although the problem with the VVTs was corrected, the area around the VVTs has remained controlled in the same fashion as when the hazard existed. Access to building 514 is controlled by locking the gate in the chainlink fence. Two locks and a chain were connected in series to allow either of two organizations to access the building independently: Site Engineering and Maintenance (SEM) and SPEAR. The key under control of SPEAR is kept in the Operations Control Room (OCR) in Building 117. A key log is maintained in the SPEAR OCR to identify personnel accessing the RFHVPS enclosure (Building 514). On the morning of the accident, no keys were checked out for Building 514 access and the gate was unlocked.

The stepladder in use at the time of the accident was a 12-foot tall fiberglass "two-step" stepladder, that is, the ladder had steps up both sets of side rails to the top of the ladder. Following the accident, the ladder was not immediately impounded and controlled to prevent extensive handling, therefore the condition of the ladder at the time of the accident could not be determined. When examined by the Board one spreader was found significantly bent, sections of the ladder had been painted and the ladder was worn and in less than optimal condition with cracks in one side rail near the top. Two of the nonslip rubber feet had rivets missing and were displaced. The underside of one step was marked "PSOG AME" which is an acronym for Power Systems Operations Group, Accelerator Maintenance East. This is an old designation for the group; it is now identified as the Electronics and Software Engineering Department (ESD) that maintains the rectifier portion of the RFHVPSs.

2.1.3 Accident Description

On the morning of Tuesday, January 28, 2003, two SLAC subcontractor electricians were standing near the entrance to Building 514 that houses the RFHVPS switchgear and enclosures. The sub-contractors were in the area reviewing work unrelated to this accident. About 9:25 a.m., the Systems Engineer passed the electricians on his way from the SPEAR OCR in Building 117, to Building 514. The electricians noted that the Systems Engineer was carrying a plastic mug in his left hand. Both electricians stated that within 5-10 seconds after the Systems Engineer had passed by them, one heard a high-pitched sound and both heard a hollow "thud". The electricians entered Building 514 and saw the Systems Engineer lying on the concrete floor in a fetal position, beneath the stepladder. One electrician ran to the SPEAR OCR in Building 117 to call for emergency help while the other electrician stayed with the Systems Engineer. (See Exhibit 2-2, Accident Scene.)

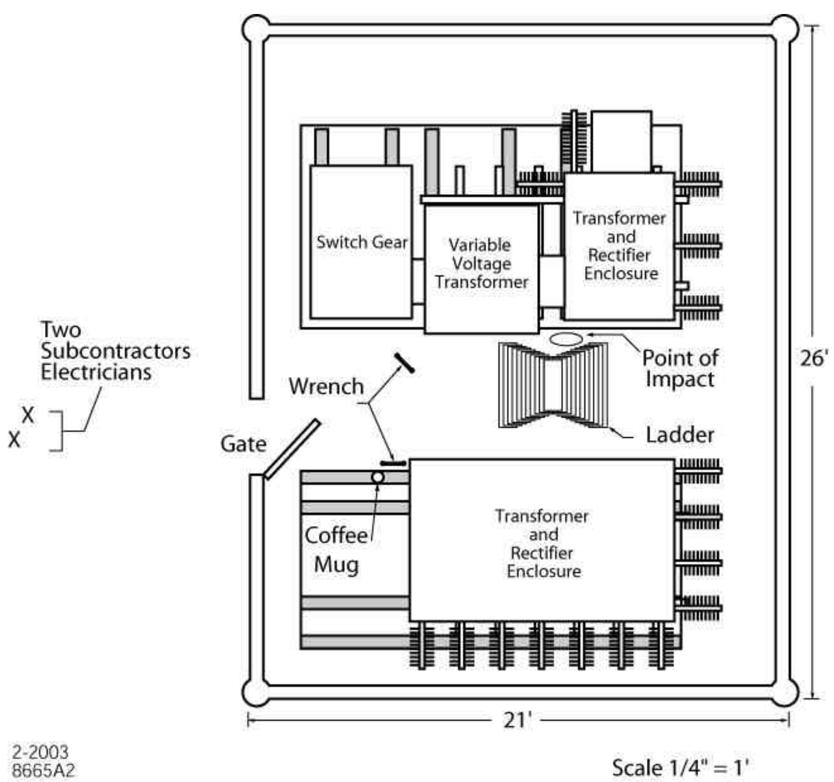

Exhibit 2-2 Accident Scene

The Systems Engineer got up on his knees for a moment and then laid down again, and appeared to loose consciousness momentarily. The subcontractor electrician who stayed with the Systems Engineer instructed him to stay down and removed his own sweatshirt and placed it under the Systems Engineer's head for comfort.

When emergency aid was requested at the SPEAR OCR, the SSRL Safety Officer, who was present in the control room, went immediately to Building 514. The SSRL Safety Officer returned to the OCR, and called the Occupational Medical Physician (OMP) and returned to Building 514. The SSRL Safety Officer and one subcontractor electrician removed the stepladder from Building 514 to facilitate access to the Systems Engineer by emergency response personnel. Within four minutes emergency response personnel arrived on site from the Palo Alto Fire Station No. 7. The Systems Engineer remained laying on the concrete floor during patient assessment by emergency response personnel. About the same time, the SLAC OMP also arrived on scene. Several minutes later, the City of Palo Alto ambulance arrived on scene. The Systems Engineer's condition was assessed by the OMP and the Fire Department Paramedics, and was transported to Stanford Medical Hospital and later to Santa Clara Valley Medical Center.

One of the subcontractor electricians noted that earlier that morning, he had observed two box end wrenches laying on the rail of the raised concrete pad on which the new RFHVPS was being installed. In their place was the mug that the Systems Engineer was carrying when he entered the building. The wrenches along with a new bottle of liquid leak detector were found on the floor of the building near the ladder after the accident. The liquid leak detector bottle had been placed near the nitrogen compressed gas cylinder serving the old RFHVPS earlier in the day by another worker (technician).

2.1.4 Engineering Evaluation and Condition of the Ladder

The Board conducted a limited engineering evaluation of static loading conditions applied to the ladder to understand the forces imparted to the ladder the day of the accident. The ladder was visually inspected and photographs were taken to document its condition. The ladder inspection revealed longitudinal cracks in one of the side rails near the top, damaged and worn non-slip rubber bases (see Exhibit 2-3, Ladder Showing Defective Nonslip Foot and Exhibit 2-4, Ladder Showing Bent Spreaders), two bent spreaders, one deformed step, painted sections of the rails, and a manufacturer’s label. The inspection also revealed the markings "PSOG AME" underneath one step.

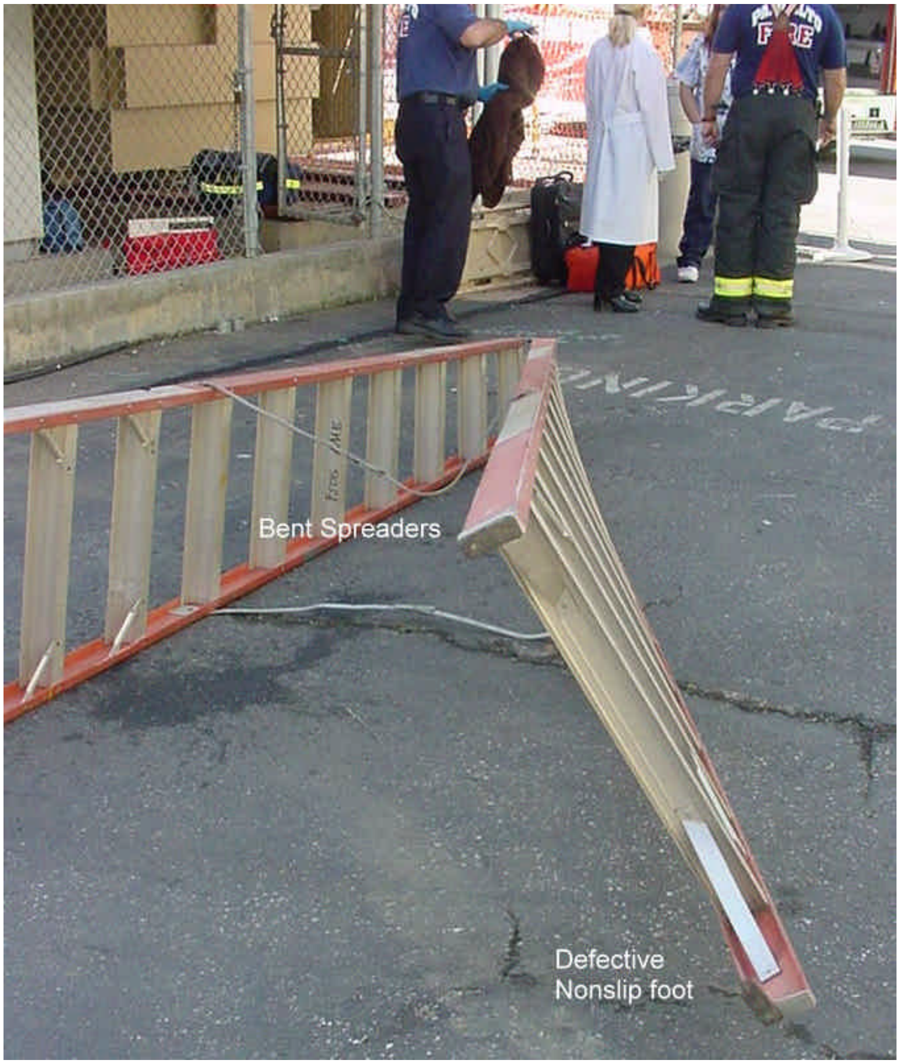

Exhibit 2-3 Ladder Showing Defective Nonslip Foot

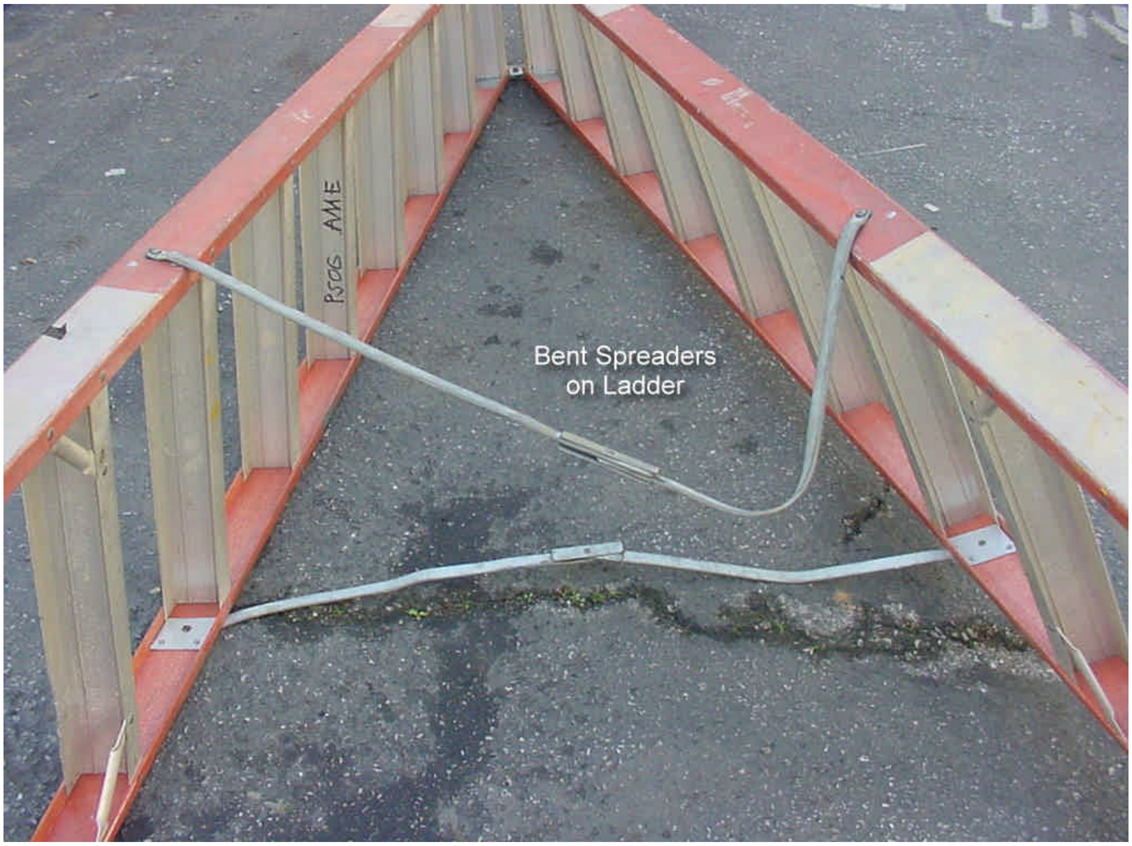

Exhibit 2-4 Ladder Showing Bent Spreaders

Measurements were taken to establish the dimensions and configuration of the rails, spreaders, steps and supports, then an idealized geometric ladder configuration in it's undamaged condition was developed. The ladder was weighed to determine its weight and documentary evidence was used to establish the Systems Engineer's weight and height.

The evaluation concluded:

- Although the ladder displayed signs of longitudinal cracking, damage to its rails, a step, and the non-slip rubber bases, the ladder did not fail from being loaded by the weight of the Systems Engineer. However, a pre-use inspection should have precluded the use of the ladder.
- For the ladder to become unstable while being loaded by the Systems Engineer, the Systems Engineer's center of gravity would be located at least 7.6 inches outside the footprint of the ladder's legs which is outside the ladder rails.
- For the Systems Engineer to locate his center of gravity 7.6 inches outside the foot print of the ladder legs he would have moved off the ladder near the top of the ladder (See Exhibit 2-5, Static Loading Conditions and Exhibit 2-6, Similar Ladder).
- Damage to the spreader nearest the old RFHVPS was consistent with a tipping of the ladder resulting from exerting a horizontal force against the ladder in combination with a fall from a height above the spreader

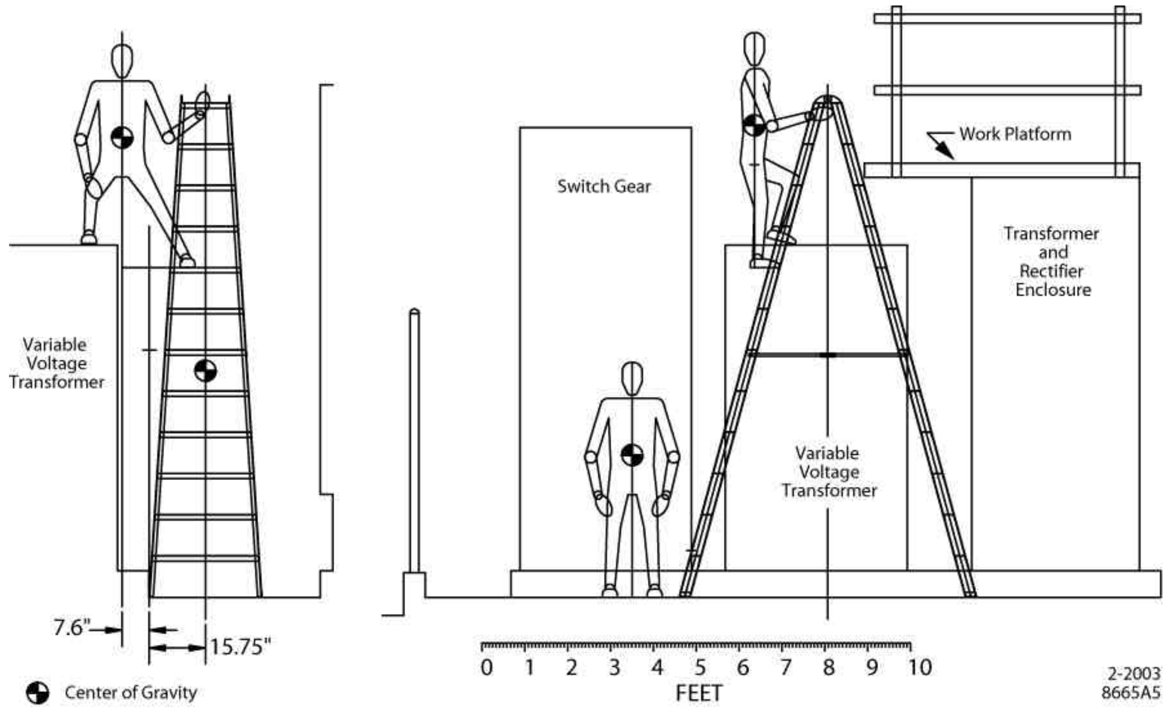

Exhibit 2-5 Static Loading Condition

Exhibit 2-6 Similar Ladder

The Board concluded that the results of the limited engineering evaluation indicate the Systems Engineer could have moved from the ladder while attempting to access the top of the VVT section of the old RFHVPS or the Systems Engineer encountered circumstances that caused him to move off the ladder. In either case the Systems Engineer would have fallen.

2.2 Emergency Response and Medical Treatment

The Board evaluated both emergency response and medical treatment to determine the effectiveness in responding to the scene and providing treatment. After receiving a phone call for assistance, emergency response personnel arrived from Palo Alto Fire Station No. 7 within four minutes. About the same time the SLAC OMP also arrived at the scene to treat the systems engineer. Emergency response by site personnel from notification of the accident through transport to medical treatment facilities at Stanford Medical Hospital was excellent.

2.3 Investigative Readiness and Accident Scene Preservation

DOE Order 225.1A contractor requirements document mandates that contractors develop provisions for supporting Type A and B accident investigations and that contractor staff establish and maintain an site readiness capability to preserve an accident scene.

During the accident investigation, the following facts were noted regarding SLAC's investigative readiness:

- Evidence provided to the Board consisted of the 12-foot two step fiberglass ladder found at the accident scene, interview records prepared by a Stanford University Legal Department subcontracted investigator, and photographs of the accident scene taken by various SLAC organizations and an engineering consultant.
- Photographs were not logged and did not document complete identification data (i.e., time, date, photographer's name) or a scale of reference to indicate the dimensions of the objects and distances in the photographs.
- Evidence control, accountability, and chain of custody were not accomplished. A composite record specifying the origin of the evidence, custodianship, and dates of transfer was not established.
- Effective and timely access controls were not instituted over the accident scene to preserve the accident scene to ensure that the area was properly secured to prevent alternation and/or the removal of evidence.
- No first person witness statements were obtained.
- The SLAC first responders placed themselves at risk by failing to wear the required Personal Protective Equipment (PPE) and inappropriately used a stepladder.
- The ESHM procedures for scene preservation were inadequate.

Inadequate procedures for accident scene management resulted in deficiencies in SLAC site readiness capabilities. ESHM Chapter 28, *Accident, Injuries, Illness and Exposure*, notes "For information on investigative and corrective actions, see the SLAC Workbook for Occurrence Reporting (DOE-5000.3) and the SLAC Guideline for Operations, Guidance 7." DOE Order 5000.3, was replaced by DOE Order 232.1, *Occurrence Reporting and Processing of Operations Information*, in 1997. Accident Investigations are required by contract to be conducted in accordance with DOE 225.1A, *Accident Investigation*.

The Board concluded that the procedures used for accident scene management required by DOE Order 225.1A were neither adequate, timely and/or effective. Although the procedural deficiencies indicated above did not affect the ultimate outcome of the investigation, they did impact its efficiency.

3 ACCIDENT FACTS AND ANALYSIS

This section addresses the facts related to the accident, along with the results of the Board's analysis. The Board presents this information in terms of the ISM core functions and guiding principles, which comprise the fundamental DOE safety and health policies that should have been incorporated into the work planning and execution.

3.1 Physical Hazards, Controls and Related Events

3.1.1 Define the Scope of Work

Effective work execution begins with the preparation of a well-defined scope of work that translates mission and requirements into terms that those who are to accomplish the work can clearly understand. The definition of work scope must provide sufficient detail to support hazard analysis, and development and implementation of controls at the task level. To fulfill its responsibilities, line management must determine the work to be performed and be accountable for understanding it as completely as possible through every phase of the work cycle. This process, discussed in the Stanford Linear Accelerator Center's (SLAC's) Environment, Safety and Health Manual (ESHM), applied to the work undertaken to control leaks of the nitrogen cover gas at the RFHVPS transformer in Building 514 on the morning of January 28, 2003.

Prior to July 12, 2002, the SSRL Accelerator Systems Department was assigned responsibility for the removal and replacement of one of the two power supplies in Building 514. The Systems Engineer accomplished this task, and the new power supply (SPEAR 3 Project) was connected to a portable nitrogen gas system to provide a nitrogen "blanket" over the oil inside the power supply. Due to evidence that nitrogen leaks were occurring, on January 23, 2003, the Systems Engineer and a technician entered Building 514 to check for leaks around the tops of the two power supplies, and used a ladder in the building to gain access to the tops of the transformers. On January 28, 2003, the Systems Engineer entered Building 514 alone. None of the work activities on January 23, 2003 or January 28, 2003 were documented or authorized by the System Engineer's line management.

The Board was not able to obtain vendor, manufacturer or operator data, manuals or information that established the design requirements or that could be used to establish maintenance requirements of the old or new RFHVPS. Without formal documentation, it was impossible to confirm that correct procedures were established for installation and maintenance of the nitrogen blanket on either the old or new RFHVPS. The Board could not confirm the correct blanketing gas type or pressure, confirm the manufacturers recommended approach to troubleshooting blanketing gas leaks, or the reported weights of the access panels on top of the step-up transformer. No guidelines for access cover gasket material, replacement or maintenance were able to be produced and provided to the Board.

Compressed gas (nitrogen) was used on both the old and new RFHVPSs to prevent moisture from entering the step-up transformer and rectifier enclosures. Compressed gas was not identified as a hazard in the area and the Systems Engineer had not received compressed gas safety training.

The ESHM established management's safety policies and expectations for the SLAC site, and stipulated that "SLAC shall integrate safety and environmental protection into its management and work practices at all levels so that its mission is accomplished while protecting the worker, the public, and the environment." The ESHM discussed line management's responsibility for preparing a well-defined scope of work to translate mission and expectations into terms that personnel could readily understand. ESHM Chapter 1, The *SLAC ES&H Program*, 15 December 1997, required Associate Directors to ensure that SLAC ES&H policy was implemented within their own divisions, and specifically, ensuring that line managers within their divisions were informed about their responsibilities for maintaining a safe workplace. In addition, this chapter discussed line management's responsibilities for implementing the SLAC ES&H policy with the personnel under their supervision, including: defining the scope of, analyzing the hazards associated with, and developing and implementing appropriate hazard controls for each work process within their areas of responsibility.

While the nitrogen leak troubleshooting activities involved a number of personnel hazards, minimal line management attention was focused on the safety and health aspects of the work. Although the Systems Engineer actively worked for two SSRL organizations, Accelerator Systems Department (ASD) and the SPEAR 3 Project, evidence gathered by the Board indicated that neither line supervisor claimed responsibility for the work being conducted on the day of the accident. In addition, the Board requested and did not receive task procedures, work orders, permits or other authorization methods which may have been used to control:

- Work on enclosures of energized electrical equipment
- Hazards associated with rotating equipment in the area
- Potential shrapnel hazards associated with the variable voltage transformer
- Hazards associated with elevated work required for nitrogen leak troubleshooting
- Compressed gas hazards

The Board concluded:

- *SSRL line management failed to adequately address safety as part of planning for troubleshooting activities and failed to enforce compliance with existing safety requirements during those tasks.*
- *Management responsible for the building and the work tasks did not identify and control the hazardous work environment in Building 514.*

3.1.2 Hazards Analysis

The objective of the hazard analysis process is to develop an understanding of task-specific hazards that may affect the worker, the public, and the environment. Each level of hazard analysis forms the foundation for a more detailed analysis; that is, a hazard analysis for facility operation, maintenance or modification is, in turn, used as the basis for an activity-level or task-specific hazard analysis. Hazard identification and analysis must occur at any phase of the work cycle to which it applies, and is dependent upon the adequate and full definition of the activity or task to be performed. If the activity or task is not fully identified or defined, it follows that an adequate task-specific hazard analysis cannot be performed.

The SLAC ESHM, Chapter 1, The *SLAC ES&H Program*, paragraph 4.3, Managers and Supervisors, stated in part that SLAC managers:

- "Define the scope of, analyze the hazards associated, with, and develop and implement appropriate hazard controls for each work process within their areas of responsibility;"
- "Ensure that the work processes within their areas of responsibility are conducted within the constraints set by the WSS Set;"

The SLAC ESHM, Chapter 19, *Personal Protective Equipment*, paragraph 3, Hazard Assessment, stated in part, "Immediate supervisors have the responsibility for the completion and documentation of the hazard assessment in their work areas." The paragraph also noted that standardized forms were available from the Safety, Health, and Assurance Department. While elements of the ESHM were clear in their expectation that line management would conduct hazard assessments, only informal (unapproved/uncontrolled) hazard analysis checklists and forms were available to line management on the SLAC local area network, and use of the forms was not required. The Board was not provided with any evidence that a task-specific hazard analysis was performed for any aspect of the troubleshooting work.

The Board noted that guidance on hazard analysis, a significant element of the site integrated safety management system, was located solely within the SLAC ESHM chapter on Personal Protective Equipment, rather than in a stand-alone chapter.

The maintenance activities conducted on January 28, 2003, involved a number of uncontrolled hazards that were identified by the Board, including:

- The ladder safety issues identified in report section 2.1.4.
- Appropriate guardrails or other fall protection systems were not utilized to protect personnel during access to the top of the 8-foot rectifier module and the 10-foot power supply.
- Guardrails installed around the perimeter of the old RFHVPS were not constructed in accordance with OSHA standards. Unguarded openings presented a serious risk of falls for personnel using the platforms.
- There was no evidence that two rope and pulley lifting devices, used to lift access panels and diode arrays, had been designed and installed in accordance with engineering specifications. The pulleys were tied to a structural member with cotton rope, and no load rating for this system was evident.
- Electrical fans, used for equipment cooling, were not guarded to prevent personnel contact with the rotating metal blades. During assessment of the controls required for this type of equipment, the Board noted that the SLAC ESHM, Chapter 14, Guarding, Mechanical, had been in draft form since October 1991.

The Board concluded the following:

Line management failed to adequately address safety as part of planning for troubleshooting activities and failed to enforce compliance with fundamental safety requirements during those work activities.

Line management failed to develop an integrated approach for conducting task-specific hazard analyses.

A hazard analysis process was not implemented on January 28, 2003, that identified and assessed the task-specific hazards involved with the nitrogen leak troubleshooting activity in Building 514.

3.1.3 Develop and Implement Controls

The objective of developing and implementing controls is to identify and provide the full range of controls (i.e., engineering, administrative, and personal protective equipment) consistent with the level and nature of the hazards expected to be encountered during task performance. The development and implementation of work controls assumes that the hazards associated with the defined scope of work have been adequately and completely identified.

The Board evaluated aspects of this process at SLAC, and noted that hazards associated with the Building 514 troubleshooting activities were not identified prior to permitting personnel to perform work within the area. No formalized work controls were established for these activities. This was indicative of a work environment that was not attentive to proper health and safety practices, and where tasks were routinely performed without a comprehensive set of formal procedures to guide the operations. Without a written task-specific hazard analysis for troubleshooting and associated jobs, the adequacy of the controls could not be evaluated, nor could hazards be mitigated. Without safety inspections of Building 514, hazards were allowed to exist over a period of time until the incident occurred. Evidence indicates that management processes were not implemented to assure program compliance with applicable safety and health regulations. Further evidence gathered by the Board indicates that hazards in Building 514, such as unprotected elevated work surfaces used by personnel, were unidentified and controls were not established for the hazards to employees in Building 514.

The Board concluded that the occupational safety and health policies, programs, and procedures for worker safety and health were not routinely implemented or enforced for Building 514 activities.

3.1.4 Perform Work Within Controls

The five core functions of the integrated safety management system serve to ensure that safety is effectively considered and implemented during all aspects of work activities. The failure of any one of the core functions will result in the failure to fully accomplish the subsequent core function. For example, if the scope of the work to be accomplished was not fully and effectively identified, it would be impossible to develop a clear understanding of the task-specific hazards that could be present in the work area. Similarly, less than adequate performance in task-specific hazards analysis would preclude the effective development and implementation of work controls to address those hazards. Safety controls must be identified and implemented before starting work. This was not the case for the troubleshooting activity being performed in Building 514 at the time of the accident.

The first three ISM core functions (1) define the scope of work, (2) analyze the hazards, and (3) develop and implement controls were not addressed for this activity and this explains why the work was not performed within appropriate controls.

1. On January 23, 2003, personnel entered Building 514 to check for nitrogen leaks around the tops of the two RFHVPSs. Line management did not define the scope of work to be accomplished. Hazards such as rotating equipment, high voltage, work at heights in

excess of eight feet and compressed gas safety were not analyzed, nor were controls for the hazards developed or implemented. In fact, none of the work activities were documented or authorized by the injured employee's line management.

2. Evidence gathered by the Board indicated that at no time was a task-specific hazard analysis performed for any aspect of the troubleshooting activity.
3. The hazards associated with the nitrogen leak troubleshooting activities were not identified prior to permitting personnel to perform the work. No formalized work controls were established for these activities.

The Board concluded that because the scope of work was not defined, task-specific hazards were not analyzed and controls to protect employees were not developed by line management.

3.1.5 Feedback and Improvement

Occurrence Reports and Lessons Learned were reviewed at regular meetings of the Operating Safety Committee (OSC). The OSC also reviewed and placed special emphasis on Near Miss events, whether reportable or not. The minutes of the OSC meetings were distributed to the SLAC Director, Associate Directors, Assistant Directors of all SLAC Divisions in addition to all heads of Citizen Committees, site safety personnel, OSC members, and other managers. Each of the Associate or Assistant Directors communicated this information using different processes. The OSC made a conscious decision in November of 2002 to continue to place special emphasis on the near miss program, which was aimed at increasing awareness of near miss events and attain a reduction of reportable and non-reportable events. Lessons learned were developed by several staff members in the ES&H Division and distributed to the other Divisions at SLAC. These were routinely discussed at the OSC meetings. Lessons Learned were brought to the OSC and distributed otherwise by the Lessons Learned Coordinator. Lessons learned were gleaned from a variety of sources and screened for applicability.

There was a good awareness and desire on the part of the OSC to recognize the need for reduction of reportable events. However, there was a less than desired level of awareness outside the OSC and the management level at which the Committee functions. On an approximately annual basis, ES&H staff presented a "top-ten" list of problems noted in the field. It was of note that for the last three years, the most prevalent violations have involved "fall protection" issues.

The ES&H Division monitors environment, safety and health activities which they conduct or are otherwise involved, and provide a quarterly summary to senior managers of the laboratory of selected performance measures. The Division maintained a 24-hour hotline that could be used to report problems or request assistance with ES&H questions. The hotline was set up to allow anonymity if desired. Evidence was provided to show that the hotline had been effective and responsive to callers. ES&H Division staff were represented on most of the citizen committees that were responsible for reviews of projects to assure they could be completed safely. The ES&H staff were encouraged to work with the University Technical Representatives (UTR) during the development and implementation of project or construction activities.

Previous ladder accidents at SLAC served as precursors to this accident. In the last five years there were five ladder accidents at SLAC, all resulting in worker injuries and Lost or Restricted Work Days. Several other ladder and fall accidents were identified in the Occurrence Reporting database, but not included in this discussion.

OAK--SU-SLAC-2003-0001, Employee Fell From Ladder - The subject of this accident investigation. Worker fell and sustained serious head trauma requiring extended hospitalization and rehabilitation.

OAK--SU-SLAC-2002-0009, Broken Arm/Dislocated Shoulder - A worker fell down a fixed ladder access. The worker spent two days in the hospital and was instructed to return for surgery to correct the injury.

OAK--SU-SLAC-2002-0004, Fall From Ladder at Sector 20 - An employee suffered a compound fracture of the left elbow and hematoma of the right knee. The worker was hospitalized for two days.

OAK--SU-SLAC-1998-0002, Fall From Ladder - A SLAC subcontractor suffered a fracture to the right femur and a hairline fracture to disk L2. Worker was hospitalized 5 days. A waiver was requested from and granted by the Assistant Secretary for Environment, Safety and Health not to conduct a Type B accident investigation.

OAK--SU-SLAC-1997-0007, Scaffolding Injury - Worker fell while stepping from a scaffold to a stepladder. The worker suffered a bump on the head, sore left knee and ribs, and a sore right wrist. The worker missed one and a half days of work as a result of the accident.

Occurrence Report OAK--SU-SLAC-2002-0004 was rejected by the DOE Facility Representative on 10-23-2002 and the corrective actions revised in concert with the DOE Stanford Site Office, to broaden the effectiveness of the corrective actions to include changes within the SLAC purchasing and contracting organization. The corrective actions for most of these events did not consider the role of SLAC in preventing future events. The corrective actions from these occurrence reports and the lessons learned have not been effective in preventing the reoccurrence of fall accidents.

SLAC has failed to categorize and report ladder accidents in a timely manner, that is, in accordance with the reporting requirements of DOE Order 232.1, *Occurrence Reporting and Processing of Operations Information* (ORPS). ORPS required that events or conditions meeting reporting thresholds be categorized within two hours of discovery. SLAC did not meet the time requirement for categorization. ORPS requires that written notification reports be completed by the close of business the next business day, not to exceed 80 hours, following categorization. SLAC had not met the time requirements for written notification in three of the five cited reports. For occurrence report OAK--SU-SLAC-2002-0004, the written notification report was processed nine days after the accident.

Table 3-1 ORPS Notification Record

ORPS No.	Discovered	Categorized	Time	Notification	Time
OAK--SU-SLAC-2003-0001	01/28/03 09:30	01/28/03 13:00	3:30	01/28/03 16:17	3:17
OAK--SU-SLAC-2002-0009	08/20/02 09:00	08/22/02 04:20	43:20	08/23/02 11:52	31:32
OAK--SU-SLAC-2002-0004	06/18/02 08:30	06/18/02 16:50	8:20	06/27/02 15:44	214:54
OAK--SU-SLAC-1998-0002	04/23/98 11:15	04/24/98 14:40	27:25	04/24/98 17:00	2:20
OAK--SU-SLAC-1997-0007	04/24/97 09:00	04/24/97 15:00	6:00	04/28/97 14:40	95:40

The Office of Independent Oversight and Performance Assurance, through the Office of Environment, Safety and Health Evaluations had responsibility for performing independent ES&H oversight of ISMS at DOE sites. Because of other higher priority site evaluations (i.e., weapons and multipurpose laboratories) and SLAC's excellent safety record, this Office had not performed oversight of SLAC prior to the date of the accident. The Office of Science has ES&H responsibility to perform line management assessments of SLAC. The Office of Science does not conduct independent ES&H oversight, however they are encouraged to participate in SC oversight with the field. For FY2001, SC-83 (Environmental, Safety and Health Division Office of Laboratory Operations, Environment, Safety and Health) participated with the SSO and SLAC on an ISM process review of Site Engineering and Maintenance. SC participates on these reviews based upon their availability.

SSO had a responsibility to conduct ES&H oversight of SLAC. SSO used the operational awareness program to maintain knowledge of SLAC's ES&H program. The operational awareness program includes: day-to-day interactions by SSO staff and OAK subject matter experts, facility walkthroughs and surveillance and document reviews. SSO also assesses SLAC's performance against ES&H outcome measures and ISM process measures and meets regularly with SLAC line management and ES&H staff.

Following completion of the ISMS Phase II verification report in 1999, the SSO did not ensure that effective corrective actions were implemented to address all of the deficiencies identified in the report. Specifically those areas included line management accountability for safety and development of criteria to determine when hazard analysis is needed.

Although the SSO followed up on corrective actions for the individual occurrences there is no process in place to analyze precursor events report the trends to management. In this case SSO did not analyze the four precursors to this accident to determine causal factors common to the ladder related events.

SSO operational awareness program was also impacted by inadequate human resources and inadequate apportionment of available skills to effectively evaluate SLAC Safety Management System.

The Board concluded that DOE oversight at multiple levels was inadequate to ensure effective implementation of ISMS as it pertains to troubleshooting activities the day of the accident.

3.1.6 Management Systems

The Board analyzed the implementation of the Integrated Safety Management System (ISMS) as it related to the accident, examined the suitability of personnel to perform their function, and evaluated the safety management systems used by SLAC.

The objective of ISMS was to assure that the DOE and its contractors systematically integrated safety into management and work practices at all levels. The ISMS guiding principles are the fundamental policies that guide DOE and contractor actions from development of safety directives to the performance of work. The review of this accident considered all of the systems, which implemented the ISM guiding principles at the SLAC/SSRL organizations.

The line management for Building 514 begins with the DOE/SC Director of the DOE Office of Science through the Office of Basic Energy Science to the Stanford Site Office Director, extends to the SLAC Director, to the Associate Director (AD) for Stanford Synchrotron Radiation

Laboratory (SSRL), to the Accelerator Systems Department Leader (ASD) and SPEAR3 Project Leader to the Accelerator Development & Controls Group Leader (ADC) and Radio Frequency Supply System Group (RFS) Leader, to the System Engineer.

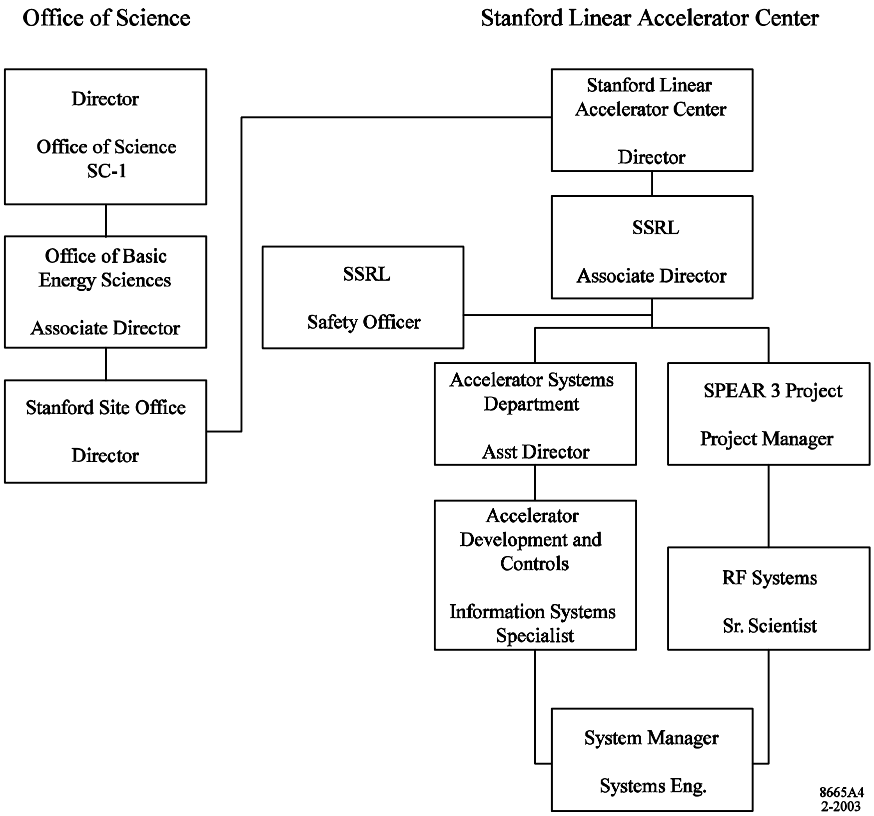

Figure 3-1 Organizational Structure for Troubleshooting Activity

During the October 1999 Phase II verification, several strengths were noted in SLAC's ISM program, including Director and AD level understanding and acceptance of their ES&H responsibilities. The expectations for safety were clearly communicated from Lab Director to Associate Directors (ADs) and the ADs appeared to understand their responsibility for safety. The line self-assessment program which included performance metrics and a feedback loop on performance metrics were still being developed and implemented. However, the Phase II verification also identified opportunities for improvement in the need for flowdown of ES&H expectations and goals from the Director to the ADs to the staff. A statement communicating that there was no flowdown of senior management ES&H expectations to the first-line supervisors and workers was also noted in the report. At the time of the incident, it was clear that the performance standards for some management levels did not clearly reflect those ES&H expectations and the implementation of those standards were not clearly understood at mid and lower management levels.

During Phase II verification, concerns with building managers not having the training necessary to accomplish their ES&H responsibilities were noted. As a corrective action, a building manager training program was initiated. The building manager for Building 514 had completed this training. However, the training did not result in assurance that a safe environment was established that would have prevented the accident. (i.e. safe ladder, adequate fall protection, an adequate walking/working surface).

The laboratory line managers (supervisors and mid-level managers) did not ensure that their staffs were aware of the safety hazards in their areas of responsibility, did not document that hazards were analyzed for the work being performed by their staff, nor did they ensure their staffs were performing work within their areas of responsibility.

An area of concern, identified in the Phase II verification, was that hazardous small jobs, projects, and experiments may not receive sufficient ES&H review/oversight, including Citizen (Safety) Committees review to analyze hazards at the task level. In order to facilitate identification of safety standards and requirements, SLAC made checklists available for use in documenting the pre-work hazard analysis. However, formal criteria for determining when a task-specific hazard analysis should be documented were not developed. SLAC had established requirements for SLAC subcontractors to perform pre-work hazard analyses, but no requirement existed for SLAC line management for the troubleshooting activities being conducted the day of the accident.

The October 1999 Phase II verification stated, "some levels of formality of craft work could ensure hazards are analyzed and mitigated before work begins." This opportunity for improvement was not acted on even though it was mentioned several times throughout the verification report at the mid-level management, first line management (supervisor), and worker levels. While SLAC had developed the tools for documenting hazard analysis, implementing procedures were not in place which determined at what task level a hazards analysis should be performed and documented. Since the hazards analysis for this task was not performed, there were no controls in place to mitigate those hazards.

The Systems Engineer worked in parallel/dual lines of authority and had line management responsibilities in both the ASD organization and the SPEAR 3 Project. The ASD organization chart and SPEAR 3 Project organization chart indicated that the employee was matrixed to the SPEAR 3 Project and ultimately assigned responsibilities in both organizations. Although the tasks, hazards, and controls related to the SPEAR 3 Project were different from those encountered in his normal ASD responsibilities, line management did not ensure that all hazards and controls were fully evaluated, considering the differences in roles and responsibilities. The employee's safety responsibilities in each organization were not fully understood and documented and it was not clear which supervisor took responsibility for the tasks performed by the employee on the day of the accident. Neither of his supervisors had a full understanding about the tasks he was performing at the time of the accident.

The System Engineer's Employee Training Assessment (ETA) based upon his Employee Position Description (dated April 8, 1996) did not identify fall protection or ladder safety as being needed to carry out his responsibilities. Neither line manager to which the employee was assigned, identified the specific hazards related to working at heights, nor had they assessed the need for him to receive ladder safety training for the tasks he performed.

Responsibility for safety within the Building 514 enclosure was not well understood among and between SLAC organizations. The safety responsibilities of the Building Manager, SEM, ESD, SSRL Safety Officer, and SPEAR Control Room operators, were clearly defined for Building 514 but not well understood. Entry and control procedures are not clearly defined. Although there has been a building manager training program implemented and the building manager had been trained, evidence indicates that safety controls in Building 514 were not effective.

As a result of NNSA re-engineering many OAK ES&H support staff were reassigned to LLNL which reduced the availability of Federal ES&H subject matter experts available to conduct oversight of SLAC. At the same time NNSA was reorganizing, the Office of Science was realigning its organizations as part of a re-engineering effort. As part of its re-engineering efforts SSO evaluated the staff's skills mix and identified the need for one additional Full Time Equivalent (FTE) to conduct ES&H oversight of SLAC. Adequate resources were not available from OAK and were not on staff at SSO. Inadequate staffing levels at the SSO and the lack of subject matter expertise from OAK was an impediment to conducting effective ES&H oversight activities at SLAC.

For SPEAR3 construction, an analysis was performed by the Citizens Committees that included the analysis for seismic, non-ionizing radiation, and electrical hazards. All other potential hazards, (fall protection, ladder usage, tripping and falling) were not analyzed by the Committees. The oversight of the unanalyzed hazards was the responsibility of the SSRL line management with the support of the full time SSRL Safety Officer.

In the area of operations authorization, SLAC had no processes in place to authorize troubleshooting activities. The work authorization process would have determined whether the employee was trained or authorized to perform this task.

Conclusion

The Board concluded that the deficiencies in implementing ISMS at SSRL contributed to an unsafe work environment in Building 514 on the day of the accident.

SLAC has not demonstrated that the ISM core functions are being effectively implemented in the areas of work planning, task-specific hazards analysis and implementing hazard controls to conduct work safely.

3.2 Barrier Analysis

Barrier analysis is based on the premise that hazards are associated with all tasks. A barrier is any management or physical means used to control, prevent, or impede the hazard from reaching the target (i.e., persons or objects that a hazard may damage, injure, or harm). The results of the barrier analysis are integrated into the events and causal factors chart to support the development of causal factors. Appendix C contains the Board's complete Barrier Analysis of physical and management barriers that did not perform as intended and thereby contributed to the accident.

3.3 Change Analysis

Change analysis examines planned or unplanned changes that caused undesirable results related to the accident. This process analyzes the difference between what is normal, or expected, and what actually occurred before the accident. The results of the change analysis conducted by the

Board are integrated into the events and causal factors chart to support the development of causal factors. Appendix D contains the Board's Change Analysis and reinforces the Barrier Analysis.

3.4 Causal Factors Analyzed

The Events and Causal Factors Analysis is a systematic process that uses methods to determine Causal Factors of an accident. Causal Factors are the significant events and conditions that produced or contributed to the Direct Cause, the Contributing Causes and the Root Cause(s) of the accident. A Tier Diagram in Appendix B contains the Board's Direct, Contributing and Root Causes. This investigation followed the processes described in the DOE Workbook, Conducting Accident Investigations, Revision 2, where the Direct, Contributing and Root Causes are defined as:

Direct Cause - the immediate events or conditions that caused the accident. The Board concluded, based upon the best available evidence, that the direct cause was a loss of footing (slip) while the employee was stepping from a stepladder to an elevated surface.

Root Causes - causal factors that, if corrected, would prevent recurrence of the same or similar accidents. The Board determines that the root cause was SLAC line managers' unstructured approach to work did not ensure that safety and health requirements were translated to work controls.

Contributing Causes - events or conditions that collectively with other causes increased the likelihood of an accident but that individually did not cause the accident. Appendix E contains the Board's Events and Causal Factors Analysis. Other contributing factors are identified in Appendices B, C, and D.

4 JUDGEMENTS OF NEED

Judgments of Need are managerial controls and safety measures believed necessary to prevent or minimize the probability of a recurrence. They flow from the causal factors and are directed at guiding managers in developing corrective actions. The Executive Summary identifies the Board's Judgments of Need. The conclusions and Judgments of Need are provided in the Table 4-1.

Table 4-1 Judgments of Need and Conclusions

Judgments of Need	Conclusions
SLAC needs to develop and implement processes for work planning and control that: • defines the scope of work • establishes a criteria for performing task-specific hazards analyses • develops procedures for implementing task-specific hazard analyses • authorizes work • provides feedback to and from the workers • ensures line management are actively engaged in the process for controlling hazards.	SLAC has not demonstrated that the ISM core functions are being effectively implemented in the areas of work planning, task-specific-hazards analysis and implementing hazard controls to conduct work safely. Line management failed to develop an integrated approach for conducting task-specific hazard analyses. The Board concluded that because the scope of work was not defined, task-specific hazards were not analyzed and controls to protect employees were not developed by line management. A task-specific hazard analysis process was not implemented on January 28, 2003, that identified and assessed the task-specific hazards involved with the nitrogen leak troubleshooting activity in Building 514.
SLAC needs to develop effective employee performance evaluation standards to promote line management accountability for Safety. SSO needs to develop and implement an ongoing process to assess the effectiveness of SLAC's process for: • holding line management accountable to ensure adequate enforcement of safety requirements addressing safety as part of the work planning and line management responsibilities for safety are implemented.	Line management failed to adequately address safety as part of planning for troubleshooting activities and failed to enforce compliance with fundamental safety requirements during those work activities. SSRL line management failed to adequately address safety as part of planning for troubleshooting activities and failed to enforce compliance with existing safety requirements during those tasks. The Board concluded that the occupational safety and health policies, programs, and procedures for worker safety and health were not routinely implemented or enforced in Building 514. Management responsible for the building and the work tasks did not identify and control the hazardous work environment in Building 514.

Judgments of Need	Conclusions
SLAC needs to develop and implement a procedure for accident scene management that meets the requirements of DOE Order 225.1A, Accident Investigations.	The Board concluded that the procedures used for accident scene management required by DOE Order 225.1A, were neither adequate nor effective. Although the procedural deficiencies indicated above did not affect the ultimate outcome of the investigation, they did impact its efficiency.
No Judgment of Need	The Board concluded that the results of the limited engineering evaluation indicate the Systems Engineer could have moved from the ladder while attempting to access the top of the VVT section of the old RFHVPS or the Systems Engineer encountered circumstances that caused him to move off the ladder. In either case the Systems Engineer would have fallen.
The Office of Science and SSO need to develop and implement an effective oversight program to ensure effective implementation of ISMS. SLAC needs to develop and implement an integrated process that effectively identifies the issues, tracks and trends the effectiveness of corrective actions, and reports results in ISMS terms to senior management for attention.	The Board concluded that DOE and SLAC oversight at multiple levels was inadequate to ensure effective implementation of ISMS as it pertains to troubleshooting activities the day of the accident. The Board concluded that the deficiencies in implementing ISMS at SSRL contributed to an unsafe work environment in Building 514 on the day of the accident.

5 BOARD SIGNATURES

Date: 2/24/03

Robert Crowley, Chairperson *
DOE Accident Investigation Board
U.S. Department of Energy
Office of Environment, Safety and Health

Date: 02/24/2003

Edward Ballard, Member *
DOE Accident Investigation Board
U.S. Department of Energy
Livermore Site Operations Division

Date: 2/24/2003

Rich Haddock, Member *
DOE Accident Investigation Board
U.S. Department of Energy
Oakland Operations Office

Date: 2/24/2003

Bill McQuiston, Member *
DOE Accident Investigation Board
U.S. Department of Energy
Idaho Area Office

* DOE Trained Investigator

6 BOARD MEMBERS, ADVISORS AND STAFF

Chairperson	Robert Crowley, DOE-HQ, EH-24
Member	Edward Ballard, DOE-LLNL
Member	Rich Haddock, DOE Oakland Office
Member	Bill McQuiston, DOE Idaho Area Office
Advisor	William Cooper, DOE-HQ, EH-24
Advisor	Dave Osugi, DOE SLAC site Office
Advisor	Knut Skarpaas, SLAC RD Mechanical Engineer
Medical Advisor	Maria Gherman, SLAC-Medical Doctor
Administrative Support	Mary Roblez, SLAC ES&H
Photographer	Diana Rogers, SLAC Director’s Office
Technical Writer	Frank O'Neill, SLAC RD

Appendix A

Board Appointment Memorandum

Appendix B

Tier Diagram

Appendix C

Barrier Analysis

Appendix D

Change Analysis

Appendix E

Events and Causal Factors Analysis

DOE F 1325.8
(8-89)
EFG (07-90)

United States Government Department of Energy

Memorandum

DATE: February 05, 2003

REPLY TO: John S. Muhlestein, SSO
ATTN OF:

SUBJECT: Establishment of a Type B Accident Investigation Board at SLAC

TO: Dr. Raymond L. Orbach, Director, Office of Science (SC-1)
THUR: Patricia M. Dehmer, SC-10
Milton D. Johnson, SC-3
James F. Decker, SC-2

I hereby establish a Type B Accident Investigation Board to investigate the accident that occurred at the Stanford Linear Accelerator Center (SLAC) on the morning of January 28, 2003. As the Director of the Stanford Site Office (DOE/SC) and the authorized "Appointing Official," I have determined that his accident meets the requirements established for a Type B accident investigation found in DOE 0225.1A ACCIDENT INVESTIGATIONS, approved on September 26, 1997.

I appoint Robert Crowley, EH-24, as the Accident Investigation Board Chairman. The board members will be Richard Haddock, NNSA/ES&H Division/OAK; Ed Ballard, NNSA/Livermore Site Office/LSOD; and William McQuiston, Idaho Operations Office. The board will be assisted by advisors and other support personnel as determined by the chairman.

The purpose of this Board is to determine the cause of the accident that occurred on January 28, 2003 at SLAC and to establish appropriate corrective actions with regards to that accident. To accomplish this goal, the Board shall ascertain the facts of the accident and analyze those facts in order to identify causal factors. Identified causal factors should then be analyzed within the context of SLAC Integrated Safety Management System (ISMS) for identification of any weakness or vulnerabilities with regards to the ladder safety policy, associated procedures and other requirements. The Board will develop conclusions, and determine judgments of need which when implemented should prevent the recurrence of the accident.

At the close of each day, the Board Chairman will provide me with a brief summary of the accident investigation process and results including the Board's expectations for the next day These daily briefings will not include any conclusions until an analysis of all the causal factors has been completed. Near the end of the investigation, draft copies of the factual portion of the investigation report will be submitted to me and to SLAC for a factual accuracy review prior to report finalization.

Since SPEAR is expected to be operational (Providing Beam to Users) during much of this accident investigation period, and the accident site contains an operational RF power supply, it is agreed that the Board will work with SLAC personnel to maximize SPEAR operations while preserving the integrity of the accident investigation.

I am targeting 14 working days from the date of this memorandum (February 25, 2003) for submittal of the accident investigation report to me for acceptance. This period may be extended by me as necessary based upon extenuating investigation circumstance. Discussions of the investigation and copies of the draft report will be controlled until I authorize release of the final report.

I will keep you informed through normal channels as to the medical status of the injured party and the progress of the Type B Accident Investigation. Should you have any questions on the establishment of this Board, please call me at 650-926-3208 or e-mail at john.muhlestein@oak.doe.gov.

Sincerely,

John S. Muhlestein
Director
Stanford Site Office

Cc: Bev. Cook, EH-1
Dave Stadler-EH2
Dennis Vernon, EH-21
Iran L. Thomas, SC-13
Stan Staten, SC-13
Simon Peter Rosen, SC-20
John R. O'Fallon, SC-22
David P. Goodwin, SC-20
Leah Dever, SC-80
Van T. Nguyen, SC-83
Robert Crowley, Type B Board Chairman, EH-24
Richard Haddock, ESHD/NNSA, Board Member
Ed Ballard, LSOD/NNSA (Livermore Site Office), Board Member
William McQuiston, ID, Board Member
Jonathan Dorfan, Director, SLAC
Greg Loew, Deputy Director, SLAC
Keith Hodgson, Associate Director, SSRL, SLAC
Ewan Paterson, Associate Director, Research Division, SLAC
Persis Drell, Associate Director, Research Division, SLAC
Jerry Jobe, Associate Director, Business Services Division, SLAC
Irene Boczek, Associate Director, ES&H Division, SLAC
Mike Grissom, SLAC/ESHD/Point of Contact, SLAC
Ian W. Evans, Safety Officer, SSRL, SLAC
Dr. Maria Gherman, SLAC Medical Officer

cc: Mary Roblez, Administrative Assistant, ESHD/SLAC
Joe Kenny, SLAC Technical Writer, SLAC
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Diana Rogers, SLAC Photographer, SLAC
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Diana Ramirez, ESHD/NNSA Camille Yuan-Soo Hoo, Manager, Livermore Site Office, NNSA
Ralph Kopenhaver, Director, ESHD/NNSA
Philip E. Hill, Director, LSOD
Dave Osugi, Advisor, SSO

APPENDIX B
TIER DIAGRAM

Root Cause

SLAC line managers' unstructured approach to work did not ensure that safety and health requirements were translated into work controls.

Tier	Causal Factors	Causes
Lab Director	5	The Director did not ensure that his senior managers implemented an effective self-assessment process to provide feedback on the status of the safety program at the site.
Mid-level Management	3, 4, 6	Management failed to demonstrate that the integrated safety management system was applied with equal rigor to all projects at the site.
Supervisor	2, 8	The supervisor failed to recognize the need for an ES&H review to mitigate the fall hazards that were present in the work area
Worker	1, 7, 9, 10	The ladder training provide to the Systems Engineer was not effective in preventing him from placing himself at increased risk for a fall
Direct Cause	The Board concluded based upon the best available evidence that the direct cause was a loss of footing (slip) while the employee was stepping from a step ladder to an elevated surface.	

Causal Factors

1. Ladder was not inspected prior to use.
2. Hazard threshold for requiring ES&H review is unclear.
3. No systematic process to identify task-specific hazards and implement controls for smaller projects/tasks/jobs.
4. Senior managers not performing walkthroughs and documenting results.
5. SLAC does not have a comprehensive site-wide, safety self-assessment program which recognizes symptoms of safety systems that are not operating properly.
6. Lessons Learned from previous ladder accidents were not effective in preventing recurrence.
7. Use of inappropriate ladder.
8. No fall protection was used by the workers.
9. Systems engineer was working alone.
10. Systems engineer steps sideways off the ladder.

APPENDIX C
BARRIER ANALYSIS

What Were The Barriers?	How Did Each Barrier Perform?	Why Did the Barrier Fail?	How Did The Barrier Affect The Incident?
Task-Specific Hazard Analyses were used to identify the hazards associated with the work and/or research to be performed.	A Task-Specific Hazard Analysis was not used for this work.	The requirement to conduct a Task-Specific Hazard Analysis was not well understood by line management.	The controls necessary to mitigate the fall hazard were not in place.
Access to hazardous areas was controlled. (The keys were controlled by two organizations: SEM and SPEAR.)	Physical – Locks were not used to control the barrier on the morning of the accident. Admin – Both SPEAR and SEM failed to assure access to the hazardous area was controlled.	UNKNOWN The key control process is not formalized (institutionalized). Control of access to a hazardous area was a shared responsibility.	UNKNOWN Failure to keep the gate locked allowed uncontrolled access to Building 514.
Ladders were inspected prior to each use to prevent use of defective ladders.	The barrier failed to prevent the Systems Engineer from using a defective ladder.	The pre-use ladder inspection was not performed by the Systems Engineer.	Failure to implement the barrier allowed the Systems Engineer to use a defective ladder.
The scope of work is defined.	The scope of work to be accomplished by the Systems Engineer was not defined.	Line Management did not understand the scope of work assigned to the Systems Engineer and did not take actions to define the boundaries of job or tasks.	Failure of Line Management to define the scope of work provided the Systems Engineer the means to work without work related hazards being identified and mitigated.
Roles and Responsibilities for ES&H are defined and understood.	The roles and responsibilities are defined in corporate documents such as the ES&H Manual and Building Manager's Manual.	The roles and responsibilities for ES&H were not well understood by Line Management responsible for controlling work.	Failure to understand line management roles and responsibilities for ES&H led to a failure to effectively implement work controls and hazard mitigation.
Ladders are secured (tied off) as the preferred method of preventing movement.	The ladder was not tied off, nor otherwise secured in place.	The Systems Engineer did not perform as expected with regard to the proper user of ladders.	Failure to properly secure the ladder provided a lost opportunity to work or from a stable platform.
Employees are expected to obey all safety postings.	The barrier failed to ensure that the Systems Engineer was not wearing a hard hat when entering Building 514.	UNKNOWN.	The failure to wear a hard hat as required was a lost opportunity to provide improved head protection.

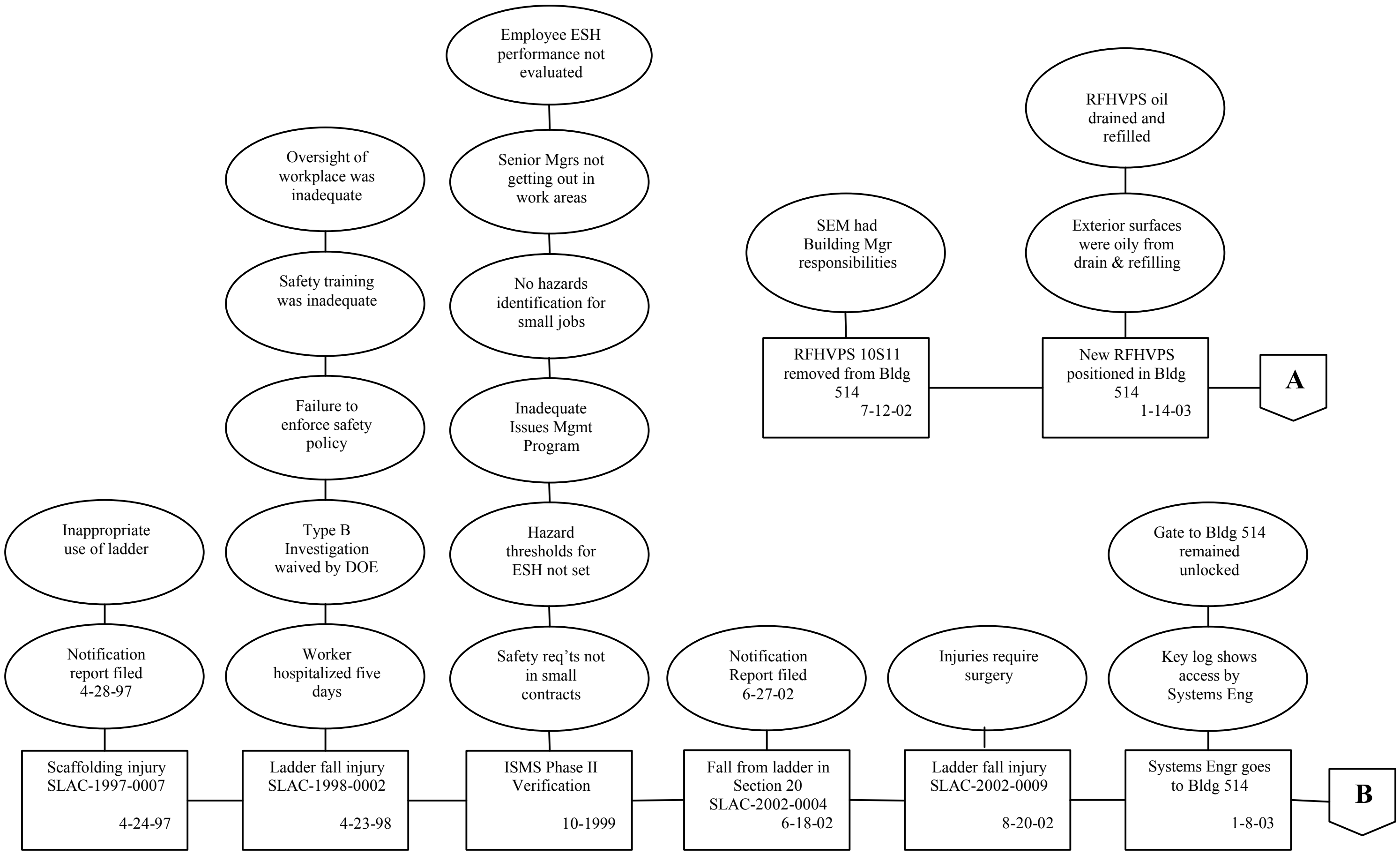
What Were The Barriers?	How Did Each Barrier Perform?	Why Did the Barrier Fail?	How Did The Barrier Affect The Incident?
A second person should be near enough to respond when ascending ladders higher than six and ½ feet. (ES&H Training Module)	The Systems Engineer was working alone on the ladder.	The Systems Engineer did not comply with the requirements of the training module.	The opportunity was lost to have a second person hold or steady the ladder.
Feedback and improvement activities were used to identify and correct deficiencies affecting safety.	Some elements of the feedback and improvement programs were generally effective, however not in the case of identifying and mitigating hazards in Building 514.	Lessons Learned were not uniformly emphasized by line management to all employees.	The opportunity was lost for line management to provide emphasis on safety issues specifically related to ladder safety and fall protection.

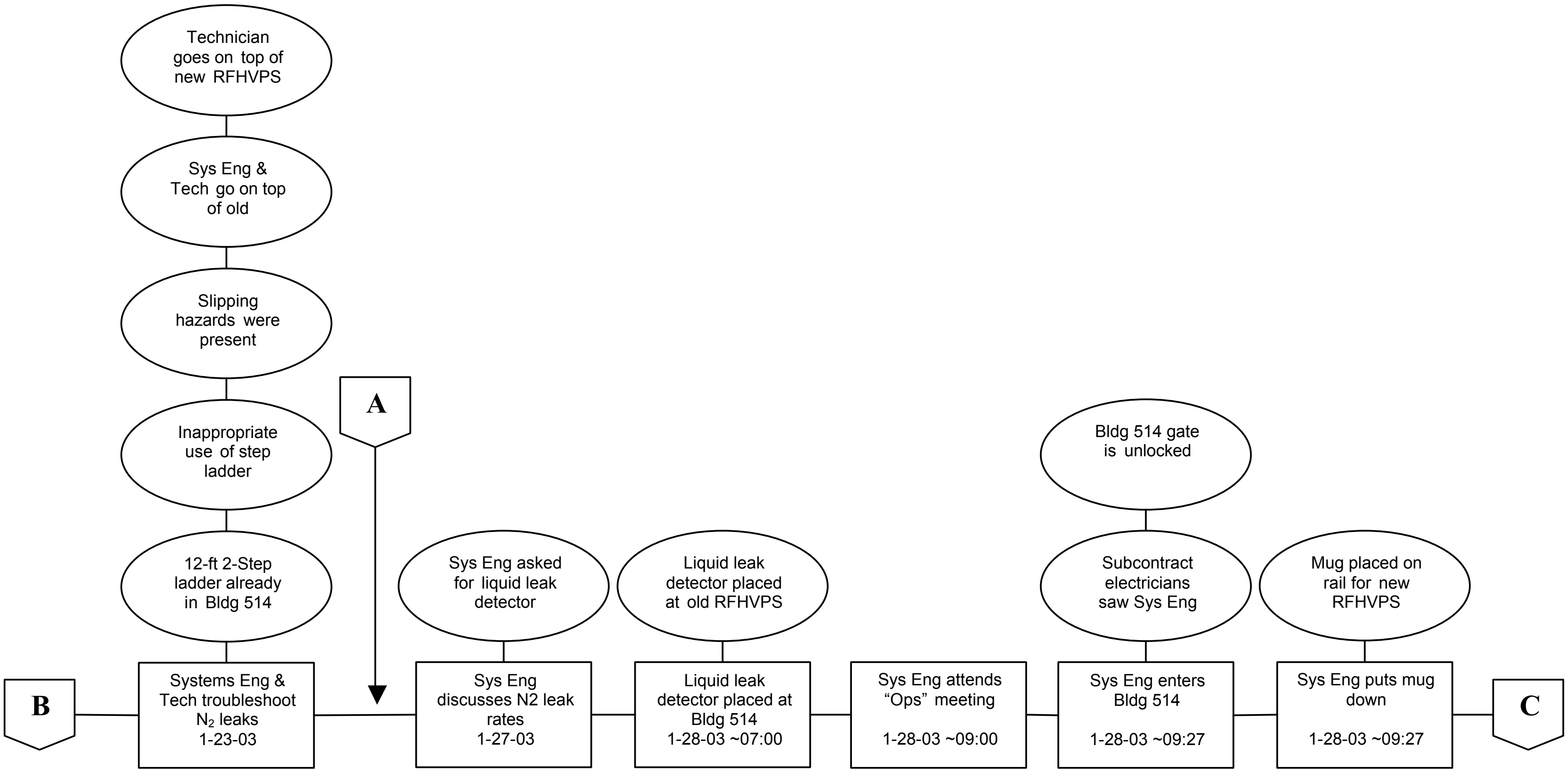
Appendix D
Change Analysis

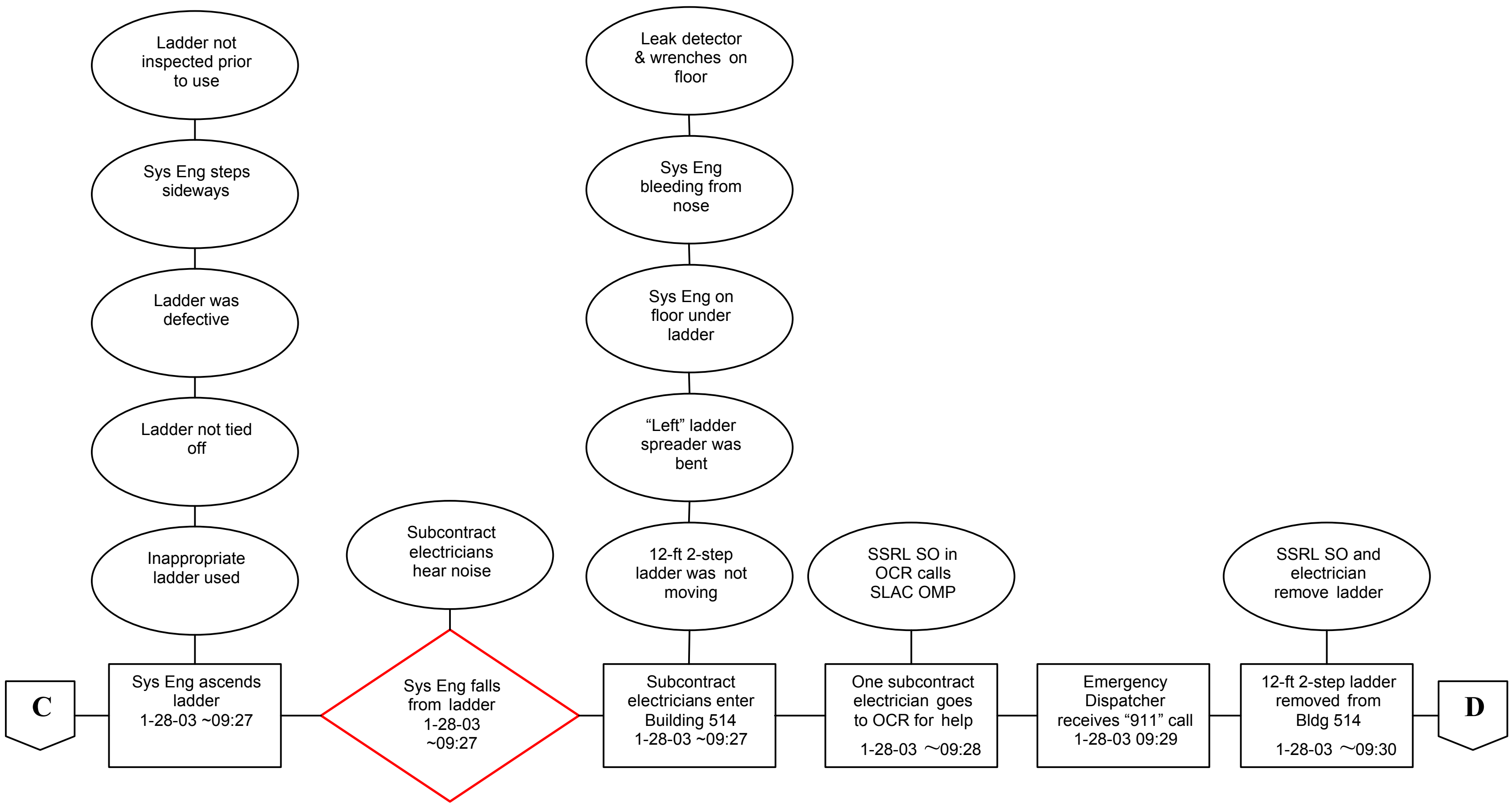
Factors	Prior, Ideal, or Occurrence-Free Situation	Occurrence Situation	Difference	Evaluation of Effect.
WHAT: Conditions, occurrences, activities, equipment	Workers ascending ladders above 6-1/2 feet have someone else to steady the ladder. (Employee orientation for ES&H)	The Systems Engineer ascended the "two-step" ladder to heights greater than 6-1/2 feet while alone.	System Engineer was working alone at heights greater than 6-1/2 feet and no one was nearby to steady the ladder.	Without assistance, there was no one to help steady the ladder used by the Systems Engineer.
	Ladders are tied off to provide a stable work platform to ascend and descend	The ladder was freestanding and not tied off.	The ladder was free to move.	The opportunity was lost to avoid the fall accident by providing a more stable situation.
	Ladders are selected and used appropriately. A properly secured straight or extension is used to access the top of the VVT.	An unsecured step ladder was used to access the top of the VVT.	An inappropriate ladder was selected and used to access the top of the VVT.	A step ladder was used in an application for which it was not designed.
	Ladders are inspected on a regular basis and taken out of service if defective.	The ladder used by the Systems Engineer was not examined and determined to have had multiple defects prior to the accident.	The ladder was not inspected and consequently a defective ladder was used by the Systems Engineer.	The ladder was found to have multiple defects that reduced its stability and strength.
	The weight of the user is kept centered between the rails of the step ladder.	The Systems Engineer dismounted the step ladder to gain access to the top of the VVT.	The Systems Engineer did not keep his weight centered between the rails of the step ladder.	The Systems Engineer shifted the center of gravity to outside the rails and made the ladder less stable.
	Vendor and/or supplier information is available that provides design specifications, operations and maintenance requirements for installed equipment.	No vendor information was provided to the Board regarding systems design, operation, or corrective or preventive maintenance.	The information provided to the Board was not sufficient to demonstrate proper operation, preventive, and corrective maintenance programs were in place for the RFHVPS.	Having insufficient information regarding operation and maintenance may have placed the Systems Engineer in a position of unnecessarily placing himself at increased risk.

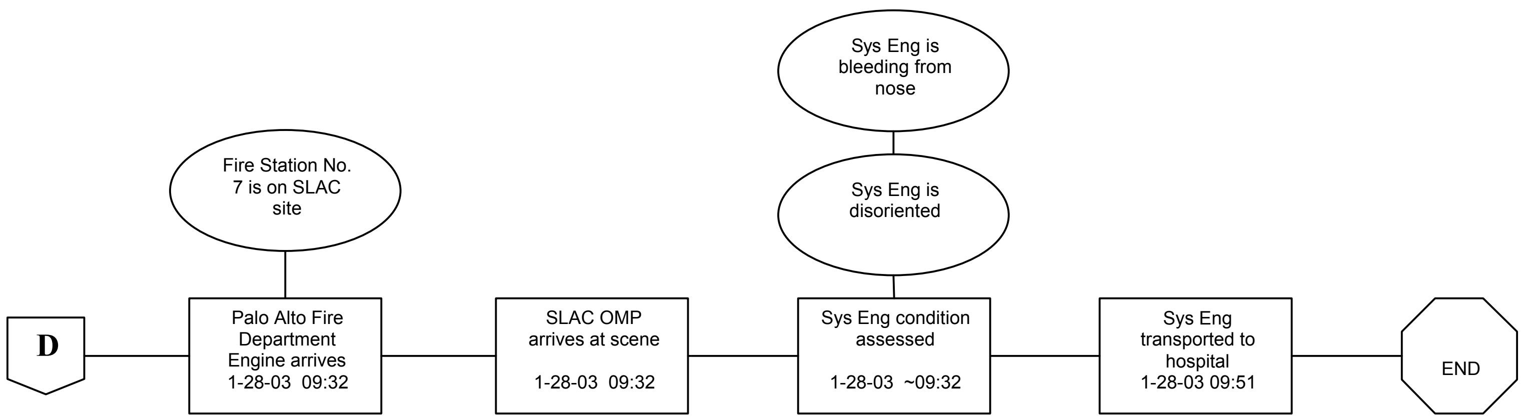
Factors	Prior, Ideal, or Occurrence-Free Situation	Occurrence Situation	Difference	Evaluation of Effect.
WHERE Physical location, environment, conditions	Walking or stepping surfaces are clean and dry. The area is neat and orderly. Housekeeping eliminates all tripping and slipping hazards.	Horizontal surfaces of old RFHVPS are oily and dirty (Technician). Housekeeping was inadequate to ensure the safety of walking and working surfaces.	The horizontal surfaces of the old RFHVPS were dirty and oily. The sides of the new RFHVPS were oily due to the transfer of oil out of and into the transformer. Slipping hazards and tripping hazards existed.	Oily surfaces provide the conditions necessary for loss of footing. In combination with an unsecured ladder, precursor conditions existed for a fall accident.
WHO Staff involved, training, qualification, supervision	Only personnel trained in the use and application of compressed gasses operate and maintain the N_2 blanketing gas on the transformer enclosures. Line Management's roles and responsibilities are clearly defined, accepted and understood to guide the operations and maintenance of research equipment. Adequate staffing levels exist to conduct effective oversight.	The Systems Engineer performing maintenance on the old RFHVPS transformer enclosure to "fix" N_2 leakage was not trained for compressed gas safety. The roles and responsibilities assigned to the Systems Engineer were not understood by his immediate supervisors. SSO staffing were inadequate to perform effective ES&H oversight.	The Systems Engineer was performing maintenance on compressed gas systems without adequate training. Roles and Responsibilities were not understood and accepted by line management personnel for whom the Systems Engineer worked. SSO resources were not available to perform effective oversight of SSRL at the time of the accident.	Although outside the scope of the investigation, work by untrained personnel places them at risk from unrecognized hazards. Line management did not ensure that the requisite hazards associated with the work were analyzed and controlled. Also, line management did not ensure safe working conditions for facilities for which they are responsible. The lack of SSO resources provided a lost opportunity to identify deficiencies in work environments and management systems.
HOW Control chain, hazard analysis monitoring	The maintenance of the N_2 blanketing gas on the RFHVPS is covered by an approved procedure.	No approved procedure is available regarding the establishment and maintenance of the nitrogen blanketing gas.	The work being conducted by the Systems Engineer was not structured to perform work safely.	Management accepted the practice of unstructured work controls, placing the worker at increased risk from unanalyzed hazards.

Appendix E
Events and Causal Factors Analysis




Technician goes on top of new RFHVPS
Sys Eng & Tech go on top of old
Slipping hazards were present
Inappropriate use of step ladder
12-ft 2-Step ladder already in Bldg 514
A
B
Systems Eng & Tech troubleshoot N2 leaks 1-23-03
Sys Eng asked for liquid leak detector
Sys Eng discusses N2 leak rates 1-27-03
Liquid leak detector placed at old RFHVPS
Liquid leak detector placed at Bldg 514 1-28-03 ~07:00
Sys Eng attends "Ops" meeting 1-28-03 ~09:00
Bldg 514 gate is unlocked
Subcontract electricians saw Sys Eng
Sys Eng enters Bldg 514 1-28-03 ~09:27
Mug placed on rail for new RFHVPS
Sys Eng puts mug down 1-28-03 ~09:27
C


Ladder not inspected prior to use
Sys Eng steps sideways
Ladder was defective
Ladder not tied off
Inappropriate ladder used
Leak detector & wrenches on floor
Sys Eng bleeding from nose
Sys Eng on floor under ladder
"Left" ladder spreader was bent
12-ft 2-step ladder was not moving
Subcontract electricians hear noise
SSRL SO in OCR calls SLAC OMP
SSRL SO and electrician remove ladder
C
Sys Eng ascends ladder 1-28-03 ~09:27
Sys Eng falls from ladder 1-28-03 ~09:27
Subcontract electricians enter Building 514 1-28-03 ~09:27
One subcontract electrician goes to OCR for help 1-28-03 ~09:28
Emergency Dispatcher receives "911" call 1-28-03 09:29
12-ft 2-step ladder removed from Bldg 514 1-28-03 ~09:30
D


D
Fire Station No. 7 is on SLAC site
Palo Alto Fire Department Engine arrives 1-28-03 09:32
SLAC OMP arrives at scene 1-28-03 09:32
Sys Eng is bleeding from nose
Sys Eng is disoriented
Sys Eng condition assessed 1-28-03 ~09:32
Sys Eng transported to hospital 1-28-03 09:51
END