Type B Accident Investigation of the July 31, 2006, Fall From Ladder Accident at the Lawrence Livermore National Laboratory, Livermore, California

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National Nuclear Security Administration
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On August 17, 2006, I appointed a Type B Accident Investigation Board to investigate the July 31, 2006, Fall from Ladder Accident at the Lawrence Livermore National Laboratory in Livermore, California. The Board's responsibilities have been completed with respect to this investigation. The analysis, identification of contributing and root causes, and judgments of need reached during the investigation were performed in accordance with DOE Order 225.1A, *Accident Investigations.*

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

Camille Yuan-Soo Hoo
Manager, Livermore Site Office
National Nuclear Security Administration

10-25-06
Date

This report is an independent product of the Type B Accident Investigation Board appointed by Camille Yuan-Soo Hoo, Manager of the Livermore Site Office of the National Nuclear Security Administration, 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 do not assume and are not intended to establish the existence of any duty at law on the part of the U.S. Government, its employees or agents, contractors, their employees or agents, or subcontractors at any tier, or other party.

This report neither determines nor implies liability.

Executive Summary

Overview

Early on the morning of July 31, 2006, an electrician in the Plant Engineering (PE) Department of the Lawrence Livermore National Laboratory (LLNL) was working alone on a project to replace four air conditioning units on the roof of Building T6179. The task that morning was to de-energize, lockout, and disconnect the electrical services to the first two units to be replaced. The worker was using a fixed ladder mounted on the exterior of the building to access the roof of the single story modular structure. After the worker's initial ascent to the roof, he realized that he needed an additional instrument to accomplish the task, and he climbed down to retrieve the instrument from his truck. He placed the parts of the instrument in his back pockets and began to ascend the ladder again. During the climb the worker missed a step, lost his balance, and fell about three to five feet to the deck below the ladder.

Fortunately, a resident of the building heard a "thud" and went outside to investigate the noise. He found the worker lying on the deck in significant pain. The resident conducted a quick first aid assessment and summoned additional help from other residents of the building. LLNL security personnel and fire department paramedics responded quickly, and the worker was transported to a local hospital for treatment. The worker was diagnosed with multiple fractures of the left wrist, shoulder, and the pelvis, along with other injuries.

Due to the extent of the injuries, the electrician was hospitalized for 26 days, and is expected to be off work for as much as four months during his recovery and therapy. On August 17, 2006, Camille Yuan-Soo Hoo, the Manager of the National Nuclear Security Administration (NNSA) Livermore Site Office (LSO), ordered a Type B Accident Investigation of this accident in accordance with Department of Energy (DOE) Order 225.1A, *Accident Investigations.*

Conclusions

The Type B Accident Investigation Board ("the Board") conducted evaluations of the scene of the accident, the work being performed at the time of the accident, and the planning for the project. The Board used the framework of DOE's Integrated Safety Management (ISM) concept to guide the lines of inquiry, and considered other DOE and industrial consensus standards, Federal Regulations, and human performance concepts to the extent they were applicable.

The Board concluded that this accident could have been prevented. The direct cause of the accident was a missed step, which probably was the result of inadvertent human error, and may have been precipitated by the physical attributes of the ladder. The Board believed that, had he been using LLNL's prescribed climbing technique, "3-points of contact," it would have enabled the worker to recover from the initial missed step without falling.

The Board wanted to stress the significance of this seemingly simple accident – a worker slipped and fell from a ladder. The event might appear to be simple and commonplace, and therefore might be considered as an acceptable risk. But the Board believed that there are three points to be considered: (1) the frequency of exposure to the hazard is high, especially for workers assigned to maintenance and construction work; (2) the potential consequences to the individual are known to be serious and potentially fatal, based on industry and DOE experience; and (3) the controls necessary to address the hazard are straightforward and easy to implement. The combination of the first two points demonstrates that the risk from climbing ladders is high; adding the third point regarding the ease of mitigating the risk demonstrates that the risk should not have been acceptable.

The Board determined that the hazards associated with climbing the ladder had not been recognized during the planning for the project. The Board also determined that several other hazards associated with the project had either not been recognized or had not been adequately analyzed. Hazard controls were not explicitly developed, implemented, nor verified for any of the recognized hazards. The worker was completely dependent on generic hazard analyses developed for his general job description. This dependency resulted in a total reliance on the worker to recognize the hazards associated with this specific task, and to implement

those controls that he felt were sufficient to address the hazards he perceived to be present. The Board concluded that the local root cause of this accident was that the PE Department did not recognize climbing ladders as a hazardous activity.

The Board determined that the fixed ladder was not compliant with the applicable Federal Regulations and consensus standards in four areas. The first rung was about five inches higher than allowed; the rungs were not designed to be slip-retardant; in some areas the building intruded into the minimum allowed clearance behind the ladder; and the hand rails in the "walkthrough" section at the top of the ladder did not provide adequate grasping surfaces. The Board concluded that two of the deficiencies were likely contributing causes to this accident, the first rung distance and the slippery rungs; and that the other two deficiencies could lead to a similar accident.

Once the Board determined that the chain of events between the initial missed step and the fall could have been broken by using the prescribed climbing technique, the Board then tried to understand why the prescribed technique was not followed. To develop this understanding, the Board evaluated the training provided to the worker, the planning and safety reviews of the work to be performed, and the implementation of ISM within LLNL and the PE Department in particular.

The Board concluded that, while the worker's training did address the proper climbing technique, the training did not instill in the worker an adequate understanding of the importance of the technique for his personal safety, nor did it ensure that the worker was proficient in the use of the technique.

The Board concluded that the work planning process used for the air conditioning unit replacement project did not effectively implement any of the core functions of ISM. Specifically, the Board concluded that:

- The tasks involved in accomplishing the project were not adequately defined or scoped to facilitate an effective safety review;
- The hazards associated with the work were not properly identified or analyzed;
- Controls for the hazards that were identified were not explicitly developed nor implemented for this work, which placed total reliance on a set of generic controls that the individual worker had to select from based on his personal perspective of the hazards associated with the work;
- Multiple chances to ensure that the work was being conducted within the established controls failed; and
- There was no indication that feedback or lessons learned from previous assessments or work experiences had been incorporated into the current project.

When the Board evaluated LLNL's implementation of the seven guiding principles of ISM, the Board concluded that the LLNL institutional requirements and guidance were overly complex and confusing, thus creating a process that could not be implemented in a reasonable and effective manner. Specifically, the Board concluded that line management roles, responsibilities, and authorities were not clearly defined and communicated to the organization; the individuals responsible for authorizing the work were not adequately trained to accomplish those responsibilities and were uncertain about what their authorizing signature meant; line management priorities were not balanced between accomplishing the work and adhering to the safety requirements; standards were not adequately implemented; and hazards controls were not tailored to the specific work, implemented, or verified before the work was authorized to commence. In fact, the Board could find no LLNL supervisor or work authorizer who would acknowledge full responsibility for the safety of the workers involved in this project.

The Board concluded that the systemic root cause of this accident was that LLNL senior management did not provide leadership to ensure that the ISM processes were implemented rigorously. The processes implemented by LLNL did not assure that the roles and responsibilities for safety and health were understood at all levels of the organization, did not identify the conduct of unsafe practices, and did not hold management accountable for accepting such practices. As a consequence, an unstructured approach

to work developed within the LLNL organizations involved in this accident that did not ensure that safety and health requirements were translated into effective work controls. This unstructured approach was facilitated by an overly burdensome, complex, and confusing institutional work control process that created the perception of safety without ensuring the reality of a safe workplace; the approach was accepted by an organization whose self-confidence and familiarity with the work had developed into complacency; and the approach was allowed to continue by several levels of management that failed to proactively and aggressively recognize and correct the warning signs that had been previously identified in both internal and external assessments.

This Board's responsibility was to identify judgments of need that, if effectively addressed, could lead to the avoidance of this or a similar accident in the future. In this regard, recognizing the act of climbing ladders as a hazardous activity and developing and implementing controls for future elevated work would be an obvious answer. However, the Board concluded that the institutional failure to establish an ISM process that facilitated the recognition and control of reasonably foreseeable hazards, such as the one involved in this accident, represented an organizational weakness that created a much broader range of potential "similar accidents." Therefore, the Board recommended that NNSA and LLNL need to proactively evaluate the extent of the condition created by these organizational weaknesses throughout the entire LLNL institution and aggressively correct any issues identified.

The Board established 14 judgments of need that it believed that LLNL and LSO should address in response to this accident. The Board believed that this number was necessary in order to ensure adequate focus on each of the widespread fundamental weaknesses the Board identified during this investigation. The judgments of need are described in Section 4 of this report.

NNSA Type B Accident Investigation of the July 31st, 2006, Fall From Ladder Accident at the Lawrence Livermore National Laboratory, Livermore, California

1. Introduction

1.1. Background

On July 31, 2006, a Lawrence Livermore National Laboratory (LLNL) electrician fell while climbing a fixed ladder on the exterior of Building T6179 at the LLNL main site. The electrician landed on his side and sustained multiple fractures and other injuries. The electrician was climbing onto the roof of the building to begin disconnecting the first two of four air conditioning units that were being replaced. The building was a one story office building of modular construction that had been placed into operation on August 30, 1985. The exterior ladder was added to the building at some time after 1991. The distance of the fall is believed to be about three to five feet. Due to the extent of the injuries, the electrician was hospitalized for 26 days, and is expected to be off work for as long as four months for recovery and therapy.

On August 17, 2006, Camille Yuan-Soo Hoo, Manager of the National Nuclear Security Administration (NNSA) Livermore Site Office (LSO), ordered a Type B Accident Investigation of this accident in accordance with DOE Order 225.1A, *Accident Investigations* (see Appendix A for the appointment memorandum).

1.2. Facility Description

Founded in 1952, LLNL is a premier research and development institution for science and technology applied to national security. The Laboratory is managed and operated by the University of California for the U.S. DOE. LLNL's primary mission is to ensure that the nation's nuclear weapons remain safe, secure, and reliable. The Laboratory's special capabilities are also applied to the prevention of the spread and use of weapons of mass destruction and to strengthen homeland security. With broadly based capabilities and leadership in mission-focused areas of science and technology, the Laboratory meets other national needs with major advances in research programs in energy and environment, bioscience and biotechnology, and basic science and applied technology. The Laboratory and its more than 8,000 employees serve as a resource to the U.S. Government and partner with industry and academia.

The office building where the accident occurred is a support building for the hazardous waste management facilities at the Livermore site. Those facilities consist of permitted units located in Area 612 and Buildings 693 and 695 of the Decontamination and Waste Treatment Facility (DWTF). Permitted waste management units include container storage, tank storage, and various treatment processes (e.g., wastewater filtration, blending, and size reduction).

T6179 is a single story wood framed modular building approximately 60 ft. x 77 ft. (3904 sq. ft. net area) installed at LLNL in 1985. It houses approximately 17 Radioactive and Hazardous Waste Management (RHWM) personnel who are part of the Environmental Protection Department (EPD) within the Safety and Environmental Protection (SEP) Directorate at LLNL. These RHWM personnel work in the field with various LLNL organizations helping them process their waste for disposal. The building contains offices, meeting rooms, work areas, and restrooms. Only administrative and office tasks take place in this building. The front (west side) of the building along the street is landscaped, the south side of the building has an asphalt driveway, the north side has an asphalt access path and the fourth, east-facing side is flanked by a "Trex" deck, installed around 1989. T6179 and T6178 share a fabric shaded area covering the deck between them, which provides for an employees' lunch area. The ladder from which the injured employee fell is located at the southeast corner of the building, attached to the east wall, with its base on the "Trex" deck (See Figures 1.2-1 and 1.2-2).

Figure 1.2-1: The scene of the accident. The extension ladder was added after the accident to provide temporary roof access. Barely visible on the right side of the fixed ladder is the rope that the worker used to lift his tool bag onto the roof.

1.3. Organizational Descriptions

The electrician (E-1) was employed by the Maintenance Production Division (MPD) Electrical Shop. MPD is a part of LLNL Plant Engineering (PE) Department which is within the Laboratory Services Department (LSD). The Associate Director of LSD reports directly to the LLNL Laboratory Director's office. At the time of the accident, the electrician was providing matrix support to a work supervisor in the Specific Work Unit, another group within MPD. The Specific Work Unit plans and conducts small value in-house projects that require multiple crafts to complete.

The LLNL organization resident in and "owner" of T6179 is the RHWM Division of the EPD within the SEP Directorate at LLNL. The EPD Facility Manager has responsibility for the management of 57 EPD facilities, including T6179. The EPD Facility Manager oversees a team of five Facility Points of Contacts (FPOCs) who have responsibility for ensuring the maintenance and upkeep for each of the EPD facilities assigned to them. The duties of the FPOC include processing WHIZ tags (maintenance requests submitted to PE), coordinating office moves, ensuring the facilities are maintained in a safe and functional condition and responding to tenant issues and needs. In the case of T6179, the assigned FPOC is also responsible for seven other buildings and trailers and is resident in T6951.

Safety oversight, training and expertise at LLNL is the responsibility of the Hazards Control Department (HCD) within the SEP Directorate. HCD is organized into three divisions, the Environment Safety and Health (ES&H) Teams Division, the Safety Programs Division and the Emergency Management Division. One of four ES&H Teams is assigned to support each of the major LLNL organizations and high-hazard facilities. ES&H Teams support planning and execution of existing and new experiments and operations and in the design, construction, and maintenance of equipment and facilities conducted by their client organizations. In addition, the ES&H Teams provide ongoing oversight of activities in progress to assure compliance with approved plans and applicable safety policies and practices. The ES&H Teams typically consist of Industrial Safety Engineers, Industrial Hygienists, Health Physicists, Construction Safety, Fire Protection Engineers, Environmental Analysts, medical clinicians, and Health and Safety Technicians, and have access to specialists in areas such as ladder and scaffold safety, electrical safety, explosives safety, criticality safety, safety basis, and ergonomics. ES&H Team 1 is assigned to the RHWM organization, and thus participates in planning and also reviews and approves plans for operations, construction and maintenance in all RHWM facilities, including T6179, where the injury occurred.

ES&H Team 4 is assigned to the PE Department and thus participates in planning and also reviews and approves plans for all new construction and maintenance activities conducted by PE. Prior to March 2006 ES&H Team 4 (instead of ES&H Team 1) was assigned to RHWM and was involved in the early planning of the T6179 maintenance project.

Figure 1.2-2: The roof of the building where the accident occured, showing the ladder walk-through to the roof and general work area. The location of one of the air conditioning units is visible, although the unit was removed at the time the photograph was taken.

1.4. Scope, Purpose, and Methodology

The Type B Accident Investigation Board (the Board) began its investigation on August 17, 2006, and completed the onsite phase of its investigation on September 22, 2006. The scope of the Board's investigation was to review and analyze the circumstances of the accident to determine its causes, and to review the response to the accident. This investigation, performed in accordance with DOE Order 225.1A, *Accident Investigations*, also included an evaluation of the adequacy of the safety management systems of LLNL, NNSA, and DOE as they relate to the accident. The purposes of this investigation were to determine the causes of the accident, to identify lessons learned, and to reduce the potential for similar accidents at LLNL and across the DOE complex. The Board conducted its investigation using the following methodology:

- Inspecting and photographing the accident scene and individual items of evidence related to the accident.
- Gathering facts through interviews, document and evidence reviews, and inspections of the area.
- Conducting technical evaluations of items of evidence, as appropriate.
- Reviewing the initial response actions taken by LLNL and NNSA.
- Using events and causal factors analysis, barrier analysis, and change analysis to correlate and analyze facts and identify the accident's causes (see box).
- Developing judgments of need for corrective actions to prevent recurrence based on analysis of the information gathered.

Accident Analysis Terminology

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

- **direct cause**, which is the immediate event(s) or condition(s) that caused the accident;
- **root cause(s)**, which is (are) the causal factor(s) that, if corrected, would prevent recurrence of the accident; and
- **contributing causes**, which are causal 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 depicts the logical sequence of events and conditions (causal factors) that allowed the event to occur, and facilitates the use of deductive reasoning to determine events or conditions that contributed to the accident.

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

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

The Board also uses specific terminology in some sections of the report to emphasize particular features of the investigation. When the Board makes a **determination**, it is a means of designating a decision by the Board that an item is a fact, based on evidence analyzed by the Board. When the Board expresses a **belief**, it is stating an opinion on a topic. A **conclusion** is a determination that the Board decides has direct bearing on the investigation. Finally, a **concern** is a determination that the Board decides may have relevance to the investigation or may be indicative of an issue that extends beyond the scope of the investigation, but either the relevance or the evidence is not strong enough for the Board to draw a firm conclusion.

2. Discussion of the Accident

2.1. Description of the Work to be Performed

At the time of the accident, E-1 was working on a PE project to replace the air conditioning units on the roof of T6179. The project, which was being managed by a PE work supervisor (WS-2) from the Specific Work Unit of MPD, required the services of multiple crafts from various MPD shops. E-1's specific assignment for this project was to de-energize, lockout, and disconnect the electrical connections to the air conditioning units, and to later reconnect the new units when they were ready to be activated.

Prior to the accident, in March 2006, PE had determined that three of the T6179 air conditioning units needed replacement based upon their age (useful lifetime). PE initiated Work Package 219007 to address this project. Shortly after the initiation of the work package a PE Operations Field Memo was approved to include a fourth air conditioning unit in the scope of work.

During the month of March and the first part of April, Work Package 219007 was circulated to the facility owner (RHWM) and the cognizant ES&H Team for their review and concurrence. (It should be noted that during this period the responsibility for the RHWM facilities was transitioning from ES&H Team 4 to ES&H Team 1. However, the ES&H Team 4 members that were assigned to the RHWM were reassigned to Team 1 during this transition, so facility-specific knowledge was maintained.) The safety review of the work package was completed on April 12, 2006.

The proposed start date in Work Package 219007 was June 12, 2006, with a completion date of July 14, 2006. The actual start date for the project was July 31, 2006, the day of the accident. Prior to the commencement of work a Pre-start Review was conducted on July 27, 2006. E-1 participated in that Pre-start Review, although the other crafts assigned to the project did not attend.

2.2. The Accident

On the Thursday or Friday prior to the accident, E-1 requested permission from his shop supervisor (S-1) to come to work early on Monday July 31, 2006. E-1 wanted to start work early to avoid working on the rooftop during the heat of the day. The practice of allowing workers to come in early was accepted by the PE Department, because of a seasonal heat wave and an increased work load.

On Monday July 31, 2006, E-1 arrived at work about 6:00 a.m. E-1 skipped his group's normal stretching exercise routine in order to get to work earlier and avoid the heat of the day. Before starting the job, E-1 called the building T6179 FPOC and obtained oral approval to access the roof. Oral approvals for access to roofs designated as "General Access" were not documented, as per LLNL policy. E-1's task that morning was to remove power from and around two of the air conditioning units located on the roof of building T6179 to facilitate their removal.

E-1 completed a "PE Pre-Task Hazard Analysis (PTHA) Worksheet" for Work Package 219007 and placed it in his tool bag. PE Department procedures require this worksheet to be completed by the workers before beginning on a new task. The worksheet's purpose was to aid the worker in identifying and addressing the routine hazards associated with the task. The worksheet was supplemental to an Integrated Work Sheet (IWS) designed to evaluate the work hazards and establish appropriate controls for the work to be accomplished.

At about 6:20 a.m., E-1 installed two personal Lockout/Tagout locks on the circuit breakers for the air conditioning units on which he was working. At about 6:45 a.m. E-1 climbed the fixed ladder to the rooftop worksite, where he identified a convenience outlet that had not been previously traced back to its circuit breaker. E-1 descended the fixed ladder to retrieve a circuit tracer from his vehicle. He placed the two units of the circuit tracer in his back pockets, and while climbing the fixed ladder again, lost his footing and fell approximately three to five feet onto the deck below, landing on his left side. There were no witnesses to the accident.

2.3. Discovery and Emergency Response

A worker (R-1) resident in building T6179 heard a "thud" and investigated the noise. The worker saw E-1 lying on the deck outside the building and went outside to check on him. E-1 told R-1 he had fallen from the ladder and was in pain. R-1 completed an initial first aid assessment and went inside building T6179 to summon help. At R-1's request, a second building resident (R-2) called "911" at 6:57 a.m. R-1 returned to E-1, joined by another resident (R-3). R-1 discovered a screwdriver and several meter components in E-1's back pockets and removed them. E-1 was complaining of arm, hip and shoulder pain. R-1 placed some rolled-up towels under E-1's head for comfort. At 6:58 a.m., the LLNL Fire Department ambulance was dispatched to building T6179. LLNL Protective Force officers heard the dispatch call and responded, arriving at building T6179 before the ambulance. A Protective Force officer assessed the area and climbed to the roof using the same ladder from which E-1 fell.

The LLNL Fire Department ambulance arrived at building T6179 at 7:02 a.m. The paramedics determined that E-1's injuries required transport to an off-site medical facility for treatment and readied E-1 for transport.

E-1's shop supervisor (S-1) arrived at the scene of the accident as E-1 was being lifted onto a gurney. S-1 gathered several tools belonging to E-1. In response to questions from the Protective Force officer on the roof about the safety of the rooftop work area, S-1 climbed to the roof using the same fixed ladder. S-1 verified that the electrical panels were safe and collected E-1's tool bag and other tools. He lowered the tool bag with the rope and descended the ladder.

At 7:49 a.m., the LLNL ambulance departed for Valley Care Medical Center in Pleasanton, CA, approximately seven miles away from LLNL. E-1's condition was stable and the transport was handled as a non-emergency transport (no lights or siren). The route taken was north on Vasco Road to I-580 west, exiting on Santa Rita Road, and then south to Valley Care Medical Center. Due to heavy commuter traffic at that time of the morning, the time en route was 16 minutes.

At about 7:30 a.m., an initial assessment of the ladder was conducted by ES&H Team personnel. The ladder had been used several times by the Protective Force and E-1's supervisor before this inspection. At about 7:45 a.m., S-1 and the electrical superintendent (S-2) departed for Valley Care Medical Center. S-1 and S-2 arrived at Valley Care Medical Center emergency room before the LLNL ambulance arrived.

The LLNL Fire Department ambulance arrived at Valley Care Medical Center emergency room at 8:05 a.m. E-1 was admitted for treatment of injuries sustained in the fall. At the emergency room only one person was allowed to talk with E-1, so only the superintendent took the opportunity to talk with E-1 concerning the accident circumstances.

2.4. Consequences

E-1 sustained a broken wrist, broken shoulder, fracture of the pelvis and other injuries. E-1 was hospitalized for eight days and was transferred to a recovery center for another eighteen days.

There were no facility-related impacts to the accident. After establishing an alternate method of getting onto the roof, PE continued with the air conditioning unit replacement work. The ladder involved in the accident was taken out of service, and some effort was made to preserve the accident scene. The project was completed on or about August 13, 2006.

2.5. Accident Reconstruction

The Board's first and primary responsibility in investigating this accident was to fully understand the nature and progression of the accident itself. In other words, the Board needed to determine what really happened. In his interview with the Board, E-1 reported that he recalled missing a rung with his foot, reaching out and trying but failing to grasp a rung with his hand, and then falling to the ground. He specifically noted that he did not have two hands on the rungs at the time of the fall. There were no witnesses to the accident, and no physical evidence (such as a broken rung) that could directly explain the cause of the accident. Therefore, the Board found it necessary to postulate conditions that could have caused a similar

accident, and consider the probability of their contribution to this particular event.

To begin with, an individual standing at rest on a ladder would have four points of contact, two hands gripping the rungs and two feet standing on the rungs. The Board assumed that under minimal conditions, an individual could be expected to remain firmly on a ladder with only two points of contact, one hand gripping a rung and one foot standing on a rung. (While it may be possible to remain on a ladder with only two hands grasping the rungs and no firm footing, the Board considered that to be an unreasonable expectation.)

When climbing, an individual would need to break at least one of the four points of contact at a time in order to progress up or down the ladder. Realistically, the natural tendency is to break two points of contact at once, one hand and one foot, and to reach for the next rungs with both hand and foot simultaneously. The proper climbing method, as described in the LLNL ladder safety training, is to use a "3-points of contact" technique where the climber is moving only one limb at a time while remaining in contact with the ladder with the other three. (The "3-points of contact" technique is required by the applicable consensus standard, ANSI A14.3-2002.) The Board concluded that E-1 was not using the prescribed climbing technique at the time of the fall.

In considering this accident, the Board postulated that such a fall while climbing would require at least two separate conditions to exist. The first necessary condition would be that which led to the first misstep, when E-1 failed to find a rung with his foot. But since E-1 apparently still had one hand and one foot firmly on the ladder, it would be unlikely for that one misstep alone to lead to the fall. Therefore, the Board postulated that a second condition would be necessary in order for E-1 to lose one of the two remaining contact points and fall from the ladder. (The Board did not consider the failure to grasp a rung with the free hand as a separate condition leading to the fall, since that failure was likely a result of E-1's spontaneous response to missing the foot rung.) That second condition would be the one that led to the loss of contact of either the second hand or the remaining foot, resulting in the fall from the ladder.

The First Condition

The first condition to be considered was that which led E-1 to miss the rung with his foot. In his interview, E-1 stated that he recalled bumping something, most likely a rung, with the top of his foot near the toe at the beginning of the fall sequence. In order for this to occur, the Board believed that there were two possible scenarios. First, E-1 either over-reached with his leg and hit the rung above the one he was aiming for, or under-reached and hit the rung he was aiming for from underneath. Alternatively, there could have been an obstruction on or near the ladder that interfered with E-1's ability to proceed up the ladder.

In evaluating the accident scene, the Board conducted a detailed examination of the ladder itself. The Board determined that the ladder was not in compliance with Occupational Safety and Health Administration (OSHA) requirements in at least four areas (a more complete discussion of this ladder evaluation is contained in Section 3.1.5). The Board believed that two of those non-compliant conditions could have resulted in a misstep similar to what E-1 experienced. Outside of the ladder itself, the Board did not find any foreign obstruction that could provide a reasonable explanation for the initial misstep. The two non-compliant conditions that the Board believed could cause such a misstep were: (1) about two-thirds of the way up the ladder there was an overhanging section with a part of the building trim that intruded roughly one-half inch inside of the seven-inch minimum clearance that OSHA requires behind the ladder (the overhang is visible in Figure 1.2-1); and (2) the first rung of the ladder was about 17.5 inches above the ground level, 5.5 inches above the OSHA requirement for rung distance (See Figure 2.5-1).

In his interview, E-1 estimated that he was roughly six feet up the ladder when he fell. Furthermore, E-1 stated that he had not reached a point anywhere near where he could see over the top of the roof. Given E-1's height and the height of the building, the Board believed it was likely that E-1 was actually lower than he estimated, with his feet perhaps as low as three to five feet above the ground. (With his feet at the six-foot level, his head would be above the roofline.)

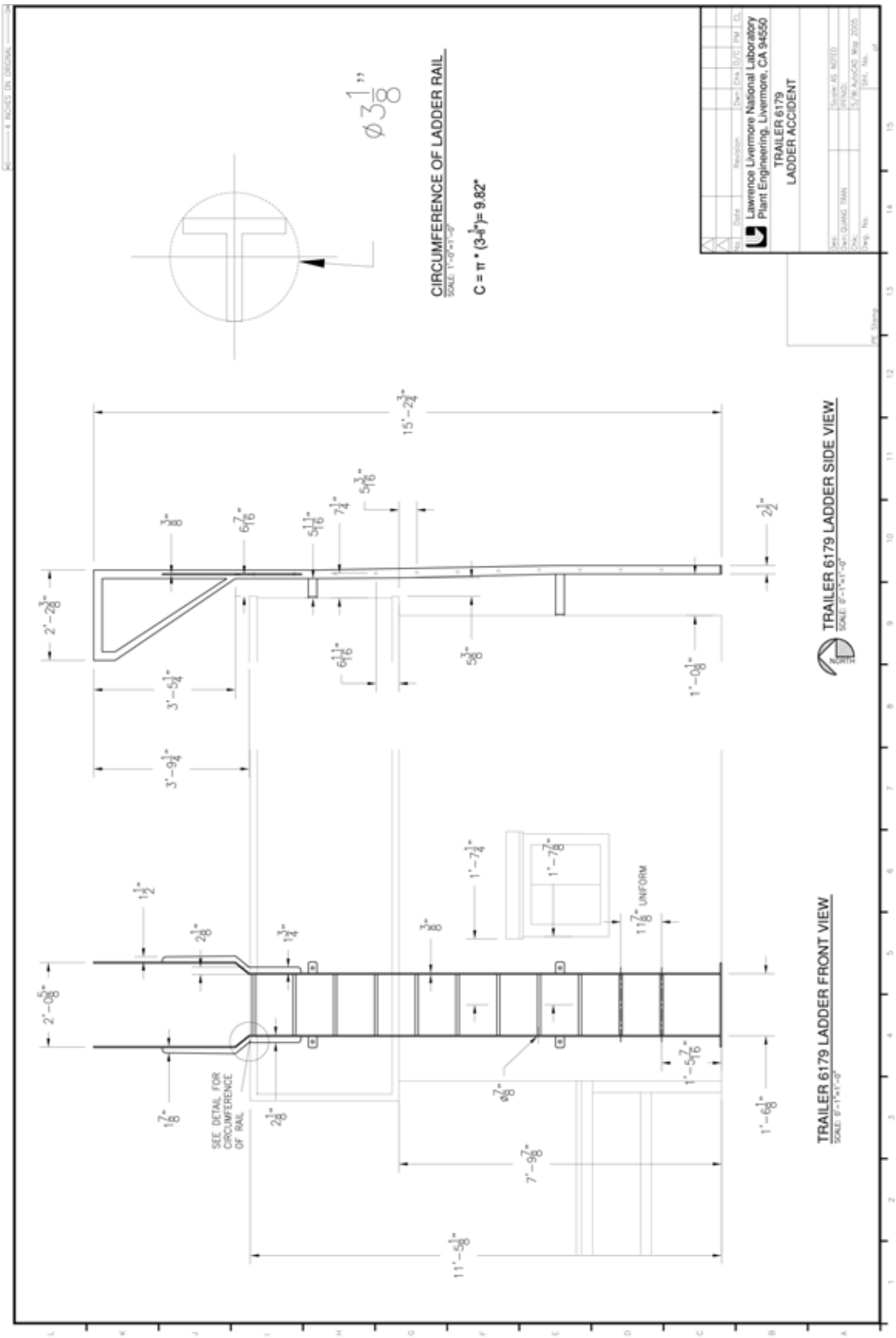

Figure 2.5-1: Detailed drawing of the as-found configuration of the fixed ladder mounted to the building.

Regarding the first condition, the building overhang and trim piece was determined to be almost eight feet above the deck. For E-1 to contact this piece with his foot, his head would have clearly been above the roof level at that point. Therefore, the Board believed that it was unlikely that it contributed to the accident, although it could potentially cause a similar accident.

Regarding the second condition, the height of the first step was not uniform with the rest of the steps, which were uniformly spaced at about 12 inch intervals, as required by OSHA. Consequently, the Board considered the possibility that the non-uniform spacing could have confused E-1 as he climbed the ladder. Given the Board's estimate of where E-1 was in the climb, it was reasonable to consider that E-1 could well have been reaching for the third step on the ladder. If this was the case, then it was likely that E-1 would be making his first full stride on the ladder, and his motion would have been influenced by the non-uniform distance of the first step. Consequently, E-1 would tend to overreach on the third step due to the difference in the distance between the two spans. This overreach would lead to E-1 striking the top of his foot on the bottom of the rung above the one he was aiming for, unbalancing him and causing him to miss the rung he was reaching for with his hand.

The Board also took note of the fact that on the morning of the accident, E-1 had changed his normal morning routine in order to start working on the roof early, because it was expected to be a hot day. Consequently, he did not participate in his work group's daily stretching exercises. The Board believed that it was possible that this could potentially affect E-1's dexterity and therefore possibly contribute to the situation.

The Second Condition

At this point, after E-1 missed the rungs with one hand and one foot, he would be hanging on the ladder with the other hand and foot. If E-1 was at a rest position, this situation would still provide a stable basis for him to recover from the first condition. However, he was most likely not at rest, but rather the momentum of his reaching for the rungs caused him to swing somewhat and shift his weight. This would leave E-1 in a vulnerable position, but will not automatically lead to a fall from the ladder.

As noted above, the Board identified four non-compliant conditions with the ladder being used. Besides the two noted above, the Board believed that a third of these conditions could have come into play at this point. The rungs of the ladder slightly exceeded the minimum acceptable diameter, but they were smooth and painted. (OSHA requirements would expect the rungs to be treated to minimize slipping.) This would result in the rungs being easy to slip on, even when they are clean and dry as they were believed to be on the day of the accident. Given E-1's unstable situation, the substandard rung surface would make it difficult for E-1 to continue standing firmly on his remaining foot.

Conclusion

The Board concluded that the following sequence of events best described the most likely scenario for E-1's fall:

1. E-1 was simultaneously reaching with both a hand and a foot for the next rungs in his climb up the ladder;

2. E-1 missed the next rung of the ladder with his foot, most likely due to the non-uniform spacing between rungs;

3. Because of the imbalance caused by missing a rung with his foot, E-1 also missed a rung with his hand;

4. The continuing momentum from missing the rungs caused E-1 to shift his weight off of his remaining foothold, resulting in E-1's remaining foot slipping off the smooth rung surface and his loosing his remaining handhold; and

5. E-1 fell backwards to the ground, twisting as he fell and landing on his left side. (Since E-1 did not land on his feet, the Board believed that it is probable that one of E-1's feet may have been momentarily caught in the ladder, which would cause the backward twisting motion.)

The Board concluded that E-1 was not using the LLNL prescribed "3-points of contact" technique when climbing the ladder. Furthermore, the Board concluded that the ladder was not compliant with OSHA requirements and consensus standards recommendations, and that two of those non-compliant conditions likely contributed to E-1's fall.

A General Perspective on Ladder Safety

Climbing ladders is a common activity performed by both members of the public and workers in a wide variety of occupations. Unfortunately, it is also often regarded as one of the least recognized hazardous activities commonly performed in either the home or the workplace. Underwriter's Laboratories estimates that ladder-related accidents in the home result in more than 222,000 emergency room visits per year. A University of Tennessee study in 2005 ranked "falls from / with ladder" as the ninth leading cause of fatalities in the construction industry for the period of time between 1991 and 2002 (J. E. Beavers, et al, "Crane-related fatalities in the construction industry," University of Tennessee, 2005).

According to the Bureau of Labor Statistics (BLS), during 2004 about 1.8% of all industrial "events or exposures" were reported to be ladder falls. For these industrial ladder accidents, 70% resulted in greater than 6 days of lost-work time, with 54% of those cases exceeding 31 days away from work. The BLS also reported that in 2005 there were 129 fatalities due to falls from ladders, which was 2.2% of all fatal occupational injuries during that year. The BLS statistics indicate that working with ladders was the seventh highest source of fatal occupational accidents during 2005. Within the DOE, there were 44 ladder falls reported between January 1, 2003, and August 18, 2006 (including this accident); 12 of these accidents resulted in serious injuries, including 1 fatality.

Typically, the ladders involved in these accidents are portable ladders such as step or extension ladders. Fixed ladders, such as the one involved in this accident, are generally less commonly available and are usually only used for industrial applications. Note that at least three of the 44 ladder falls in DOE, and 6 of the 129 total fatalities in the BLS statistics involved a fixed ladder.

Fixed ladders generally have different characteristics from portable ladders, with the most notable one being that they are usually mounted in a more vertical orientation. Portable ladders will generally be erected at an angle of about 60 to 70 degrees from the horizontal surface, but fixed ladders can be mounted at angles up to 90 degrees (in other words, straight up). This orientation results in the climber's center of gravity being outside of the ladder, and the climber must depend more on the ability to grasp the ladder with the hands. As a consequence, falls from fixed ladders can often result in the climber falling away from the ladder, rather than down the ladder, creating a potential for more serious injuries. For example, one study analyzed 925 ladder fall accidents, and found that there was a 14% fatality rate for falls from 4 feet or less, and a 13% fatality rate for falls from 5 to 10 feet. Those fatalities were most often due to head injury. The report went on to show that persons who fell less than 20 feet landed on their heads 74% of the time, while persons who fell more than 20 feet landed on their feet 63% of the time (D. Riches, "Preliminary investigation into the fall-arresting effectiveness of ladder safety hoops", funded by the Health and Safety Executive for Great Britain, 2004).

3. Accident Facts and Analysis

3.1. Integrated Safety Management Guiding Principles

The DOE and NNSA expect that all work at DOE/NNSA facilities be conducted within the framework of a formally established ISM System. In accordance with that expectation, LLNL has an institutionalized ISM process, and this project fell within the scope of that process. Therefore, the Board used the framework of ISM to analyze the conditions present at the time of the accident and drew conclusions from that analysis regarding the LLNL implementation of the DOE/NNSA expectations.

The ISM framework is composed of seven guiding principles and five core functions. The guiding principles set the overall philosophy and general approach to be used in implementing ISM, and the core functions define the essential steps to be followed by any work process.

In this section, the Board evaluated the LLNL ISM implementation, as it was related to this accident, against each of the guiding principles and core functions. The Board drew conclusions in each area regarding the effectiveness of the LLNL implementation as applied to the project being conducted when this accident occurred.

During this analysis the Board also reviewed other recent internal and external assessments of the LLNL ISM implementation. The Board sought to determine whether other assessments had related observations, and whether those observations could have served as warning signs for this accident.

3.1.1. Line Management Responsibility for Safety

"Line Management is directly responsible for the protection of the public, the workers, and the environment." (ISM Guiding Principle 1)

The LLNL contract required the establishment of an ISM System in accordance with DOE Directives. Interviews with LLNL line managers indicated that they support the precepts of ISM and the established polices and procedures to implement those polices.

The Board reviewed the LLNL ISM System Description and other LLNL institutional policy documents. Those documents demonstrated a corporate recognition and senior management commitment to the principle of line management responsibility for safety.

Within the PE Department, the principle of line management responsibility for safety appeared to be carried down into the working level documents and procedures. However, the Board determined that the various institutional and PE documents that governed the air conditioning replacement project implemented the principle in multiple and sometimes contradicting manners.

For example, the first line supervision for this type work was referred to as the (1) job manager; (2) project manager; (3) senior supervisor; (4) responsible individual; (5) plant engineer individual responsible for job execution; (6) shop supervisor; (7) payroll supervisor; (8) craft supervisor; (9) technical supervisor; (10) business unit supervisor; (11) work supervisor; and (12) authorizing individual. In many cases these multiple titles have somewhat different definitions and functions, but combinations of these titles can often be simultaneously vested within a single individual.

To further complicate this situation, the LLNL ISM processes often allow the delegation of responsibilities to lower organizational levels depending on the situation. In some situations related to this accident, it would appear that inconsistencies between processes could result in the delegation of line management authority and responsibility all the way down to the worker for functions that he/she would not be able to fulfill due to a lack of technical knowledge or intrinsic conflicts of interest within the delegated authorities.

The Board concluded that although the LLNL ISM processes captured the principle of line management responsibility for safety, its implementation within PE was confusing and ineffective.

3.1.2. Clear Roles and Responsibilities

"Clear and unambiguous lines of authority and responsibility for ensuring safety shall be established and maintained at all organizational levels within the Department and its Contractors." (ISM Guiding Principle 2)

In order to evaluate this guiding principle, the Board reviewed both PE work planning processes and the work package for the air conditioning replacement project. As noted in the previous section, the Board determined that the LLNL descriptions of line management were confusing and ineffective. With regards to the clarity of roles and responsibilities, the Board also made the following observations:

- The original Job Manager (WS-1) for this task changed positions sometime in May due to organizational and job specific changes. The Job Manager (WS-2) that executed the work was not the same person that planned the work.
- Interviews were held with various personnel involved in the process of defining, reviewing, and authorizing the work. There was not a common understanding of the process, what all the steps were, or who was authorizing what.
- The Job Manager who executed the project (WS-2) indicated he was not responsible for safety items, such as ensuring lockout and tagging was done, although he would often verify that it had been done. He felt this was the responsibility of the craft foreman. The craft foreman felt that on multiple-craft jobs, the Job Manager was responsible for all workers involved in the job. With the current method of dual supervision with split responsibilities, it was unclear who was responsible.
- The current work control procedures and work flow failed to clearly communicate expectations. It was not possible to tell which signature was the final signature, authorizing the work to begin.
- The LLNL ES&H Assurance Office (EAO) Annual ES&H Assurance Report dated August 25, 2006, found that, within multiple directorates, Authorizing Individuals (AIs) and Responsible Individuals (RIs) have not performed all their required responsibilities associated with Integrated Work Sheets (IWSs).
- The Facility Manager (FM) or his designated FPOC was one of the "concurring individuals" for work according to the ES&H Manual. In this role, the FPOC is "concurring that the work can be safely performed in the facility"; "participating in the Pre-start Review of the work when one is conducted"; "concurring that work may proceed in the building, prior to it beginning"; and "monitoring work activities to assure that there are no hazards or unacceptable collateral effects to the facility or other occupants." The FPOC did participate in the Pre-start Review. However, none of the interviews indicated that the FPOC responsibilities were fully understood by the people involved in this project.
- The ES&H Manual required that after the RI declares that he or she is ready for the Pre-start Review, the AI shall conduct the Pre-start Review for WAL-C activities. (Work Authorization Level, or WAL, is a designation of the level of authority and review necessary before a task governed by an IWS can commence. A WAL-A task is one that is commonly performed by the public and WAL-B and WAL-C are assigned to higher hazard tasks. The Lockout/Tagout portion of E-1's task was governed by IWS/SP 12005, a WAL-C IWS.) The AI was expected to assemble an appropriate review team, which may consist of peers, workers, Subject Matter Experts (SMEs) (either technical or ES&H), and the FPOC or FM. The AI for the Lockout/Tagout IWS/SP12005 did not conduct the required Pre-start Review.

- There were a number of individuals and approval signatures in the work documents. No evidence was presented that any of these individuals physically confirmed the controls were in place for the T6179 work.

- For this particular job there were numerous interpretations on who the first line supervisor was, who was responsible to provide hazard communications, and who was responsible to ensure that the hazard controls were in place.

- The Trade/Service IWS documents included fall protection as a requirement for working on the roof (>6 feet). This requirement was not identified in any of the interviews during the discussion of fall protection.

The Board could not identify a clear planning element to the work package process. As various elements of the package were brought together there was no integration and review for adequacy or completeness. The Pre-start Review appeared to be the only time there was a walk down of the job site to ensure that the hazards had been identified and the controls were in place specific to this job, and this occurred after the planning was completed. There were no clear expectations to the worker in the work package in a useable layout and format. The Electrical Trade/Service IWS provided to the Board was IWS 31.05 r3; the IWS in E-1's clipboard was IWS 31.04 r6 and the currently authorized version was IWS 31.05 r6. The Board was told the Safety Packet (which was not recovered from the work site) did not include the Trade/Service IWS documents so the worker did not have current work controls available. The Board could not determine which IWS revision the worker was supposed to be using.

An MPD memorandum had been issued to clarify the Roles and Responsibilities (R&Rs) for MPD supervisors. That memorandum defined two types of supervisors, shop supervisors (SS) and business unit supervisors (BU). Both SS and BU were to conduct Pre-start Reviews. For this project only the BU conducted a Pre-start Review and only E-1, the FPOC, and the Authority Having Jurisdiction (AHJ) attended. There was no indication that the BU adequately addressed craft specific hazards, nor were the crosscutting fall protection and working alone policies addressed. The BU Supervisor did not recall LLNL having a hazardous working alone policy. Having both SS and BU responsible caused confusion on who is responsible.

Both SS and BU were required to review completed PTHA Worksheet, but according to the PTHA instructions this is not done until after the work is performed. The SS was responsible to ensure that Personal Protection Equipment (PPE) was available, inspected, and was being used correctly. This appeared to have failed for fall protection equipment that was required and not implemented for this project.

The SS was responsible for coordinating informal shop safety tailgate meetings. There was no tailgate meeting on the day of the accident and the Board was informed that tailgate meetings were superseded by the PTHA worksheet approach.

The ES&H Manual required that work supervisors shall ensure that tailored controls were developed and implanted for each hazard associated with the work activity. Looking at this particular work package it was very difficult to identify who was responsible/accountable for what. Responsibility for protecting the workers on the specific job by hazards communication and verifying that adequate controls were in place appeared to fall between the FM/FPOC, the job manager, and the payroll/craft supervisor. Interviews, the PE policy letter, and a review of ES&H Manual provided different and overlapping expectations.

There was reasonable evidence that individuals did not feel direct pressure to work in an unsafe manner or on an unsafe activity. The Board identified a number of deficiencies in the work planning, review and approval for this work activity. Those deficiencies were not recognized by LLNL management involved in those processes nor corrected prior to allowing the performance of work. While the failure to identify those deficiencies was significant, the Board believed that because these deficiencies were not recognized, the workers did not intend to work unsafely.

The Board concluded that Roles, Responsibilities and Authorities were not effectively integrated into the work control process and implemented in a manner such that individuals were aware of their responsibilities.

The Board concluded that the procedures delineating roles and responsibilities were complex, making it difficult for personnel to determine their responsibilities and the relationship of others' responsibilities to achieving the task.

The Board concluded that the work control process did not result in current and accurate work control documents at the work site.

The Board concluded that the Trade/Service IWSs were not adequate work planning documents, at least as they were used in the current LLNL work process.

3.1.3. Competence Commensurate with Responsibility

"Personnel shall possess the experience, knowledge, skills, and abilities that are necessary to discharge their responsibilities." (ISM Guiding Principle 3)

The Board evaluated the training for E-1 and other individuals directly involved in the planning and execution of this work package.

E-1 was current with required hazard training. He received Fall Protection training 8/26/99; OSHA 10-hour course (includes a segment on ladders) 11/23/99; OSHA 10-hour refresher – ladder module 1/13/04; Lockout/Tagout 8/7/97 and 3/30/98 (and a refresher 2/5/03). At the time of the accident, he was climbing with his hands free of tools.

At LLNL, ladder training was provided either through online course HS5959-W "Stairways and Ladders", or course PE8136-COR (10-hour OSHA Core Training) which included a section on ladders. PE primarily used the OSHA 10-hour course. The OSHA 10–hour training devoted less time and material to ladders than LLNL's course HS5959-W "Stairways and Ladders". Both courses contained a written test.

The Board noted that both forms of ladder training contained discussion of the "3-points of contact" technique for climbing ladders. However, it should be recognized that this prescribed climbing technique tends to be counter to the natural or instinctive approach to climbing ladders, which would result in only two points of contact. For an individual to learn and accept the "3-points of contact" technique would likely require hands-on training, practice, and proficiency testing in order to effectively overcome the natural tendency to use only two points of contact when climbing. The Board believed that such practical training would be necessary to provide the adequate fundamental competency to instill the prescribed climbing technique in the workforce.

Most IWSs involved in this job specified course PE8136-COR (10-hour OSHA Core Training). However, two did not:

a. IWS #31.05 r6 "General Electrical Work" authorized 13-JUL-05 did not list either PE8136-COR (10-hour OSHA Core Training) or HS5959-W "Stairways and Ladders" among the required training for workers.

b. IWS#5.06 r1 "Design, fab & installation of sheet metal components" authorized June 14, 2006, listed PE8136-30 (30 Hour OSHA #510) among the required training for supervisor, but did not list either PE8136-COR (10-hour OSHA Core Training) or HS5959-W "Stairways and Ladders" among the required training for workers.

The LLNL ES&H Manual, stated "Ensur[e] that training is provided to workers on the proper use of ladders."

The FPOC was responsible for authorizing work within his/her assigned facility, including verifying hazard controls were in place according to the ES&H Manual. The interviews indicated that the FPOC did not have the experience, knowledge, and skills to verify that the controls were in place prior to allowing the work to take place without assistance, and in this instance there was no thought to requesting that assistance.

Interviews with workers and first line supervisors revealed weaknesses in their ability to recognize hazards and assure appropriate controls were implemented,

such as working at heights that required fall protection, and the hazards associated with working alone. Individuals were not familiar with the ES&H Manual requirements, the informal PE planning process, and the paperwork associated with the work package. The meaning of approval signatures could not be determined through interviews and documents provided.

The Board concluded that work supervisors and others responsible for authorizing work were not adequately trained to accomplish those responsibilities.

3.1.4. Balanced Priorities

"Resources shall be effectively allocated to address safety, programmatic, and operational considerations. Protecting the public, the workers, and the environment shall be a priority whenever activities are planned and performed." (ISM Guiding Principle 4)

In reviewing this accident, the Board recognized that the controls necessary to perform this work safely all depended on established LLNL institutional safety processes. There was no indication that there was a lack of safety resources that contributed to this accident. Therefore, the Board's evaluation of this guiding principle focused on the balancing of the priorities between safety and performance of the work.

Adequate resources were available to identify and control the hazards to the worker(s). Regardless, the working alone hazard, the ladder hazard, the fall hazard, and the lift over potentially occupied buildings were not identified.

The Pre-start Review only included E-1, AHJ, FPOC, and WS-2. Based on interviews, other crafts did not feel it was necessary to attend. Interviews with workers left the Board with the perception that the Pre-start Review meetings were not highly regarded. There were comments that appropriate tail-gate / Pre-start Review meetings were much better than the current PTHA process. The Board determined during interviews that WS-2 was more concerned that the budget sheet was signed than the hazards were identified and controls were in place.

Recent reductions in PE staffing were reported to have forced a change in the previous PE practice that craft personnel work in teams. That staffing reduction likely influenced the workers to the point that they do not request support in "hazardous to work alone" situations such as this activity. This situation was not questioned by E-1, SS, FPOC, or BU.

E-1 completed the PTHA Worksheets which, while a good practice, did not replace proper planning and tailgate meetings. The PTHA identified the ladder hazard, but not the working alone or fall hazard. Though the ladder hazard was identified there were no changes to the work package or to E-1's behavior in climbing the ladder.

The Board concluded that PE and Facility management had accepted this non conservative balance of priorities contrary to LLNL policy.

The Board concluded that LLNL management accepted less than complete and accurate work planning. The work planning and execution was not conducted in accordance with the requirements of the ES&H Manual.

3.1.5. Identification of Safety Standards and Requirements

"Before work is performed, the associated hazards shall be evaluated and an agreed-upon set of safety standards and requirements shall be established which, if properly implemented, will provide adequate assurance that the public, the workers, and the environment are protected from adverse consequences." (ISM Guiding Principle 5)

With regard to this accident, the Board considered the OSHA laws regarding fixed ladders and the laws regarding fall protection particularly relevant.

This job met the OSHA definition of "Construction Work". Per 29 CFR 1926.32(g), "Construction work" means work for construction, alteration, and / or repair, including painting and decorating, and Work Package 219007 was issued as a Construction work package. It was not clear whether LLNL had identified that the ladder involved in the accident was subject to 29 CFR 1926 standards.

The ladder in question was never critically inspected against the requirements of ANSI A14.3 *Safety Requirements for Fixed Ladders*, as specified in the ES&H

Manual and OSHA. OSHA requires ladders to be inspected regularly. The standard indicates that maintenance and inspection logs should be maintained for ladders. The LLNL expectation was that fixed ladders be inspected informally as part of the ES&H Team's routine facility inspections. However, no inspection criteria had been developed or promulgated; fixed ladders were not routinely identified on facility equipment lists; the requirement to inspect the ladder was not explicitly stated in the appropriate procedure; and if ladder inspections did occur, they were not documented unless deficiencies were noted.

Several non-compliances with OSHA requirements were found for the ladder involved in the accident:

a. First Rung Distance: Requirement: 29 CFR 1910.27(b)(1)(ii) and OSHA Interpretation Letter "12/04/1978 – Information on fixed ladders and cages": The distance between rungs, cleats, and steps shall not exceed 12 inches and shall be uniform throughout the length of the ladder. As Found: The rungs were 12" apart, except the distance between the ground and the first rung was about 17.5." The first rung cannot be more than 12" from the ground. (OSHA has indicated in an interpretation letter that the requirement is 12," but they will accept as "de minimus" a deviation of up to 2" from that requirement.)

b. Ladder Rungs: Requirement: 29 CFR 1926.32(g) definition of Construction, and 29 CFR 1926.1053(a)(6)(ii) "The rungs and steps of fixed metal ladders manufactured after March 15, 1991, shall be corrugated, knurled, dimpled, coated with skid-resistant material, or otherwise treated to minimize slipping." As Found 1: The ladder on T6179 had round rungs, not slip-resistant. The best evidence available to the team indicated that this ladder was installed on T6179 after 1991. As Found 2: The Board determined that multiple ladders at LLNL were of similar construction to the one involved in this accident, although the Board could not confirm the date of their manufacture.

c. Ladder Rails: Requirement: 29 CFR 1910.27(b)(2) and OSHA Interpretation Letter "08/08/2005 – Requirements for step-through fixed ladder side rails that might be used as climbing aid": "Side rails which might be used as a climbing aid shall be of such cross sections as to afford adequate gripping surface…" As Found: The side rails on the upper portion of the ladder were constructed with an angle-iron configuration and had a gripping circumference of nearly ten inches, making it difficult to grip (see Figure 3.1.5-1). In an interpretation letter, OSHA determined that the angle-iron arrangement does not afford an adequate gripping surface.

d. Rear Ladder Clearance: Requirement: 29 CFR 1910.27(c)(4) and 1926.1053(a)(13): The distance from the centerline of rungs, cleats, or steps to the nearest permanent object in back of the ladder shall be not less than 7." As Found: The rear ladder clearance varied from 6 7/16" to 6 7/8" in the upper section of the ladder.

Regardless of the above discrepancies, the Board noted that LLNL ES&H staff reported after the accident that the ladder was in compliance with the OSHA requirements.

Fall protection was identified in Trade/Service IWS documents but was not recognized and implemented for this work activity. (Fall protection was not required for climbing the ladder, but would apply for working on the T6179 roof.) The ES&H Manual conditions requiring fall protection were not adhered to. In addition, the Board determined that The ES&H Manual conditions requiring fall protection were not consistent with OSHA requirements and published interpretations.

The Board concluded that LLNL's implementation of the OSHA fixed ladder and fall protection requirements and standards were ineffective and not consistent with those requirements.

Figure 3.1.5-1: The walkthrough section of the ladder showing the angle-iron configuration of the side rails.

3.1.6. Hazard Controls Tailored to Work Being Performed

"Administrative and Engineering controls to prevent and mitigate hazards shall be tailored to the work being performed and associated hazards." (ISM Guiding Principle 6)

The Board spent a significant fraction of the investigation trying to understand LLNL's approach to tailoring the hazard controls to the work being performed. Detailed analysis of the work planning process for this project will be discussed in later sections, but the general approach will be introduced here in order to discuss this principle.

The work package for this project was initiated in early CY2006, and funding was approved for the project on March 1, 2006. Following the approval of the funds, the work package began to be circulated for facility and ES&H reviews. To the extent that the Board could determine, the only description of the work that was provided to the facility and ES&H Teams for their review was:

> "Remove ACHPS01 thru 03 and replace with new units. Please attempt to deplete the stock of heat pumps in B411 before ordering replacement units. Job Manager: Contact requestor for a pre job walk upon receiving this request. Any changes in the scope of work must be approved by the requestor."

Also, on March 13, 2006, a field change was approved to revise the scope to include the replacement of 6179ACS01, the fourth air conditioning unit on the roof, but that field change provided no further description of the work to be performed.

When the package was distributed for facility and ES&H Team review, the review cover page identified four Trade/Service IWSs that PE indicated as covering the work to be performed. Note that Trade/Service IWSs are a PE-specified version of the LLNL IWS. The Trade/Service IWS was designed to provide general coverage for the specific craft people working within its scope, by evaluating all hazards that could be commonly encountered by the craft person, and identifying the training and controls necessary to address each hazard. The IWSs identified for this work package included one for each craft expected to be involved in this work.

The facility and ES&H Team reviews were completed within about ten days of their receipt of the package. The only comment provided dealt with the need for a "Certified Appliance Recycler" if the work involved removing refrigerant from the air conditioning units, in order to comply with State of California requirements. The Board could find no indication that the reviews had considered the controls identified in the Trade/Service IWSs or had determined the subset of those controls that were actually applicable to this project.

In contrast the Board identified the following additional conditions that it believed should have been captured during the reviews and tailored to the work being performed:

- Use of a ladder was apparently considered an "Activity Commonly Performed by the Public." However, ES&H Manual Document 2.2, Appendix B, stated that "Use of a step stool or ladder (with your feet less than 6 feet above the working surface) to reach something that is not hazardous" is an activity commonly performed by the public. Note that the "less than 6 feet" criterion was not discussed in ES&H Manual Document 11.2, Section 6.0, "Ladders and Step Stools."

- OSHA requires that truck crane operators should avoid moving loads over people. Available information indicated there was no evacuation of building occupants below the load path.

- Hazards and associated controls for climbing ladders, fall protection while working on the roof, and the movement of overhead loads, were not identified or not followed through.

- The LLNL ES&H Manual and OSHA require that fall protection shall be worn when a fall hazard exceeds six feet. The generic IWS calls out fall protection, however WS-2 and the workers on the project apparently did not recognize the hazard. There was no indication that the workers were wearing fall protection PPE at any time during the work.

- The LLNL working alone policy was not well understood and interviews indicated that personnel had a non conservative perception of when a person should working alone.

- The Work Package ES&H Assessment indicated that roof access permit was required. In reality no roof access permit was required or completed.

- The Unreviewed Safety Question (USQ) Determination worksheet indicates this was a critical lift. The lift plan did not indicate that this was a critical lift and had no signatures or dates. The lift plan was incorrect in several details and not corrected.

The Board concluded that the work control process failed to establish hazards controls that were tailored to the work being performed.

3.1.7. Operations Authorization

"The conditions and requirements to be satisfied for operations to be initiated and conducted shall be clearly established and agreed-upon." (ISM Guiding Principle 7)

The Board had particular difficulty in understanding how this principle was implemented for this project. The work package contained two signature blocks that indicate the approval to perform the work. The first block, "Approvals," is signed by the person authorized

to allocate the funds to the project. That first signature block stated "This authorizes Plant Engineering to proceed with the requested work in Section I." The second block is a concurrence block for the FPOC, the ES&H Team leader, and the PE "Individual Responsible for Job Execution." That concurrence block stated that "Facility Hazards/Impacts have been identified, controls are in place. Work has been authorized to proceed." From the work package it appeared the only "authorizing individual" for this work was the person with budget authority. The Board made the following observations concerning the work package:

- The work package indicated that the final concurrence for the work to proceed was on April 12, 2006; almost three months before work actually began.
- Any follow-up reviews or approvals would be contained in a "Safety Packet" that was supposed to be available at the work site; the Board could not evaluate this packet because LLNL could not locate it during the investigation.
- The "Individual Responsible for Job Execution" that concurred on the work package was assigned to a different job before the work began, and turned over the project to another work supervisor. That work supervisor was not identified anywhere in the work package.
- The Trade/Service IWSs were designed for work activities performed by the crafts/trades workers. Those general job tasks were approved by the AI and RI supervising the crafts/trades. They were not job specific and only reviewed annually. The specific authorization was a shared responsibility between the FPOC and work supervisor (in this case WS-2).
- The Trade/Service IWS that E-1 was working under actually incorporated a second, higher hazard IWS by reference for the electrical lockout and tag activities. For such a higher-level IWS, LLNL expected an explicit Pre-start Review. However, since that IWS was pre-authorized by PE and then embedded by reference in a lower-level IWS, the Pre-start Review did not take place in accordance with LLNL expectations.

The Board concluded that the work authorization process did not ensure that all hazards were identified nor that all controls were put in place before the work commenced on the project.

3.2 Integrated Safety Management Core Functions

In this section the Board evaluated the conditions surrounding this accident within the framework of each of the core functions of ISM.

3.2.1. Define the Scope of Work

At the time of the accident, E-1 was working on a project to replace the air conditioning units on the roof of T6179. E-1's job was to disconnect electrical hook-ups to air conditioning units, and reconnect the electrical services after replacement.

In March 2006, PE determined building T6179 air conditioning units needed replacement, based upon the age of units (useful lifetime). Work Package 219007 was initiated to replace the air conditioning units at building T6179. PE Form 1 was completed to "Remove ACHPS01 thru 03 and replace with new units." The requested start date of the replacement was June 12, 2006 and the requested completion date was July 14, 2006. The Block II approval authorizing funds for this project was signed and dated March 1, 2006. The Block III PE Action is signed by the Job Manager and undated.

On March 2, 2006, the PE Job Area Hazard Analysis Form was completed by the ES&H Team. The person(s) completing the form did not select "Fall (slip/trip)" or "Temperature Extremes (<32 deg F and/or >100 deg F)" from the provided checklist of common hazards. The form's checklist did not include "ladders," "working at heights greater than six feet," or "fall protection" as common hazards on the checklist, though the work tasks included a rooftop worksite accessed by fixed ladder, and the work was scheduled during the summer months.

A PE Facilities Operation Field Memo was approved on March 13, 2006, to include the replacement of air conditioning unit 6179ACS01 in the scope of work covered by Work Package 219007. There was no indication this document was other than an accounting authorization and it had no other signatures.

The PE ES&H Assessment Document Form for Work Package 219007 received concurrence from the "Plant Engineering Individual Responsible for Job Execution" on March 20, 2006, and the Hazards Control ES&H Representative Member on April 12, 2006. The form indicated the presence of "unique facility hazards" and the need to contact the FPOC. The form indicated a "Roof Access" permit was required. The form did not indicate the need for a critical lift to hoist the units onto and off of roof. The form indicated that the Lockout/Tagout procedure was required. Contrary to this, no unique hazards were actually identified. No roof access permit was processed or actually required to perform this work. A critical lift was completed and used to accomplish the lifting activities. The Lockout/Tagout log provided to the Board indicated incorrect lock numbers for the lockout performed by E-1 and removed by E-1's supervisor.

The "Hazards Control Bridging Document Review" sheet was signed by ES&H Team 1 Leader as having undergone the ES&H review on April 10, 2006. The review included SMEs for Fire Protection, Industrial Safety, Environmental, Industrial Hygiene and Health Physics. Only the Environmental SME included comments to be resolved. The Hazards Control Bridging Document review was returned to ES&H Team 4 on April 10, 2006. The environmental comment resolutions were accepted on April 12, 2006.

The work package documentation provided to the Board by PE was inaccurate and incomplete. Initially, an incorrect comment form from the Environmental SME was included in the review package for a different job (building B694 vs. T6179). The ES&H Team 1 Leader signed for the review being complete, although the correct environmental comments were not resolved until two days later, April 12, 2006. The review document was provided to ES&H Team 1 on March 30, 2006; however, the dated initial for the Industrial Safety SME was "3/5/06." Note that the Responsible Individual concurred on the package on March 20, 2006, before the package was sent to the ES&H Team for review.

On April 11, 2006, a Lift Plan (JO 29007-1-6179) was completed for the air conditioning unit lifts. The plan did not include the weight of the original units being removed from the rooftop. The plan did not assess the hazard to building occupants in the event of a drop accident onto the building roof. The plan showed the crane set up in front of building 6197 and indicated the lifts onto/from building 6197. Building 6197 is adjacent to building T6179. The actual location for the lifts was building T6179. The crane was set up in front of T6179 (the actual work location) when the lifts were performed. The need for a critical lift was not identified on the PE ES&H Assessment Document. There was no indication that the lift plan was corrected prior to the work being performed or adhered to by workers performing the critical lift.

On May 12, 2006, a USQ (No. 612-06-049-D) (USQ) "Critical Lift for Replacement of Air Conditioning Units on Trailer 6179" was completed to assess the potential consequences of the lift activities in the "Facility 612" area, a Hazard Category 2 nuclear facility, against the safety basis accident analysis. The USQ screen was negative.

A Pre-start Review was conducted by the PE work supervisor on Thursday July 27, 2006. Not all crafts involved in the air conditioning unit replacement job (Work Package 219007) attended the Pre-start Review. There was a question on whether the electrical AHJ was required. If so, this was not identified on the PE Job Area Hazards Analysis form, completed on March 2, 2006 by the ES&H Representative. The top of the PE Form 1 had a hand-written note that AHJ was required.

The entire scope of work for this job was "Remove ACHPS01 thru 03 and replace with new units." A Field Memo was completed which added "Revision in scope to include the replacement of 6179ACS01." The work documentation did not identify the task-specific job steps in any fashion. This job required multiple crafts to accomplish the scope of work, including a critical lift, which was not identified in the scope of work.

The Board was not able to determine what constituted the final Work Package. Four requests for the work package resulted in four different submittals. The work packages were inconsistent, showed inattention to detail, and consistently contained incorrect documents or incorrect information.

Lift Plan JO219007-2-6179 describes four air conditioning unit lifts. Various verbal statements indicated there were either three or four air conditioning units. A field change memo had added a 4th unit.

Job Manager WS-2 was not familiar with the lifting plan portion of the work package.

The LLNL EAO Annual ES&H Assurance Report dated August 25, 2006, reported that this core function was identified as a weakness in the 2004 OA-40 report and is being addressed. The Defense Nuclear Facility Safety Board (DNFSB) Report titled "Summary of Reviews of Documentation and Practices Associated with Activity-Level Work Planning at NNSA Sites" (2004) cited that LLNL "authorizations do not adequately define the specific scope of work." They also found that "key individuals indicated a lack of knowledge, or at least, appreciation for the elements of an effective work planning and control process," and that "work packages reviewed were not user-friendly."

The OA-40 audit of LLNL, in 2004, found weaknesses in IWS implementation and in clearly defining requirements in accurate work instructions. They also found that deficiencies in work instructions and implementation of requirements at the work-activity level are not identified and corrected.

The Board could not clearly establish through interviews and institutional documentation whether the work planning documents presented a complete picture of the scope of work. Therefore, the Board concluded that the scope of work had not been clearly defined for this project. The Board also concluded that this issue had previously been identified in other internal and external assessments of LLNL.

3.2.2. Analyze the Hazards

The Board identified a number of deficiencies in the work planning documentation as shown in the table below. (Table 3.2.2-1)

Table 3.2.2-1: Errors Identified in the Work Planning and Execution Process

Work Control Document	Discussion
PE Form 1 – Request for PE Services	Block I – The work was identified as "■ Construction." However the Hazard Control Bridging Document review did not include Construction Safety in the review. Block I – The FPOC identified was not the same FPOC identified in Block IV, Standard Distribution. Block III – The PE signatures (four required) were not dated. A hand written note indicated "WIB AHJ Required." However, this was not indicated on the PE– Job Area Hazards Analysis. (WIB is the Work Induction Board)
PE– Job Hazards Analysis	While this work involved use of a fixed ladder (> 6 feet), the fall hazard was not identified. The work tasks included working within six feet of the roof edge. Fall protection was not identified as need in this work planning.

Table 3.2.2-1: Errors Identified in the Work Planning and Execution Process (Continued)

Work Control Document	Discussion
	The work, although planned in March, was accomplished in July during a heat wave. There was nothing to indication the ES&H disciplines reviewed the work to ensure proper precautions were taken. In fact, the decision to work earlier in the day to avoid rooftop heat was left to the worker. Interviews indicated the need for the electrical AHJ to be present at the job site to inspect the new air conditioning units for proper certifications before being installed. The need for electrical AHJ was not indicated on this form.
PE– ES&H Assessment Document	Block 1 indicated the presence of unique Facility hazards. None were listed or identified. The document indicated the need for a Roof Access permit. None was obtained and none were needed to access the rooftop job site for this work activity. The work was authorized to proceed more than 60 days before the arrival of worker at the job site.
Hazards Control Bridging Document Review	The Hazard Control Bridging Document review sheet was signed by the ES&H Team Leader on 4-10-06. Comments by the Environmental SME were not resolved until 4-12-06. The signed comment resolution copy was not in the ES&H Team 1 files. Comments made by the Environmental SME for a different work task were incorrectly filed with this document review. The error was not caught until the Board questioned the accuracy of the work document.
Lift Plan	The title of the plan indicated this plan was for a single lift: "Replace ACHPS#02." The plan identified eight lifts in total. No management approval was evident on the lift plan. The USQ associated with this work activity indicated this was a Critical Lift. The plan did not comply with the ES&H Manual requirements or DOE-STD-1090-2004 for a critical lift. The load radius was not specified for the 4th lift. Only the load description for "ACHPS#02" was used in the planning. The crane setup and the load landing locations identified in the plan were for the wrong building. This was not identified during the lift, or corrected on the lift plan. After the accident, the lift was accomplished with the crane not set up in the location as specified in the lift plan.

The scope of work did not identify the need for a Critical Lift Plan to safely lift and land the air conditioning units onto and from the roof and ground. No documentation was provided to the Board to show that the safety of the workers inside the building was considered in the event of a drop accident onto the roof of the building.

The ES&H Team 1 review did not identify that fall protection would be required for portions of this work. The ES&H Team 1 Leader signed that the Hazards Control Bridging Document had undergone a review two days before comments from the environmental SME were satisfactorily resolved. The review document did not identify the need for a Pre-start Review Meeting or that the job was "High-Risk" construction job, even though it involved a Critical Lift. The work planning and review process did not document what task-specific hazards were reviewed by the disciplines (if any).

PE workers identify their own task-specific hazards independently on the PE PTHA Worksheets. In this case, the reverse side of the worksheet left hand column did not match the permits required or used in developing the undocumented work steps such as Lockout/Tagout, Critical Lift, and Roof Access Permits. Fall protection, which would be required to remove/install unit 6179ACHPS02, was not identified in any of the work package documentation.

Several documents, including IWS and Hazard Analysis worksheets, did not list "climbing ladders" as a hazard:

a. IWS #31.04 r5 "General Electrical Work" authorized July 1, 2003, listed roof access and working at heights as hazards, but did not list "climbing ladders" as a hazard.

b. IWS #31.05 r3 "General Electrical Work" authorized July 13, 2005, listed roof access and working at heights as hazards, but did not list "climbing ladders" as a hazard.

c. IWS #31.05 r6 "General Electrical Work" authorized July 13, 2005, listed roof access and working at heights as hazards, but did not list "climbing ladders" as a hazard.

d. IWS #19.04 "Installation, Maintenance & Repair on HVAC Systems" authorized July 15, 2005, listed roof access and working at heights as hazards, but did not list "climbing ladders" as a hazard.

e. IWS #414.05 "Rigging Activities" authorized July 12, 2005, listed roof access and working at heights as hazards, but did not list "climbing ladders" as a hazard.

f. IWS #5.06 r1 "Design, fab & installation of sheet metal components" authorized June 14, 2006, listed roof access and working at heights as hazards, but did not list "climbing ladders" as a hazard.

g. PE Job Area Hazards Analysis sheet for this job did not list "climbing ladders" or "working at heights >6ft." as a hazard for this job.

h. PE Job Area Hazards Analysis sheet did not have available categories for "climbing ladders" or "working at heights >6ft." as hazards.

The LLNL ladder inspection process did not enable the ES&H inspector to comply with federal law. Specifically, the requirement (29 CFR 1910.27(f)) states: "All ladders shall be inspected regularly, with the intervals between inspections being determined by use and exposure." In contrast, the LLNL ES&H Manual stated "ES&H Teams Health and Safety techs shall be responsible for informally inspecting ladders during walkthroughs of facilities." Formal documentation to demonstrate compliance with the OSHA standard did not exist. Informal inspections of ladders do not meet the OSHA requirement of "regular inspections." Note that this weakness of "less than adequate documentation and demonstration of compliance with regulations" was also identified by LLNL EAO Annual ES&H Assurance Report dated August 25, 2006.

Also, LLNL closed an audit finding on this subject without correcting the deficiency. The LLNL audit of July 29, 2004, "Baseline Assessment of Compliance with Proposed Rulemaking 10CFR851," states: "There was no evidence that fixed ladders are inspected periodically. The inspector found no evidence of an

established interval inspection process based on use and exposure." This finding was closed after determining that the requirement to conduct inspections was in place, but without addressing the two implementation aspects of the finding.

An opportunity to identify the deficient condition of the ladder was missed. The LLNL ES&H Manual, required that the FPOC request a Health and Safety technician review proposed activities and the necessary safety controls before roof access work. The FPOC indicated that this occurred prior to posting the "general access" sign. The Board could not determine if this review was accomplished verbally or via a site visit. In either case, the deficient condition of the ladder was not recognized.

The ES&H Construction discipline did not review the work package, even though the project involved crane lifts.

The Job Manager WS-2 held a Pre-start Review on July 27, 2006. Not all crafts involved in the job attended. E-1, the electrical AHJ, and the FPOC attended. The riggers and the sheet metal mechanics declined to attend, because each craft felt they had already conducted one. This is a lost opportunity to share knowledge and discuss the hazards of the job. The Board was not able to determine whether this was an accepted practice at LLNL.

The LLNL process of allowing a worker to fill in his PTHA alone presented an opportunity to miss hazards. This was a change from the previous "tail-gate meetings," where supervisors and all trades were present. If all trades were required to fill out their sheets together at the Pre-start Review, there would have been more opportunity for sharing and reinforcement of hazards recognition.

The LLNL EAO Annual ES&H Assurance Report dated August 25, 2006, found that implementation of this core function had improved over the past three years. In 2004, the DNFSB found that "the identification and analysis of hazards are routinely performed in an informal manner."

The Board concluded that work package documentation did not identify all the hazards.

The Board concluded that inspection protocols for fixed ladders did not ensure compliance with OSHA requirements. Several opportunities to identify hazards were missed through informal or accepted practice behavior. LLNL closed out internal audit findings without fixing the identified problem.

The Board concluded that in the course of planning the work activity with which this accident was associated, LLNL line management repeatedly accepted incomplete and incorrect work documentation without question and did not ensure that all hazard controls were in place prior to authorizing the work to begin.

3.2.3. Develop and Implement Controls

The focus of the first two steps of ISM, defining the work and identifying the hazards, were intended to lead to this step, developing and implementing controls to protect the worker from the hazard. With regard to this project, the work package reviews apparently concluded that the controls contained in the Trade/Service IWSs were sufficient to adequately protect the worker.

As discussed earlier, the Trade/Service IWSs were designed to capture a wide variety of work situations and to identify the hazards and applicable controls for those situations. However, the Board determined that at no time in the progress of planning this project was there any effort made to identify those controls from the IWSs that would be applicable to this particular project, nor to ensure that those controls were tailored to the specific tasks of the worker. By default, this situation left the final decision to the individual worker as to what applied and how to implement it.

During interviews, the Board determined that the Pre-start Review, which was intended to be used for verifying that the controls were in place, was mainly used to discuss only the electrical work activities and controls. Other safety aspects of the project apparently were not discussed, nor were all crafts associated with the work involved in the Pre-start Review.

In lieu of a more structured implementation of hazard identification and controls for specific work, the Board viewed the PTHA as the final "safety net" in capturing hazards and concerns not previously identified.

The PTHA was intended to be completed by the workers, was craft-specific, and did not include all hazards that may be encountered in the performance of work. The PTHA was not checked by WS-2, S-1, FPOC, or the ES&H Teams (either PE ES&H Team 4 or the facility specific team, ES&H Team 1) prior to the performance of work.

The Board reviewed the PTHAs completed by E-1 in the previous 30 days. Those records indicated E-1 had used ladders in the performance of his work and had not previously identified the ladders as hazards. For this specific job, the PTHA contained a cross out not common to the previous 30 days of PTHAs completed by E-1, and the correction (cross out and write-over) was specific to the ladder. However, during his interview with the Board, E-1 indicated that he did not see the PTHA as adding value to his safety.

Management created and documented expectations at the Policy, ES&H Manual, Trade/Service Integrated Work Sheet (IWS) level, and internal PE letters. There appeared to be a breakdown in applying these via the bridging document to the specific work.

Interviews indicated that there was a desensitization or inability to recognize hazards such as hazardous to working alone, low slope roof fall protection, ladder safety. The result was a reduction in safety to the worker. These deficiencies were consistent with deficiencies identified in the 2004 OA Report.

The ES&H Manual required the FM, FPOC, or designee, to verify that required safety barriers or fall-protection equipment was used, as necessary. Based on interviews and photographs of the scene of the accident, there was no indication this was accomplished for this project. Except for the phone call approval of roof access there appeared to be minimal involvement by the building owners in the work activity.

The Board reviewed the safety packet. The Board could not evaluate the information contained in the actual safety packet that was required to be at the work site, that packet was reported as lost. A simulated safety packet provided to the Board included a Safety Packet check off sheet, lift plan, PE form 1, PE Job Area hazards analysis, Budget Sheet, PE ES&H Assessment Document, building contacts, Hazards Control Bridging Document review sheet, and the USQ determination worksheet.

The PE ES&H Assessment Document referenced Trade/Service IWSs 31, 414, 5, 19 as the governing IWSs for this project. Trade/Service IWS 31.05 was the IWS applicable to E-1. It referenced and invoked IWP/SP 12005 for establishing PPE requirements for the lockout/tagout portions of E-1's work, and IWS 12005 also contained a reference link to the ES&H Manual for the rest of the lockout/tagout process. IWS 31.05 essentially listed the hazards but provided no work planning or direction to the RI or worker. The RI and/or the worker must apply the ES&H Manual requirements to work. IWS/SP 12005 was a WAL-C document. The ES&H Manual required the AI for WAL-C documents to perform the Pre-start Review. The available evidence indicated that the AI for IWP/SP 12005 did not perform the Pre-start Review and confirm that hazard controls were implemented.

LLNL Management had inappropriately delegated line management responsibility for safety to the individual worker for WAL-A and WAL-B activities and did not exercise responsibilities for WAL-C activities. The individual worker was by default tasked with identifying the hazard and applying the ES&H Manual controls to the work activity essentially without guidance or assistance.

As noted previously, the Trade/Service IWS did identify the LLNL working alone policy and fall protection as controls that would govern an activity such as E-1 was performing. However, the Board could find no evidence that either of these controls had actually been implemented for this work.

The Board concluded the worker was the highest level LLNL employee to confirm the appropriate hazards were identified and the controls were implemented.

The Board concluded that the LLNL processes for developing hazard controls failed to establish a set of controls adequate or appropriate to address the work being performed. Furthermore, the Board concluded that those controls that had been developed were not effectively implemented or verified before the work commenced.

3.2.4. Perform Work Within Controls

Performing the work within the established controls is clearly a necessary component of working safely. The Board has already noted in previous sections that there were significant deficiencies in the work planning, hazard identification, and implementation of controls. In evaluating the conduct of the work, the Board noted the following observations:

- E-1 did not use the LLNL prescribed "3-points of contact" technique when climbing the ladder;
- A Safety Packet was to be left at the job site to which the workers were supposed to refer for questions concerning the work to be accomplished and any safety requirements. The Board could not confirm that this safety package existed because LLNL could not find it after the accident.
- The LLNL working alone policy was not adhered to. According to the LLNL ES&H Manual, "working alone means performing any activity out of sight or communication for more than a few minutes at a time. For work on exposed, energized electrical equipment, an individual is considered to be working alone if not within sight of someone else." In addition, the IWS that E-1 was working under stated that "Unless specifically approved by supervisor, do not work out of audible or visible range of another employee when performing hazardous work that may result in being unable to self-rescue." By definition, lockout/tagout activities were considered to be work on energized electrical equipment.

  The Board could find no evidence that E-1's working alone had been explicitly recognized or authorized, or that anyone had ensured that "adequate help can be made available," a necessary condition for authorizing working alone. The Board also found that interviewees, including the work supervisor responsible for this project, were not familiar with the working alone policy. The injured worker was found by chance.
- Fall protection was not implemented during this job. As required by OSHA, fall protection or warning lines are required when working within fifteen feet from the edge of the roof. Also, E-1's IWS required the use of fall protection for "work at heights > 6 ft." The Board was not able to determine whether E-1 used any fall protection or restraint techniques while lifting a 31 lb. bag of tools over the edge of the roof. Furthermore, the unit that E-1 was working on was eight feet from the edge of the roof. Three of the four air conditioning units on the roof were closer than fifteen feet from the edge, and one was almost six feet from the edge. The Board could find no evidence that fall protection or fall warning devices had been used for this project. All interviewees questioned stated there was no evidence of any fall protection devices.
- At the time of the accident, E-1 was in the process of locking out and tagging the electrical supplies to the air conditioning units. The Board believed, but could not confirm, that E-1 was following the correct process for that activity.

The Board concluded that work was being performed without the benefit of appropriate hazards controls because of the failure of the hazards identification during the work planning and authorization processes.

3.2.5. Provide Feedback and Continuous Improvement

The final core function of ISM is feedback and continuous improvement. The Contractor is expected to be regularly collecting information and evaluating the work and the implementation of the ISM processes, and continually striving to improve the safety systems of the site. The Board noted that the deficiencies identified in the other core functions and guiding principles appeared to be widespread and systemic. Therefore, the Board evaluated LLNL's feedback and improvement processes to determine if similar deficiencies had been previously identified and addressed.

Discipline Action Plans (DAPs) existed for ES&H personnel, such as Health and Safety Technicians and Safety Engineers. These plans guided the personnel in the common surveillance actions that must be accomplished. A generic DAP was provided to each ES&H Team, and they drew items from this generic DAP when developing a DAP specific to their needs. The generic, unsigned draft DAP for Industrial Safety (dated Jan 17, 2006) listed a requirement for semi-annual inspection of the condition of fixed ladders, but a signed, in-effect version of the DAP was not provided to the Board, so it was unclear whether the DAP in effect at the time of the accident required inspection of fixed ladders. The ES&H Team 4 DAP "2006 Field Implementation Plan for RHWM" did not include the two sections (IS-1 and IS-15) that addressed inspections of fixed and portable ladders.

An all-hands electrical shop meeting was held in the afternoon on the day of the accident. The sequences of the job and the accident were shared with the electrical employees. The meeting was presented by the Maintenance Production Division Leader, the Electrical/Mechanical Shop Superintendent, and an Industrial Safety Engineer from ES&H Team 4. Approximately 25 employees attended, although there are 50 electricians in PE Shop. There is no evidence that the remainder of the electricians were briefed. The LLNL ES&H Manual, Document 40.2, Section 5.2, stated that "when safety meetings are used to convey ES&H information, keep a record of the meeting to confirm the event. The record should include the date, subject, acceptable positive identification (such as signatures or magnetic strip readers) of attendees, and the presenter's name." However, no handouts or written material were used. No written documentation of the topics discussed was created. A briefing attendance sheet was not used.

Three Lessons Learned concerning ladders have been issued by LLNL, with the most recent one issued in 2005. The other Lessons Learned were issued in 2001 and 1997. All three were issued only after a LLNL accident. PE Executive Safety Committee minutes discussed ladder safety in 4/2005, 1/2003, and 10/2001.

The LLNL Assurance Review Office (ARO), (whose name was changed to the LLNL ES&H Assurance Office, EAO, in 2005), published Annual ES&H Assurance Reports on August 31, 2004, January 4, 2006, and August 25, 2006. In the 2004 report, all Directorates reported that they had implemented an effective ES&H program and an effective self-assessment program. ARO found that while continued improvement had occurred in Defining Scope of Work, improvement was needed in Developing and Implementing Hazards Controls and also performing Work within Controls. In the January 2006 report, EAO stated that the Directorates did not show any significant improvement in ISMS/ES&H performance in 2004 compared to recent years.

On August 25, 2006, EAO reported on the status of each of the 12 ISMS Guiding Principles and Core Functions, citing where improvements have been made and where improvement is needed. With regards to the seven guiding principles, EAO noted continuing weaknesses in the areas of line management responsibility for safety; clear roles and responsibilities; and hazard controls tailored to work performed. In addition, EAO noted implementation of operations authorization had degraded over the past three years.

Concerning the five core functions, EAO noted continuing weaknesses in defining the scope of work; developing and implementing hazard controls; and feedback and continuous improvement. Significant degradation over the past three years was noted in the area of performing work within controls. Regarding the area of developing and implementing hazard controls, EAO stated "the avoidance of implementing administrative controls (e.g. procedures) due to the adherence of an expert-based system in the ES&H Manual is the major impediment in improving this core function."

In the area of performing work within controls, EAO stated "the directorate ISM certification at the activity level reports pointed out that AIs and RIs have not always performed their pre-job reviews, two EAO assessments identified the lack of administrative controls between HACs [Hazard Assessment and Control] and IWSs…contributing to some employees not being properly trained prior to starting work, and the expert-based system that results in a culture where individuals do not realize the importance of following procedures."

Specifically for Feedback & Improvement, in 2004, the DNFSB found that "None of the feedback and assessment provisions prescribed effectively evaluated activity-level work planning," and "The process for capturing feedback from work activities does not require input from the workforce." The August 25, 2006, EAO Annual ES&H Assurance Report found that implementation of the Feedback & Improvement core function had not improved over the past three years. No action had been taken on the four recommendations from EAO's 2005 report.

The OA-40 audit in 2004 found that the LLNL self-assessment program lacked sufficient rigor and planning and execution to be fully effective in evaluating ES&H performance. They also found that LLNL deficiency and issues management processes and performance were not fully effective in documenting ES&H program and performance deficiencies and ensuring effective corrective and preventive actions were developed and tracked to completion.

The December 2004 corrective action plan for the OA-40 audit identified a number of corrective actions that appeared to directly impact areas for improvement identified in this accident investigation:

- ❑ Evaluate existing ISM system implementation at the activity level.
- ❑ Identify systemic deficiencies/issues.
- ❑ Effectiveness review of ISM system implementation.
- ❑ Strengthen Accountability [personnel comply with requirements].
- ❑ Clarify and simplify work control system.
- ❑ Implementation of the revised work control system.
- ❑ Strengthen feedback and improvement at work activity level.
- ❑ Effectiveness review of work control system.

Some of these were completed, others had due dates out to January 31, 2008. Eighteen months after the OA-40 audit, this Board's review of this accident indicated that these issues have not been improved.

The Board could not establish whether Extent of Condition assessments were conducted for OSHA compliance issues. The Board found the same and similar OSHA compliance issues on other fixed ladders at LLNL during this investigation (see Table 3.2.5-1), and during previous inspections by LLNL personnel. Since the deficiencies on the ladder involved in this accident were not corrected prior to the accident, it was apparent that individual deficiencies may get corrected when identified but the corrections were not being extended to similar cases around the Laboratory.

A discrepancy was found between the requirements for roof access and the implementation of those requirements. Per the ES&H Manual Document 15.1 Section 3 and the sign posted next to the ladder on T6179, this roof is "general access" only and no permit is required. However, the PE ES&H Assessment Document (version 3.5, dated 1/06) for the job involved in the accident has the block for "roof access permit" checked, although no roof access permit was issued.

The Board concluded that LLNL and DOE had identified weaknesses similar to those that led to this accident in multiple assessments over the past few years, but LLNL had not taken effective steps to correct those weaknesses. The Board also concluded that, based on the preponderance of evidence from both this and other assessments, there was a fundamental programmatic weakness in LLNL's implementation of the ISM expectations for continuous improvement.

Table 3.2.5-1: LLNL Fixed Ladders similar in design to T6179

Building / Trailer Number	Type	Approx. Height (ft.)	Location (Wall)
Trailer 5672	Fixed Ladder	10	North West Corner
Trailer 4675	Fixed Ladder	10	North
Trailer 3724	Fixed Ladder	10	East
Trailer 3725	Fixed Ladder	10	South
Trailer 3726	Fixed Ladder	10	West
Trailer 2580	Fixed Ladder	10	2nd Floor East
Building 365	Fixed Ladder	10	2nd Floor South
Building 165	Fixed Ladder	10	North
Building 131	Fixed Ladder	10	2nd Floor North West
Building 511	Fixed Ladder	10	2nd Floor West
Trailer 2554	Fixed Ladder	20	West
Trailer 6325	Fixed Ladder	20	North East
Building 364	Fixed Ladder	20	2nd Floor North
Building 363	Fixed Ladder	20	West
Building 362	Fixed Ladder	20	West
Building 271	Fixed Ladder	20	North
Building 272	Fixed Ladder	20	North
Building 253	Fixed Ladder	20	East
Building 152	Fixed Ladder	20	South
Building 153	Fixed Ladder	20	South
Building 121	Fixed Ladder	20	North West
Building 511	Fixed Ladder	20	East North
Building 405	Fixed Ladder	20	West
Building 516	Fixed Ladder	20	East
Building 517	Fixed Ladder	20	South

3.3. Human Performance and Organizational Behavior

The Board considered the concepts of Human Performance Improvement (HPI) in the context of this accident. Within the context of HPI, human error is defined as an inadvertent and therefore unavoidable mistake on the part of an individual. In this regard, one may be able to reduce an individual's error rate through training, practice, or other techniques, but ultimately it must be recognized that an error may still occur. Therefore, the HPI approach is to improve the identification of error-likely situations and to establish additional barriers between the individual and the hazard, such that the individual is protected even if the error occurs. Furthermore, HPI also demonstrates that a large fraction of human errors are due to organizational weaknesses that create situations leading to error-prone conditions or behaviors. Also, it is important to acknowledge that HPI and human error considerations apply only to unintentional behavior; purposeful behavior, such as a failure to follow a procedure, policy, or requirement, is considered to be an organizational behavior issue outside the purview of the HPI framework.

In terms of the context of this accident, the Board believed that the direct cause of this accident, the missing of the initial rung by E-1, was truly an inadvertent error. The worker clearly did not intend to fall from the ladder. The primary means of addressing this potential for error would be through the use of the "3-points of contact" technique for ladder climbing, as required by the consensus standard and prescribed in the LLNL ES&H Manual. Since the error was inadvertent and unavoidable, the "3-points of contact" technique does not attempt to eliminate the error, but rather to ensure that, given the occurrence of the error, the individual still is able to maintain adequate contact with the ladder to avoid the consequence, falling from the ladder. In this particular case, since E-1 did not adhere to the prescribed technique, its value as a barrier was circumvented.

On the other hand, the Board was concerned that the rest of the conditions present that led to this accident appeared to be due to organizational behaviors outside of the HPI framework. As the first example, E-1 acknowledged that he had received ladder training, but did not demonstrate an appreciation for the prescribed climbing technique, and did not adhere to it while climbing the ladder. But going beyond that example, the Board identified multiple other issues associated with this event that demonstrated an organizational behavior that was not proactively or aggressively ensuring that work was being conducted safely. Examples of those behaviors (analyzed in other sections) included:

- The Trade/Service IWSs that applied to this work, and all ES&H reviews of this project, failed to identify the climbing of the ladder as a hazard, even though the LLNL ES&H Manual indicated that the task of climbing ladders above six feet needed to be considered as a work hazard requiring an IWS (Section 3.2.2);
- The Board determined that several other requirements and controls that were applicable to this project and contained within the Trade/Service IWS for the worker were not implemented in accordance with the LLNL ES&H Manual expectations (such as the Working Alone and Working at Heights Greater than Six Feet policies) and in general the Trade/Service IWS controls were not effectively implemented for this project (Section 3.3.2.3);
- The Board identified a pervasive confusion within PE staff and managers regarding their safety-related roles, responsibilities, and authorities, and those of their co-workers and superiors; furthermore, this confusion was promulgated by the complex and poorly integrated set of institutional documents that established those roles, responsibilities, and authorities (Sections 3.1.1 and 3.1.2);
- The Board determined that, while the planning of this project was generally consistent with PE directions, the planning documents did not provide a clear understanding of the tasks necessary to accomplish the project, did not adequately communicate the work or work area hazards to the workers, and did not clearly identify

the controls that are to be followed for conducting the work (Sections 3.1.6, 3.2.3, and 3.2.4);

- The Board determined that multiple components of the PE feedback and improvement processes (e.g., self-assessments, compliance inspections, and corrective action processes) were ineffective in either identifying deficiencies or in correcting deficiencies once identified (Section 3.2.5);

- The Board concluded that the Pre-start Review conducted before this project was not consistent with LLNL ES&H Manual expectations, did not verify that identified controls were in place before work commenced, and did not clearly communicate the identified hazards and their controls to the workers involved in the project (Sections 3.1.2, 3.1.4, 3.2.1, and 3.2.4); and

- The Board could not clearly identify any first-line or work supervisor who would acknowledge direct responsibility for the worker's safety during the conduct of the work for this project (Sections 3.1.2, 3.1.7, and 3.2.3).

The Board believed that these examples demonstrated an organizational behavior that was not proactively or aggressively managing the workplace and planning the work to ensure that the worker was properly and adequately protected. The Board concluded that multiple organizational weaknesses existed within the PE organization, and that several of those weaknesses contributed directly or indirectly to this accident. The Board also concluded that the organizational behavior prevalent in the PE organization did not create or support a strong, compliant, safety-conscience environment for its workers.

The Board also evaluated the role of the LLNL ES&H organization in this accident. That role was primarily fulfilled by the ES&H Teams that were assigned to the facility and to PE, and mainly involved the review of the work package before the activity began. That review of the work package actually took place roughly four months before the work commenced, and the work package that was reviewed did not provide a reasonable or accurate description of the activities involved in the work. In that review, no workplace safety issues were documented. Between that review and the commencement of the work, the Board could find no evidence to suggest that the ES&H Teams were involved in this project. The Board concluded that the ES&H Teams were not actively engaged in the planning and execution of this project.

3.4. NNSA and DOE Oversight Processes

ISMS performance measures were passed to LLNL through DOE Contract No. W-7405-ENG-48, Appendix F, *Standards of Performance*. Performance Objective 8 states:

"*Maintain safe, secure, environmentally sound, effective, and efficient operations in support of mission objectives. The measures associated with this objective are:*

8.1 Achieve continuous improvement in Integrated Safety Management System performance:

- *Assure consistent and effective application of ISM principles across all organization levels and across all Laboratory facilities.*

- *Ensure effective implementation of an ES&H corrective action management program, including institutional corrective actions derived from violations enforceable under the Price Anderson Amendments Act.*

Without further delineation, the measures of performance were arbitrary and lacked specific goals for improvement against which to measure (e.g., 10% decrease in injury rates, 20% decrease in Lockout/Tagout events, 10% increase in feedback from workers documented in work packages).

LSO monitored LLNL ISMS performance through the collection of personal observations: (FR and SME field activities) and analysis of the information provided by the FRs and SMEs. One LSO staff person was assigned specifically to assess LLNL's performance.

LSO reviewed work performance of LLNL and the LSO Manager met weekly with the LLNL senior

management. LSO employed a "Stoplight" status sheet to indicate and track the performance of the Contractor. LSO's most recent "Stoplight" showed Feedback and Improvement was assessed as RED.

LSO had not done an oversight audit specifically targeted at ladders. As part of oversight, occasionally a specific ladder was targeted for questioning. LSO facility oversight regularly occurred at the group of facilities associated with RHWM. A variety of surveillances were documented in LSO's operational awareness database.

On August 16, LSO conducted a surveillance to review the circumstances of the accident. LSO noted that work resumed after the accident, and the accident scene was not protected. However, LSO was involved in the resumption of activities. On August 4, LLNL requested to resume the job. On that day, LSO approved the resumption of work; on August 7 they withdrew approval, but on August 10 again supported the resumption of work, due to personnel in T6179 being subjected to hot working conditions. LLNL complied with LSO directions regarding the resumption of work.

The OA-40 audit of 2004 also evaluated the LSO programs, and found that important elements of the LSO line management oversight program were not fully established or effectively implemented (understanding, clear responsibilities and authorities, standard operating procedures, lessons-learned). They also found that LSO operational awareness activities, assessments, Facility Representative (FR) reviews, and issues management processes were not sufficiently rigorous to ensure continuous improvements in LLNL ES&H programs and performance.

Concerning LLNL programmatic areas specifically related to this accident, OA-40 stated "First, within several LLNL directorates, divisions, and departments, LLNL management has not ensured that institutional requirements are adequately implemented at the activity level during work activities and in support of ES&H activities. Second, many work instructions (e.g. procedures) either have not been developed or are inadequate. Third, in those cases where requirements are inadequately defined, they are often not implemented as specified in the work instructions. LLNL does not have adequate directions defining expectations for procedure/work instructions usage (e.g. when and how procedures need to be used, how procedures are approved, and expectations for verbatim compliance). Fourth, processes for identifying and correcting deficiencies in work instructions and implementation of requirements have not been effective. As a result, deficiencies in procedures, worker performance, and attitudes toward procedure compliance have not been adequately identified and corrected."

Specific to PE, OA-40 stated "very little Plant Engineering work at the remainder of the LLNL facilities [outside of the National Ignition Facility construction project] is subject to the detailed planning expected of an effective ISM system. Instead, the system relies heavily on verbal communication, electronic mail, and other memoranda between craft personnel, facility point of contact, ES&H personnel, and customers. Decisions reached during those communications are not always captured within work documents, leaving workers to rely on their individual expertise to be aware of and control hazards. Workers were aware of most of the hazards they could be exposed to, but there were cases where hazards were not adequately identified, controls were not clearly implemented, and laboratory safety polices were not followed."

The Board concluded NNSA and DOE oversight tended to look at more general aspects of ES&H programs, rather than target specific individual items; however, it was clear that DOE and NNSA oversight had previously identified many of the programmatic weaknesses that had contributed to this accident.

3.5. Event and Causal Factors, Barriers and Change 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 were integrated into the events and causal factors chart to support the development of causal factors. Appendix C contains the complete Barrier Analysis of physical and management barriers that the Board

considered, whether they adequately performed as intended, and whether they contributed to the accident.

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 were 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.

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. The Board determined that the following were the causes of this accident:

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 climbing a fixed ladder to the roof of a building.

Root Causes-The Board determined the local root cause of this accident was that the PE Department did not recognize the act of climbing ladders as a hazardous activity.

The Board determined the systemic root cause of this accident was that LLNL senior management did not provide leadership to ensure that the ISM processes were implemented rigorously. The processes implemented by LLNL did not assure the roles and responsibilities for safety and health were understood at all levels of the organization, did not identify the conduct of unsafe work practices, and did not hold management accountable for accepting such practices.

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 B contains the Board's Events and Causal Factors Analysis. Other contributing factors are identified in Appendices C, D, and E.

4. Conclusions and Judgments of Need

The Board conducted evaluations of the scene of the accident, the work being performed at the time of the accident, and the planning for the project. The Board used the framework of DOE's Integrated Safety Management (ISM) concept to guide the lines of inquiry, and considered other DOE and industrial consensus standards, Federal Regulations, and human performance concepts to the extent they were applicable.

The Board concluded that this accident could have been prevented. The direct cause of the accident was a missed step, which probably was the result of inadvertent human error, and may have been precipitated by the physical attributes of the ladder. The Board believed that, had he been using it, LLNL's prescribed climbing technique, "3-points of contact," would have enabled the worker to recover from the initial missed step without falling.

The Board wanted to stress the significance of this seemingly simple accident – a worker slipped and fell from a ladder. The event might appear to be simple and commonplace, and therefore might be considered as an acceptable risk. But the Board believed that there are three points to be considered: (1) the frequency of exposure to the hazard is high, especially for workers assigned to maintenance and construction work; (2) the potential consequences to the individual are known to be serious and potentially fatal, based on industry and DOE experience; and (3) the controls necessary to address the hazard are straightforward and easy to implement. The combination of the first two points demonstrates that the risk from climbing ladders is high; adding the third point regarding the ease of mitigating the risk demonstrates that the risk should not have been acceptable.

The Board determined that the hazards associated with climbing the ladder had not been recognized during the planning for the project. The Board also determined that several other hazards associated with the project had either not been recognized or had not been adequately analyzed. Hazard controls were not explicitly developed, implemented, nor verified for any of the recognized hazards. The worker was completely dependent on generic hazard analyses developed for his general job description. This dependency resulted in a total reliance on the worker to recognize the hazards associated with this specific task, and to implement those controls that he felt were sufficient to address the hazards he perceived to be present. The Board concluded that the local root cause of this accident was that the PE Department did not recognize climbing ladders as a hazardous activity.

The Board determined that the fixed ladder was not compliant with the applicable Federal Regulations and consensus standards in four areas. The first rung was about five inches higher than allowed; the rungs were not designed to be slip-retardant; in some areas the building intruded into the minimum allowed clearance behind the ladder; and the hand rails in the "walkthrough" section at the top of the ladder did not provide adequate grasping surfaces. The Board concluded that two of the deficiencies were likely contributing causes to this accident, the first rung distance and the slippery rungs; and that the other two deficiencies could lead to a similar accident.

Once the Board determined that the chain of events between the initial missed step and the fall could have been broken by using the prescribed climbing technique, the Board then tried to understand why the prescribed technique was not followed. To develop this understanding, the Board evaluated the training provided to the worker, the planning and safety reviews of the work to be performed, and the implementation of ISM within LLNL and the PE Department in particular.

The Board concluded that, while the worker's training did address the proper climbing technique, the training did not instill in the worker an adequate understanding of the importance of the technique for his personal safety, nor did it ensure that the worker was proficient in the use of the technique.

The Board concluded that the work planning process used for the air conditioning unit replacement project did not effectively implement any of the core functions of ISM. Specifically, the Board concluded that:

- The tasks involved in accomplishing the project were not adequately defined or

scoped to facilitate an effective safety review;

- The hazards associated with the work were not properly identified or analyzed;
- Controls for the hazards that were identified were not explicitly developed nor implemented for this work, which placed total reliance on a set of generic controls that the individual worker had to select from based on his personal perspective of the hazards associated with the work;
- Multiple chances to ensure that the work was being conducted within the established controls failed; and
- There was no indication that feedback or lessons learned from previous assessments or work experiences had been incorporated into the current project.

When the Board evaluated LLNL's implementation of the seven guiding principles of ISM, the Board concluded that the LLNL institutional requirements and guidance were overly complex and confusing, thus creating a process that could not be implemented in a reasonable and effective manner. Specifically, the Board concluded that line management roles, responsibilities, and authorities were not clearly defined and communicated to the organization; the individuals responsible for authorizing the work were not adequately trained to accomplish those responsibilities and were uncertain about what their authorizing signature meant; line management priorities were not balanced between accomplishing the work and adhering to the safety requirements; standards were not adequately implemented; and hazards controls were not tailored to the specific work, implemented, or verified before the work was authorized to commence. In fact, the Board could find no LLNL supervisor or work authorizer who would acknowledge full responsibility for the safety of the workers involved in this project.

The Board concluded that the systemic root cause of this accident was that LLNL senior management did not provide leadership to ensure that the ISM processes were implemented rigorously. The processes implemented by LLNL did not assure that the roles and responsibilities for safety and health were understood at all levels of the organization, did not identify the conduct of unsafe practices, and did not hold management accountable for accepting such practices. As a consequence, an unstructured approach to work developed within the LLNL organizations involved in this accident that did not ensure that safety and health requirements were translated into effective work controls. This unstructured approach was facilitated by an overly burdensome, complex, and confusing institutional work control process that created the perception of safety without ensuring the reality of a safe workplace; the approach was accepted by an organization whose self-confidence and familiarity with the work had developed into complacency; and the approach was allowed to continue by several levels of management that failed to proactively and aggressively recognize and correct the warning signs that had been previously identified in both internal and external assessments.

This Board's responsibility was to identify judgments of need that, if effectively addressed, could lead to the avoidance of this or a similar accident in the future. In this regard, recognizing the act of climbing ladders as a hazardous activity and developing and implementing controls for future elevated work would be an obvious answer. However, the Board concluded that the institutional failure to establish an ISM process that facilitated the recognition and control of reasonably foreseeable hazards, such as the one involved in this accident, represented an organizational weakness that created a much broader range of potential "similar accidents." Therefore, the Board recommended that NNSA and LLNL need to proactively evaluate the extent of the condition created by these organizational weaknesses throughout the entire LLNL institution and aggressively correct any issues identified.

The Board established 14 judgments of need that it believed that LLNL and LSO should address in response to this accident. The Board believed that this number was necessary in order to ensure adequate focus on each of the widespread fundamental weaknesses the Board identified during this investigation.

Judgments of Need

	Judgment of Need	Supporting Discussion
JON 1	The Plant Engineering Department needs to ensure that the implementation of established hazard controls are verified by competent management personnel within a reasonably short period of time before the start of the work. This is particularly important in the case of Trade/Service IWSs which pre-authorize craft work to be performed without any job-specific tailoring of the controls, thereby placing a heavy reliance on individual workers to recognize a broad range of hazards and implement appropriate controls beyond their technical expertise.	The Board concluded that the work control process did not result in current and accurate work control documents at the work site. The Board concluded that the work control process failed to establish hazards controls that were tailored to the work being performed. The Board concluded that the work authorization process did not ensure that all hazards were identified or that all controls were put in place before the work commenced on the project. The Board concluded the worker was the highest level LLNL employee to confirm the appropriate hazards were identified and the controls were implemented. The individual worker was by default tasked with identifying the hazard and applying the ES&H Manual controls to the work activity essentially without guidance or assistance. The Board could not clearly identify any first-line or work supervisor who would acknowledge direct responsibility for the worker's safety during the conduct of the work for this project.
JON 2	The Plant Engineering Department needs to clarify the overlap of the roles, responsibilities, and authorities that exists between shop and work supervisors when workers are matrixed to specific projects. Furthermore, Plant Engineering needs to ensure that all supervisors and workers clearly understand their safety roles, responsibilities, and authorities and are held accountable for them.	The Board concluded that although the LLNL process captured the principle of line management responsibility for safety, its implementation within PE was confusing and ineffective. The Board concluded that Roles, Responsibilities and Authorities were not effectively integrated into the work control process and implemented in a manner that individuals were aware of their responsibilities. The Board concluded that the procedures delineating roles and responsibilities were complex, making it difficult for personnel to determine their responsibilities and the relationship of others' responsibilities to achieving the task.

	Judgment of Need	Supporting Discussion
		The Board concluded that work supervisors and others responsible for authorizing work were not adequately trained to accomplish those responsibilities. The Board concluded the worker was the highest level LLNL employee to confirm the appropriate hazards were identified and the controls were implemented. The Board could not clearly identify any first-line or work supervisor who would acknowledge direct responsibility for the worker's safety during the conduct of the work for this project.
JON 3	The Plant Engineering and Hazards Control Departments need to jointly ensure that the ES&H Teams are actively engaged in the work planning and safety review processes, and that the ES&H Teams are directly involved in the verification of the controls and overseeing the conduct of the work performed by Plant Engineering personnel.	The Board concluded that LLNL management accepted less than complete and accurate work planning. The work planning and execution was not conducted in accordance with the requirements of the ES&H Manual. The Board concluded that the work control process failed to establish hazards controls that were tailored to the work being performed. The Board concluded the worker was the highest level LLNL employee to confirm the appropriate hazards were identified and the controls were implemented. The individual worker was by default tasked with identifying the hazard and applying the ES&H Manual controls to the work activity essentially without guidance or assistance. The Board concluded that work was being performed without the benefit of appropriate hazards controls because of the failure of the hazards identification during the work planning and authorization processes. The Board concluded that the ES&H Teams were not actively engaged in the planning and execution of this project.

	Judgment of Need	Supporting Discussion
JON 4	The Plant Engineering Department needs to ensure that work packages are sufficiently detailed to define the main steps necessary to accomplish the project, so that a more robust hazard analysis can be conducted and reviewed. Furthermore, the Plant Engineering Department needs to ensure that work packages receive a level of review, work authorization, and Pre-start Review consistent with the work authorization level of the IWSs (including Trade/Service IWSs) embedded in the package or incorporated by reference.	The Board could not identify a clear planning element to the work package process. The Board could not clearly establish through interviews and institutional documentation whether the work planning documents presented a complete picture of the scope of work. Therefore, the Board concluded that the scope of work had not been clearly defined for this project. The Board also concluded that this issue had previously been identified in other internal and external assessments of LLNL. The Board concluded that in the course of planning the work activity with which this accident was associated, LLNL line management repeatedly accepted incomplete and incorrect work documentation without question and did not ensure that all hazard controls were in place prior to authorizing the work to begin. The Board determined the local root cause of this accident was that PE Department did not recognize the act of climbing ladders as a hazardous activity.
JON 5	The Plant Engineering Department needs to re-evaluate the Trade/Service IWS process to ensure that the process adequately identifies hazards and the associated controls specific to the job being performed, and that there are appropriate mechanisms in place to ensure that controls established through this process are effectively implemented and verified by competent management personnel when work is ready to begin. The Plant Engineering Department also needs to conduct a review of other current and recent work packages to determine the extent of condition of these concerns; take appropriate actions to correct identified deficiencies; and periodically review future work packages to monitor the effectiveness of the corrective actions.	The Board could not determine which IWS the worker was supposed to be using. The Board concluded that the Trade/Service IWSs were not adequate work planning documents, at least as they were used in the current LLNL work process. The Board concluded that the work control process failed to establish hazards controls that were tailored to the work being performed. The Board concluded the worker was the highest level LLNL employee to confirm the appropriate hazards were identified and the controls were implemented. The individual worker was by default tasked with identifying the hazard and applying the ES&H Manual controls to the work activity essentially without guidance or assistance.

	Judgment of Need	Supporting Discussion
		The Board determined the local root cause of this accident was that PE Department did not recognize the act of climbing ladders as a hazardous activity.
JON 6	The Plant Engineering Department needs to ensure that proficiency is tested during training when a particular physical technique, such as the "3-points of contact" technique, is relied on to ensure the safety of the worker. In addition, LLNL needs to consider similar situations across the Laboratory.	The Board concluded that E-1 was not using the prescribed climbing technique at the time of the fall. The Board concluded, based upon the best available evidence, that the direct cause was a loss of footing (slip) while the employee was climbing a fixed ladder to the roof of a building.
JON 7	The Hazards Control Department needs to ensure that ES&H Team reviews of work packages are comprehensive and robust. Acceptance criteria need to be considered for the minimum level of quality and detail in a work package to be reviewed, and for the minimum level of formality and rigor to be applied to the review by the ES&H Teams.	The Board could not identify a clear planning element to the work package process. The Board concluded that LLNL management accepted less than complete and accurate work planning. The work planning and execution was not conducted in accordance with the requirements of the ES&H Manual. The Board concluded that in the course of planning the work activity with which this accident was associated, LLNL line management repeatedly accepted incomplete and incorrect work documentation without question and did not ensure that all hazard controls were in place prior to authorizing the work to begin. The Board concluded that the LLNL processes for developing hazard controls failed to establish a set of controls adequate or appropriate to address the work being performed. Furthermore, the Board concluded that those controls that had been developed were not effectively implemented or verified before the work commenced.

	Judgment of Need	Supporting Discussion
JON 8	The Hazards Control Department needs to conduct a formal assessment of fixed ladders at LLNL facilities to determine the extent of conditions of the non-conformance with applicable Federal Regulations and industrial standards. Significant deficiencies identified during this assessment need to be corrected. Furthermore, the Hazards Control Department needs to ensure that periodic inspections of fixed ladders are formally conducted and documented in accordance with applicable Federal Regulations and consensus standards.	Furthermore, the Board concluded that the ladder was not compliant with OSHA requirements and consensus standards recommendations, and that two of those non-compliant conditions likely contributed to E-1's fall. The Board concluded that LLNL's implementation of the OSHA fixed ladder and fall protection requirements and standards were ineffective and not consistent with those requirements. The Board concluded that inspection protocols for fixed ladders did not ensure compliance with OSHA requirements. Several opportunities to identify hazards were missed through informal or accepted practice behavior. LLNL closed out internal audit findings without fixing the identified problem.
JON 9	The Hazards Control Department needs to ensure that roles, responsibilities, and authorities of the ES&H Teams are clarified; that they are adequately communicated to the ES&H Teams; and that the Team Members are held accountable for these roles, responsibilities, and authorities.	The Board concluded that Roles, Responsibilities and Authorities were not effectively integrated into the work control process and implemented in a manner that individuals were aware of their responsibilities. The Board concluded that the procedures delineating roles and responsibilities were complex, making it difficult for personnel to determine their responsibilities and the relationship of others' responsibilities to achieving the task. The Board concluded that the ES&H Teams were not actively engaged in the planning and execution of this project.
JON 10	LLNL needs to clarify and fully implement the roles, responsibilities, and authorities for facility managers and designated facility points of contacts with regards to the authorization of work to be conducted within their facility, as described in LLNL Policy and Procedures. LLNL needs to review these requirements for integration with other internal work processes that extend across directorates.	The Board concluded that Roles, Responsibilities and Authorities were not effectively integrated into the work control process and implemented in a manner that individuals were aware of their responsibilities. The Board concluded that the procedures delineating roles and responsibilities were complex, making it difficult for personnel to determine their responsibilities and the relationship of others' responsibilities to achieving the task.

	Judgment of Need	Supporting Discussion
		The Board concluded that work supervisors and others responsible for authorizing work were not adequately trained to accomplish those responsibilities. The Board concluded that the work authorization process did not ensure that all hazards were identified or that all controls were put in place before the work commenced on the project.
JON 11	LLNL needs to modify the Integrated Work Sheet process in order to: ❑ improve the identification of task-specific hazards and the associated controls; ❑ ensure that controls are tailored to the specific work activities; ❑ enhance the methods for ensuring that controls are verified to be in place and that work is conducted within those controls; ❑ identify the appropriate pre-requisites and hold-points before work can begin; and ❑ most importantly, simplify and clarify the communication of those hazards and controls to the workers.	The Board concluded that the Trade/Service IWSs were not adequate work planning documents, at least as they were used in the current LLNL work process. The Board concluded the worker was the highest level LLNL employee to confirm the appropriate hazards were identified and the controls were implemented. The Board concluded that the LLNL processes for developing hazard controls failed to establish a set of controls adequate or appropriate to address the work being performed. Furthermore, the Board concluded that those controls that had been developed were not effectively implemented or verified before the work commenced. The Board concluded that LLNL and DOE had identified weaknesses similar to those that led to this accident in multiple assessments over the past few years, but LLNL had not taken effective steps to correct those weaknesses. The Board also concluded that, based on the preponderance of evidence from both this and other assessments, there was a fundamental programmatic weakness in LLNL's implementation of the ISM expectations for continuous improvement.

	Judgment of Need	Supporting Discussion
JON 12	LLNL needs to develop and implement processes for identifying and correcting complacency, policy non-adherences, and "accepted" unsafe work behaviors in the LLNL workforce and management. LLNL needs to encourage an attitude within the workforce that always questions the adequacy of the established controls and seeks continuous improvement in the safety of the work being performed.	The Board concluded that PE and Facility management had accepted this non conservative balance of priorities contrary to LLNL policy. The Board concluded that in the course of planning the work activity with which this accident was associated, LLNL line management repeatedly accepted incomplete and incorrect work documentation without question and did not ensure that all hazard controls were in place prior to authorizing the work to begin. The Board concluded that work was being performed without the benefit of appropriate hazards controls because of the failure of the hazards identification during the work planning and authorization processes. The Board could not clearly identify any first-line or work supervisor who would acknowledge direct responsibility for the worker's safety during the conduct of the work for this project. The Board concluded that multiple organizational weaknesses existed within the PE organization, and that several of those weaknesses contributed directly or indirectly to this accident. The Board also concluded that the organizational behavior prevalent in the PE organization did not create or support a strong, compliant, safety-conscience environment for its workers. The Board determined the systemic root cause of this accident was that LLNL senior management did not provide leadership to ensure that the ISM processes were implemented rigorously.
JON 13	LLNL needs to ensure that feedback and improvement and corrective action processes are robust and aggressively implemented and overseen so that previously and newly identified issues and deficiencies are effectively corrected in a timely manner, and that the corrections are validated as complete.	The Board concluded that inspection protocols for fixed ladders did not ensure compliance with OSHA requirements. Several opportunities to identify hazards were missed through informal or accepted practice behavior. LLNL closed out internal audit findings without fixing the identified problem.

	Judgment of Need	Supporting Discussion
		The Board concluded that LLNL and DOE had identified weaknesses similar to those that led to this accident in multiple assessments over the past few years, but LLNL had not taken effective steps to correct those weaknesses. The Board also concluded that, based on the preponderance of evidence from both this and other assessments, there was a fundamental programmatic weakness in LLNL's implementation of the ISM expectations for continuous improvement. The Board concluded NNSA and DOE oversight tended to look at more general aspects of ES&H programs, rather than target specific individual items; however, it was clear that DOE and NNSA oversight had previously identified many of the programmatic weaknesses that had contributed to this accident.
JON 14	LLNL and LSO need to evaluate the extent of the organizational weaknesses related to clear roles and responsibilities for safety, management's acceptance of unstructured (incomplete) work and lack of accountability for safety across all laboratory organizations. LLNL and LSO must take actions to lessen the complexity of the LLNL safety management program and demonstrate improvement of hazard recognition and control prior to authorizing work.	The Board concluded that the systemic root cause of this accident was that LLNL senior management did not provide leadership to ensure that the ISM processes were implemented rigorously. The processes implemented by LLNL did not assure that the roles and responsibilities for safety and health were understood at all levels of the organization, did not identify the conduct of unsafe practices, and did not hold management accountable for accepting such practices. The Board could not clearly identify any first-line or work supervisor who would acknowledge direct responsibility for the worker's safety during the conduct of the work for this project. The Board concluded that LLNL and DOE had identified weaknesses similar to those that led to this accident in multiple assessments over the past few years, but LLNL had not taken effective steps to correct those weaknesses. The Board also concluded that, based on the preponderance of evidence from both this and other assessments, there was a fundamental programmatic weakness in LLNL's implementation of the ISM expectations for continuous improvement.

5. Board Signatures

Douglas M. Minnema, Ph.D., CHP, Chairperson
DOE Accident Investigation Board
National Nuclear Security Administration
Office of the NNSA Senior Advisor for ES&H

Date: 10/20/06

Dean W. Decker, CIH, Member
DOE Accident Investigation Board
National Nuclear Security Administration
Los Alamos Site Office

Date: 10/20/06

Jeff Irwin, PE, WSO/CGSO, Member
DOE Accident Investigation Board
National Nuclear Security Administration
Sandia Site Office

Date: 10/20/06

William C. McQuiston, Member
DOE Accident Investigation Board
Idaho Operations Office

Date: 10/20/06

6. Board Members, Advisors, and Staff

Board Chair	Douglas M. Minnema, Ph.D., CHP National Nuclear Security Administration Office of the NNSA Senior Advisor for ES&H
Member	Dean W. Decker, CIH National Nuclear Security Administration Los Alamos Site Office
Member	Jeff Irwin, PE, WSO/CGSO National Nuclear Security Administration Sandia Site Office
Member/Trained Investigator	William C. McQuiston Idaho Operations Office
Member-in-Training	Quanq Tran Future Leaders Program Intern Livermore Site Office
Legal Advisor	Janis Parenti Livermore Site Office
Medical Advisor	James Seward, MD Lawrence Livermore National Laboratory
Laboratory Advisor	Jeff Williams Lawrence Livermore National Laboratory
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Appendix A: Board Letter of Appointment

National Nuclear Security Administration

Department of Energy
National Nuclear Security Administration
Livermore Site Office
PO Box 808, L-293
7000 East Avenue
Livermore, California 94551-0808

File Code 2353
LSOAMTS:060103

AUG 17 2006

MEMORANDUM FOR DOUGLAS MINNEMA
OFFICE OF THE SENIOR ADVISOR
FOR ENVIRONMENTAL, SAFETY AND HEALTH

FROM: CAMILLE YUAN-SOO HOO
MANAGER

SUBJECT: Type B Accident Investigation

You are hereby appointed Chairperson of the Investigation Board to investigate the subject incident that occurred on July 31, 2006. You are to perform a Type B investigation and to prepare an investigation report. The report shall conform to requirements detailed in Department of Energy (DOE) Order 225.1A, *Accident Investigations*, and DOE G 225.1A-1, *Implementation Guide for Use with DOE 225.1A, Accident Investigations*. The Board will be comprised of the following members:

Jeffrey Irwin, Sandia Site Office (SSO);
William McQuiston, Idaho Operations Office (IOO);
Dean Decker, Los Alamos Site Office (LASO); and
Quang Tran, Livermore Site Office (LSO).

Janis Parenti, LSO, will serve as the legal advisor for the Board; Jim Seward, Lawrence Livermore National Laboratory (LLNL), will serve as the medical advisor for the Board; and Jeff Williams, LLNL, will be an observer during the investigation. The scope of the Board's investigation is to include, but is not limited to, identifying all relevant facts; analyzing the facts to determine the direct, contributing, and root causes of the incident; developing conclusions; and determining judgments of need that, when implemented, should prevent the recurrence of the incident. The Board will focus on and specifically address the role of DOE and contractor organizations and Integrated Safety Management Systems, including oversight of subcontractors, as they may have contributed to the overall accident. The scope will also include an analysis of the application of lessons learned from similar accidents within the Department.

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

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

The draft investigation report should be provided to me by September 22, 2006. Any delay in this date shall be justified and forwarded to LSO. Discussions of the investigation and copies of the draft report will be controlled until LSO authorizes release of the final report.

If you have any questions, please contact Robert Kong, at (925) 423-6790.

cc:
L. Brooks, FORS/NA-1
T. D'Agostino, FORS/NA-10
F. Russo, FORS/NA-1
G. Miller, LLNL, L-001
W. Bookless, LLNL, L-668
J. Williams, LLNL/L-477
J. Seward, LLNL/L-723

LSOAMTS:060103:DNakahara:ale:081506

Appendix B: Events and Causal Factors Table and Analysis

Event	Conditions	Causal Factors
	Note, these barriers and changes were identified as pervasive throughout the accident analysis:	B6 – Improperly performed ladder inspection provided a lost opportunity to identify potential contributors to this accident. B7 – The absence of ladder cage allowed the accident to occur. B14 – Not stretching may have resulted in less dexterity of E-1, contributing to the accident. C15 – Failure of line management to assure RRAs were clear, understood and acted upon, lead to the acceptance of less than accurate and incomplete work planning documentation, proper hazard identification and control of the hazards and unsafe execution of this work activity.
8-30-85 – Trailer T6179 was placed in operational status. Note: Between 1987 and 1991 there were multiple modifications and additions to the building.		B5 – E-1 had to climb the ladder to access the rooftop job site.
c.1992 – The fixed ladder was installed on east side of southeast corner (exact date could not be determined, best estimate based on annual aerial photographs of site).	Ladder was manufactured on site. Ladder was not compliant with OSHA requirements: ❑ 17.5" height of bottom rung ❑ < 7 inches clearance behind upper rungs ❑ Angle iron arrangement and circumference of upper grab rail section >9". CAL OSHA iterates the requirements stated in OSHA.	B4 – As constructed, the rungs did not provide traction. Non-uniform rung spacing may have resulted in E-1's inability to judge the distance between the rungs and lead to improper foot placement. The reduced clearance could have influenced how E-1 placed his feet.
8-6-97 – Lessons Learned issued – *Use Ladders Safely.*	Followed non-Livermore worker, portable ladder incident.	
10-9-01 – Lessons Learned issued - *Portable Ladders Can Collapse if Overloaded.*	Followed a Livermore worker portable ladder incident.	
1-13-04 – E-1 took ladder training module.		

Event	Conditions	Causal Factors
3-10-04 – Subcontractor injured in ladder fall accident (Occurrence Report NA—LSO-LLNL-LLNL-2004-0007).	Second-tier subcontractor ladder accident. Serious injury requiring surgery.	
3-7-05 – Lessons Learned issued – *Ladder Safety.*	Followed multiple ladder accidents across the DOE complex, including LLNL subcontractor fall (one year earlier).	
4-4-05 – LLNL issued formal self-assessment of T6179.	This building self-assessment did not explicitly discuss inspection of ladder (not clear if done).	C19 – Existing ladder deficiencies may have contributed to E-1 slipping from the ladder and falling.
7-6-05 – IWS 31.05 Rev 3 General Electrical Work published.	"Roof access" and "working at heights" are listed as hazards, but not "climbing ladders." Ladder safety is not listed among required training.	C18 – Climbing a ladder >6' was not recognized as a hazard in the work planning process and therefore not controlled. E-1 fell.
7-6-05 – IWS 19.04 *Installation, Maintenance and Repair on HVAC Systems* is published.	"Roof access" and "working at heights" are listed as hazards, but not "climbing ladders." Ladder safety is not listed among required training.	B-12 – The hazard of climbing a ladder >6' was not identified and no control s were established. Absent the controls, the accident occurred. The hazard of potential falls when working within six feet of the roof edge was not identified and no controls established. No effect on this accident.
12-2005 – LLNL implements staffing cut backs.	Electrical shop staffing reduced.	C16 – The field electricians do not use two-man teams, common to some other trades due to staffing cuts.
3-2006 – LLNL begins ES&H Team 1/ES&H Team 4 transition.	Team management changes. Most SMEs remain in the same positions.	C13 – Differences in the ES&H management teams may introduce differences of understanding of work activities, identification of hazards and hazards controls. Additionally, there is a potential for incomplete turnover of information.

Event	Conditions	Causal Factors
3-1-06 – Plant Engineering Form 1 completed to "Remove ACHPS01 thru 03 and replace with new units."	Work Requested: "Construction" was checked. Requested start date 6-12-06. Requested completion date 7-14-06. The FPOC in block I is not the same FPOC on the distribution.	B12 – The hazard of climbing a ladder > 6' was not identified and no controls were established. Absent the controls, the accident occurred. The hazard of potential falls when working within six feet of the roof edge was not identified and no controls established. No effect on this accident. C6 – The change in the start of the workday had several effects: E-1 did not complete his stretching exercises, he had no contact with S-1 prior to starting work, he had no contact with WS-2 prior to starting work, and he worked alone.
3-2-06 – Plant Engineering – Job Area Hazard Analysis form completed.	Block 1, step 1, Fall (slip/trip) or Temperature Extremes hazards were not selected. The roof was accessed by fixed ladder; the work day start time was altered to accommodate "heat of the day" on roof surfaces. The form does not include pre-identified common hazards of "ladders" or "working at heights >6 ft." No method is provided to add other identified hazards.	B8 – A safer method of rooftop access (e.g., a scaffold or man-lift) was not used. The accident occurred. B9 – A second worker could have assisted in retrieving the additional instruments needed to continue the job tasks and avoided repetitive climbing. Absence of a second worker was a lost opportunity for peer feedback and correction of error likely situations (climbing technique). A second worker would have assured prompt response in the event of an accident. Actual response was by happenstance. B12 – The hazard of climbing a ladder > 6' was not identified and no controls were established. Absent the controls, the accident occurred. The hazard of potential falls when working within six feet of the roof edge was not identified and no controls established – no effect on this accident. C10 – Working at new job location and with new tools placed a higher reliance on individual's knowledge skills and experience.
3-13-06 – Field Memo issued to add air conditioner unit 6179ACS01 to the work package.		

Event	Conditions	Causal Factors
4-10-06 – Hazards Control Bridging Document Review (HC Record No. 06-140) approved by ES&H Team Leader.	Routing included fire protection, industrial safety, environmental, industrial hygiene and health physics. Construction safety was not included. OSHA considers such maintenance activities "construction" activities. No reviewing SME initialed or dated the form. The attached comments from environmental are "accepted" by [unreadable signature] on 4-12-06, two days after the review was approved by the ES&H Team leader.	B8 – A safer method of rooftop access (e.g., a scaffold or man-lift) was not used. The accident occurred. B9 – A second worker could have assisted in retrieving the additional instruments needed to continue the job tasks and avoided repetitive climbing. Absence of a second worker was a lost opportunity for peer feedback and correction of error likely situations (climbing technique). A second worker would have assured prompt response in the event of an accident. Actual response was by happenstance. B12 – The hazard of climbing a ladder > 6' was not identified and no controls were established. Absent the controls, the accident occurred. The hazard of potential falls when working within six feet of the roof edge was not identified and no controls established. No effect on this accident. C14 – Increasing the level of involvement of ES&H Team would have provided an opportunity to identify and correct non-compliant conditions and error likely situations.
4-11-06 – Lift plan (JO#29007-1-6179) was completed for air conditioner lifts.	The USQ identified this lift as a "Critical Lift." The lift plan did not identify this as a Critical Lift. [ref: DOE-STD-1090-2004]. Lift plan showed four lifts to be completed "off the roof." Lifts onto roof were "reverse of the removal". Fourth lift does not indicate the load radius. Lift plan shows a "boxed X" on the adjacent building (T6197 vs. T6179) without explanation. The plan did not assess hazards to building occupants during lifting activities. "Critical Lift" permit is not identified on the Plant Engineering ES&H Assessment Document.	

Event	Conditions	Causal Factors
4-12-06 (ES&H Rep concurrence), 3-20-2006 (PE concurrence) – Plant Engineering ES&H Assessment Document form was completed.	First block Item #2 is checked, indicating "unique Facility hazards." There is no further discussion or identification of those hazards. Second block; Permits, Roof Access is checked. No permit is included with the work documents. "Critical Lift" is not identified and one is completed. Second block, Procedures, Lock Out & Tag is checked. Building is posted for General Roof Access – No permit required, only verbal authorization from FPOC is necessary.	
5-12-06 (approved date) – USQ #612-06-049-D was processed to address critical lift in the "Facility 612" area.	USQ described the replacement of the "existing four A/C units" on Trailer 6179.	
5-22-06 – Work Package #219007 transferred to WS-2.	Previous Job Manager (WS-1) was reassigned to other duties.	C1 – The Job Managers had different understandings of the work and job expectations. Changing personnel in charge of the work created a potential for incomplete turnover.
7-27-2006 – Pre-Start Review conducted at T6179. Review was attended by WS-2, E-1, AHJ, and FPOC.	Not all crafts at review. Attendees use non-compliant ladder to access roof. Distance to roof edge not identified as a fall hazard. E-1 not included in discussion of safety requirements.	B13 – The hazard controls associated with climbing a ladder >6' were not established. Absent the controls, the accident occurred. The hazard of potential falls when working within six feet of the roof edge was not identified and no controls established. No effect on this accident. C12 – Job hazards were not identified and the hazards were not controlled. Lacking the assurance that the hazard controls were in place, the job was not properly authorized to start by line management in accordance with LLNL procedures. C20 – Failure to identify the fall hazards during the work planning placed workers at increased risk to injury from a fall.

Event	Conditions	Causal Factors
7-28-06 – E-1 requested of Shop supervisor to come in early the next Monday.	Request was based upon continuing hot weather and working on roof top. E-1 wanted to complete work while weather was still cool. Shop supervisor agreed to request.	C6 – The change in the start of the workday had several effects: E-1 did not complete his stretching exercises, he had no contact with S-1 prior to starting work, he had no contact with WS-2 prior to starting work, and he worked alone. B17 - Lost opportunity for the supervisor to evaluate E-1's physical/mental fitness for duty.
7-31-06 0600 – E-1 arrived at work.	Work was requested to start by 6-12-06 and be completed by 7-14-06 (Plant Engineering Form 1). E-1 skipped morning stretching exercises. E-1 does not meet with S-1.	B18 – Failing to meet in the morning as usual, represented a lost opportunity for the supervisor to assess E-1's physical and mental fitness for duty. C6 – The change in the start of the workday had several effects: E-1 did not complete his stretching exercises, he had no contact with S-1 prior to starting work, he had no contact with WS-2 prior to starting work, and he worked alone. C7 – E-1 may have experienced a loss of dexterity that caused him to misplace his foot on the ladder. C11 – The change in the start of the workday had several effects: E-1 did not complete his stretching exercises, he had no contact with S-1 prior to starting work, he had no contact with WS-2 prior to starting work, and he worked alone. Not meeting with S-1 provided a lost opportunity to be reminded of precautions and for S-1 to assess E1's physical and mental fitness for duty.
7-31-06 ~0630 – E-1 called FPOC and obtains oral approval to access the roof. He also confirmed with FPOC that building would be open when he arrived.	Plant Engineering ES&H Assessment Document (a.k.a. Bridging document) required "Roof Access Permit" for this activity. The roof was designated "General Access." ES&H Manual does not require documented approval to access General Access roofs.	C2 – Immediate assistance was not assured in the event of an accident. C3 – R-1's response to E-1's fall was timely and by chance rather than in accordance with the expectations of the work alone policy.
7-31-06 ~0630 – E-1 went to T6179 worksite.	Four workers were in building T6179.	

Event	Conditions	Causal Factors
7-31-06 ~0630 – E-1 completed "Pre-Task Hazards Analysis Worksheet."	"Slips, trips and falls" was crossed out and "be careful climbing ladder" written in. Ladder hazard was not otherwise identified.	C21 – A single worker has a higher potential to miss some or not recognize all hazards associated with the overall accomplishment of the work activities; in this case working at heights, and close to roof edges.
7-31-06 ~0630 – E-1 applies two locks to power panel.	Locks number 3000 and 3004 were recorded on the Lock Out Log. Locks 30002 and 30003 were the found in E-1's tool bag. The Board talked with all (four) known occupants of the building and could find no one who had talked with E-1 before the accident.	B13 – The hazard controls associated with climbing a ladder > 6' were not established. Absent the controls, the accident occurred. The hazard of potential falls when working within six feet of the roof edge was not identified and no controls established. No effect on this accident. C2 – Immediate assistance was not assured in the event of an accident. C3 – R-1's response to E-1's fall was timely and by chance rather than in accordance with the expectations of the work alone policy.
7-31-06 ~0630 – E-1 climbed ladder to roof worksite.		B13 – The hazard controls associated with climbing a ladder > 6' were not established. Absent the controls, the accident occurred. The hazard of potential falls when working within six feet of the roof edge was not identified and no controls established. No effect on this accident. C9 – Taking the circuit tracer to the roof on the first trip up the ladder (hauling up with tool bag) would have reduced E-1's need to make repeated climbs of the ladder. C18 – Climbing a ladder higher than six feet was not recognized as a hazard in the work planning process and therefore not controlled. E-1 fell. C20 – Failure to identify the fall hazards during the work planning placed workers at increased risk to injury from a fall.
7-31-06 ~0640 – E-1 pulls up tool bag using rope.	The tool bag weighed 31 lbs. The rope was 5/16 inch polypropylene single twist rope.	B13 –The hazard of potential falls when working within six feet of the roof edge was not identified and no controls established.

Event	Conditions	Causal Factors
7-31-06 ~0640 – E-1 identified additional junction box that needed to be traced back to circuit breaker.	Working under IWS 12005, E-1 is working on energized equipment (WAL-C). E-1 identified an additional convenience outlet box not previously traced and needed additional tools to check it out (voltmeter, circuit tracer).	B11 – The use of proper footwear did not prevent the accident. Failure to wear a hard hat did not contribute to the accident. B13 – The hazard controls associated with climbing a ladder > 6' were not established. Absent the controls, the accident occurred. The hazard of potential falls when working within six feet of the roof edge was not identified and no controls established. No effect on this accident.
7-31-06 ~0640 – E-1 descended ladder to retrieve voltmeter and circuit tracer.	Circuit tracer and voltmeter were in E-1's truck.	
7-31-06~640 – E-1 obtained voltmeter and circuit tracer and placed them in his back pockets.	E-1 left the instrument case near base of ladder.	
7-31-06 ~0645 – E-1 climbed ladder for a second time.	E-1 bumped his foot on something and missed a rung with his free hand, shifted weight to other foot, lost balance and fell. E-1 was climbing the ladder using alternating hand-foot motion. **Weather:** 60.1 °F, Dew point 52.0 °F, Winds 6 mph / NW, Clear, Visibility 10 miles. **Working alone, carrying loads:** E-1 was working alone. Reportedly, he had placed tools in his back pockets prior to ascending the ladder. **Time / Pressure / Urgency:** The start of the work day was altered to accommodate the "increased work load" and "heat of the day" for rooftop activities (0600 hrs). This task was the only one scheduled for this day. Expected completion was around 0700 hrs. **Personal Physical Condition**: No known fitness for duty concerns or pre-existing physical limitations.	The first two rungs of the ladder are not uniform. E-1 did not keep normal routine of stretching exercises. Worker did not maintain three points of contact. "Work Alone" policy was not understood by workers or job supervision and not appropriately implemented. B1 – The absence of a fall protection (arrest) device allowed E-1to fall. B2 – A landing cushion would not have prevented the fall from occurring. However, it may have prevented injuries due to a fall event. The accident occurred. B3 – Failure to maintain 3-point-contact resulted in E-1's inability to remain on the ladder. The "hands free" climbing did not prevent the accident from occurring. B4 – As constructed, the rungs did not provide traction. Non-uniform rung spacing may have resulted in E-1's inability to judge the distance

Event	Conditions	Causal Factors
	Work Area Physical Condition: No adverse work area conditions were identified (LLNL was not aware of any ladder compliance issues; the Board identified those conditions during investigation). **Environmental**: (noise, dust, distractions, etc.) No adverse environmental conditions were identified. E-1 had a circuit tracer and a screw driver in back pockets.	between the rungs and lead to improper foot placement. The reduced clearance could have influenced how E-1placed his feet. B9 – A second worker could have assisted in retrieving the additional instruments needed to continue the job tasks and avoided repetitive climbing. Absence of a second worker was a lost opportunity for peer feedback and correction of error likely situations (climbing technique). A second worker would have assured prompt response in the event of an accident. Actual response was by happenstance. B11 – The use of proper footwear did not prevent the accident. Failure to wear a hard hat did not contribute to the accident. B13 – The hazard controls associated with climbing a ladder > 6' were not established. Absent the controls, the accident occurred. The hazard of potential falls when working within six feet of the roof edge was not identified and no controls established. No effect on this accident. C7 – E-1 may have experienced a loss of dexterity that caused him to misplace his foot on the ladder. C9 – Taking the circuit tracer to the roof on the first trip up the ladder (hauling up with tool bag) would have reduced E-1's need to make repeated climbs of the ladder. C18 – Climbing a ladder higher than six feet was not recognized as a hazard in the work planning process and therefore not controlled. E-1 fell. C19 – Existing ladder deficiencies may have contributed to E-1 slipping from the ladder and falling. C20 – Failure to identify the fall hazards during the work planning placed workers at increased risk to injury from a fall.

Event	Conditions	Causal Factors
7-31-06 ~0645 – E-1 fell from ladder.	**E-1 was injured when he fell from the ladder onto the patio deck.**	
7-31-06 ~0645 – R-1 (T6179) heard "thud" and went outside.	R-1 was not normally in a location where he would hear the noise. R-1 saw E-1 on the ground at the base of the ladder holding his left arm. E-1 was alert, breathing and complaining of pain. Stated he fell from ladder about half way up. Various tools described as being in the area included voltmeter, circuit tracer, screwdriver, nut driver and wrench.	C2 – Immediate assistance was not assured in the event of an accident. C3 – R-1's response to E-1's fall was timely and by chance rather than in accordance with the expectations of the work alone policy.
7-31-06 – R-1 saw E-1 on the ground.	R-1 talked briefly with E-1. E-1 told R-1 he fell off the ladder and was in pain.	
7-31-06 - R-1 went inside T6179 to summon help.		
7-31-06 - R-2 called "911".		
7-31-06 – R-1 returned to E-1, joined by R-3.	E-1 continued to complain of pain.	
7-31-06 - R-1 discovered screwdriver and meter in E-1's back pocket and removed them.		
7-31-06 - R-1 placed rolled-up towels under E-1's head.	E-1 was more comfortable.	
7-31-06 0658 – Ambulance dispatched to T6179.	"911" call response.	
7-31-06 - Protective Force responds to T6179.		
7-31-06 – Protective Force officer accesses the roof.	Officer uses the same fixed ladder from which E-1 fell.	
7/31/06 0702 – Ambulance arrived at T6179.	Patient was assessed and prepared for transport to Valley Care Medical Center. Protocol requires transport off-site due to extent of injuries.	

Event	Conditions	Causal Factors
7-31-06 – E-1's Shop Supervisor arrives at scene of accident.	Protective Force Officer asks if the roof area is safe (while on the roof).	
7-31-06 – E-1's Shop Supervisor goes up on the roof.	Shop supervisor uses the same fixed ladder involved in the accident to retrieve E-1's tool bag and other tools.	
7/31/06 0715 – Ambulance departed accident scene. May have gone to lab medical facility.	EMT response records have 30 minute gap between time ambulance left scene of accident and time ambulance noted as en route to hospital. Board could not confirm through interviews or records exactly what occurred in this timeframe.	
7-31-06 0730 – Initial assessment of ladder by ES&H Team.	This assessment was done after at least two individuals used the ladder to access the roof after the accident.	
7/31/06 ~0745 –Shop Supervisor and Superintendent departed for Valley Care Medical Center.	Shop supervisor and Superintendent arrived at Valley Care Medical Center before the ambulance.	
7/31/06 0749 – Ambulance departed site for Valley Care Medical Center.	Route taken was Vasco Rd. north to I-580 west to Santa Rita and south to VCMC. Time en route was 16 minutes. Traffic on I-580 was heavy (morning rush hour). No lights/siren used. Patient was stable.	
7/31/06 0805 – Ambulance arrived at Valley Care Medical Center.	Route chosen is Vasco Rd, I-580, Santa Rita, to VCMC. Time en route is 16 minutes. No lights/siren. Patient is stable. Fractures of left wrist, left shoulder, pelvis & possible vertebrae.	
7-31-06 – LLNL Electrical Superintendent talks with E-1 in emergency room.	E-1's Shop supervisor present outside emergency room – does not talk with E-1 because emergency room staff would only allow one visitor in the room.	
7-31-06 0820 – PE critiques and fact finding process initiated.	Final report not completed per procedure (8-14-06).	
7-31-06 – LLNL crafts continue work on the T6179 air conditioner job following the accident.	Extension ladder was tied to fixed ladder as means to access the roof.	
7-31-06 – Fixed ladder was taped off to prevent access.	Sign posted to contact FPOC prior to use.	

Event	Conditions	Causal Factors
7-31-06 ~1415 – Safety Briefing conducted at electric shop.	Verbal presentation. No handouts or written materials were passed out. No written documentation of the topics discussed.	
8-1-06 – LLNL stops work on the T6179 air conditioner job.		
8-1-06 – Ladder safety was reviewed and reinforced at each PE Craft Shop at star of workday.		
???? – Scaffolding was subsequently erected (several days later??) to allow rooftop access at another point of the building and the extension ladder was removed.		
8-2-06 – Ladder inspection conducted by LLNL Industrial Safety SME.	Non-compliance issues were not identified.	
8-2-06 0700 – E-1's supervisor over-locks E-1's locks on panel 784A/15 and 784A/21.		
8-7-06 – LLNL resumes the air conditioner task at T6179.	Performed sheet metal work on the four air conditioner units.	
8-7-06 1500 – LLNL stops work on the T6179 air conditioner units. Work later restarted and job was completed on or before 8/13/06.		
8-11-06 1315 – E-1's supervisor removes E-1's locks from 784A/15 and 784A/21.		
8-14-06 – Ladder Safety article featured in NewsOnLine.		
8-15-06 – Ladder Safety video provided to Lab TV for broadcast for two weeks.		

Appendix C: Barrier Analysis

Hazard: Fall From Ladder		Target: Worker (Electrician)	
What were the barriers?	**How did each barrier perform?**	**Why did the barrier fail?**	**Evaluation of Effect**
Fall Protection (Fall Arrest). **B-1**	Fall protection (an arrest device) was not used.	Fall protection was not required for this activity. Climbing ladders higher than six feet was not recognized as a hazard.	The absence of a fall protection (arrest) device allowed E-1to fall.
A cushion (foam/air) to land on. **B-2**	A "landing cushion" was not used.	A landing cushion was not required for this activity. Landing cushions are not commonly used for this type of activity.	A landing cushion would not have prevented the fall from occurring. However, it may have prevented injuries due to a fall event. The accident occurred.
Use of proper climbing techniques: ❑ Use of "3-points of contact" technique. ❑ Avoid speed/ rushing – climbing in a slow and deliberate fashion. ❑ "Hands Free" Climbing. **B-3**	"3 point contact" was not maintained by E-1 while climbing the ladder. E-1's speed of climb was unknown. E-1 kept his hands free for climbing.	E-1did not climb the ladder as expected and/or trained to climb. Unknown. The barrier did not fail.	Failure to maintain 3-point-contact resulted in E-1's inability to remain on the ladder. Unknown. The "hands free" climbing did not prevent the accident from occurring.
Ladder Properties ❑ Slip resistant coating ❑ Rails ❑ Rungs ❑ Uniformity ❑ Clearance **B-4**	The rungs were smooth and round with no slip resistant coating. The walkthrough rails at the top of the ladder were "T" shaped angle iron and too large too grip. The 1st rung spacing was not uniform with the remainder of the ladder. Clearance from the ladder to the wall was less than required.	The 1991 OSHA 29 CFR 1926.1053, ladder standard was not implemented.	As constructed, the rungs did not provide traction. No effect on this accident. Non-uniform rung spacing may have resulted in E-1's inability to judge the distance between the rungs and lead to improper foot placement. The reduced clearance could have influenced how E-1 placed his feet.

Hazard: Fall From Ladder		Target: Worker (Electrician)	
What were the barriers?	**How did each barrier perform?**	**Why did the barrier fail?**	**Evaluation of Effect**
A building designed for ease of maintenance, limiting roof access. **B-5**	Not used. The air conditioning units were rooftop mounted, requiring roof access to perform maintenance.	Not Required; pre built. (Unknown.) Not considered.	E-1 had to climb the ladder to access the rooftop job site.
Ladder inspections were used to assure only compliant ladders were in use, constructed or available. **B-6**	Inspections of ladders did not identify non-compliant conditions of the ladder involved in this accident.	Inspections were focused on the physical condition of the ladders and not compliance to accepted (OSHA) standards.	Improperly performed ladder inspection provided a lost opportunity to identify potential contributors to this accident.
Caged Ladder (to the ground). **B-7**	A ladder cage – extending to the ground - was not used.	A ladder cage is not required. This type of cage is not commonly implemented.	The absence of ladder cage allowed the accident to occur.
An alternative to a ladder was used to access the rooftop job site. (Scaffolding, man-lift, JLG, elevator, helicopter.) **B-8**	An alternative method to access the roof was not used.	An alternative was not required. Climbing ladders higher than six feet was also not recognized as a hazard.	A safer method of rooftop access (e.g., a scaffold or man-lift) was not used. The accident occurred.
A second person (helper/observer) was present to assist with the job tasks. **B-9**	A second person was not at the job site.	A second person was not required to assist in the job tasks. Climbing the ladder was not identified as hazardous work. The Working Alone Policy was not understood or followed by E-1, other workers or management.	A second worker could have assisted in retrieving the additional instruments needed to continue the job tasks and avoided repetitive climbing. Absence of a second worker was a lost opportunity for peer feedback and correction of error likely situations (climbing technique). A second worker would have assured prompt response in the event of an accident. Actual response was by happenstance.

Hazard: Fall From Ladder		Target: Worker (Electrician)	
What were the barriers?	**How did each barrier perform?**	**Why did the barrier fail?**	**Evaluation of Effect**
Training and proficiency were used to demonstrate appropriate ladder use skills. **B-10**	Current ladder training does not ensure proficiency in using the proper techniques discussed in the training. Proficiency was not tested.	Proficiency testing of ladder usage skills is not required.	Not performing proficiency testing represented a lost opportunity to assure E-1 demonstrated proper ladder usage skills. The accident occurred.
Proper personal protective equipment (PPE) was used by E-1 to accomplish the planned job tasks (proper shoes, hard hat, fire retardant clothing). **B-11**	A hard hat was not located at the accident scene. Appropriate footwear was used. The Board was not able to determine whether the required clothing was in use by E-1.	Proper footwear was worn by E-1.	The use of proper footwear did not prevent the accident. Failure to wear a hard hat did not contribute to the accident.
Work planning identified the trade/service and job-specific hazards and hazards controls. **B-12**	The work planning did not identify ladder use > 6' high as a hazard. The work planning did not identify the need for fall protection when working within 6 feet of the roof edge.	LLNL management accepted less than complete and accurate work planning and documentation. The work planning and execution was not conducted IAW requirements of the ES&H Manual and as described in the Integrated Safety Management System Description. *{A number of work planning issues were identified by the Board and described in section 3.2.2 of this report.}*	The hazard of climbing a ladder > 6' was not identified and no controls were established. Absent the controls, the accident occurred. The hazard of potential falls when working within six feet of the roof edge was not identified and no controls established. No effect on this accident.
Work execution implements the hazards controls and performs work within the controls. **B-13**	The Job Manager did not conduct a Pre-start Review in accordance with the requirements of the ES&H Manual.	*{A number of work execution issues were identified by the Board and described in section 3.2.4 of this report.}*	The hazard controls associated with climbing a ladder > 6' were not established. Absent the controls, the accident occurred. The hazard of potential falls when working within six feet of the roof edge was not identified and no controls established. No effect on this accident.

Hazard: Fall From Ladder		Target: Worker (Electrician)	
What were the barriers?	**How did each barrier perform?**	**Why did the barrier fail?**	**Evaluation of Effect**
Morning stretching was done to increase flexibility and reduce chances of injury. **B-14**	E-1 did not do morning stretching exercises – his normal routine – on the morning of the accident.	E-1 changed his routine to start this job earlier in the day to avoid working on the rooftop in the heat of day.	Not stretching may have resulted in less dexterity of E-1, contributing to the accident.
Behavior Based Safety Program was implemented to help assure performing work safely. **B-15**	The Behavior Based Safety program was not implemented in the PE Electrical Shop.	The Behavior Based Safety program was not required.	Not implementing the Behavior Based Safety Program represents a lost opportunity to improve safe performance of work and reduce error likely situations. The accident occurred
Self-Assessment programs were used to identify and correct program and plant deficiencies. **B-16**	The rigor demonstrated in the results of self-assessments showed that most were superficial.	Self-assessments were performed to fulfill the requirement of performing self-assessments.	The poor quality of the self-assessments represented a lost opportunity to identify and correct discrepant work management and training issues.
Morning meeting with supervisor can assess fitness for duty. **B-17**	E-1 did not meet with his supervisor the day of the accident.	E-1 changed his routine to start this job earlier in the day to avoid working on the rooftop in the heat of day and did not meet with his supervisor.	Lost opportunity for the supervisor to evaluate E-1's physical/mental fitness for duty.
A morning meeting provided an opportunity for E-1's supervisor to assess E-1's physical and mental fitness for duty. **B-18**	E-1 and his supervisor did not meet on the morning of the accident, prior to E-1 going to the job site.	E-1 changed his routine to start this job earlier in the day to avoid working on the rooftop in the heat of day.	Failing to meet in the morning as usual, represented a lost opportunity for the supervisor to assess E-1's physical and mental fitness for duty.

Appendix D: Change Analysis Worksheet

Accident Situation	Prior, Ideal, or Accident-Free Situation	Difference	Evaluation of Effect
WS-1 developed the work package and WS-2 executed the work package. **C-1**	Ideal – One work supervisor planned and executed the work.	The work supervisor that planned the work was not the same work supervisor that executed the work.	The work supervisors had different understandings of the work and job expectations. Changing personnel in charge of the work created a potential for incomplete turnover.
E-1 did not assure that others in the area were aware of him working in the area in accordance with the Working Alone Policy. **C-2**	Ideal – E-1 made others in the immediate area aware he was working on the roof, in accordance with the policy for working alone.	Workers in the immediate area were not aware of E-1's presence. E-1 was not know by others to be working within their audible-visual in accordance with the expectations of the working alone policy.	Immediate assistance was not assured in the event of an accident.
R-1 was in an area not normally occupied and was coincidently within "earshot" of hearing E-1's fall onto the patio deck. **C-3**	Ideal – R-1 was in an area where he would not hear E-1's fall.	R-1 was, by chance, in an area where he heard the "thud" when E-1 fell onto the patio deck and he investigated the noise.	R-1's response to E-1's fall was timely and by chance rather than in accordance with the expectations of the working alone policy.
The fixed ladder used by E-1 to access the building roof was installed outside the building c.1992. **C-4**	Prior – The ladder used to access the roof previously was installed inside the building.	The ladder location was reportedly changed from inside to outside the building.	No fall accidents were reported/known.
The fixed ladder installed c.1992 was not compliant with OSHA requirements adopted March 15, 1991. **C-5**	Ideal – The ladder installed c.1992 was built to the 1991 OSHA requirements.	The installed ladder was not constructed in compliance with the requirements adopted by OSHA in 1991.	Deficient rungs and rung spacing could have contributed to lose of footing/balance.
The start of the work day was adjusted by E-1 due to hot days w/o input from ES&H. **C-6**	Ideal – ES&H monitored changing weather to identify severe trends and recommend to management adjustments in the work day.	ES&H did not recommend to line management changes in the work day or identify other controls to avoid exposure to weather extremes.	The change in the start of the workday had several effects: E-1 did not complete his stretching exercises, he had no contact with S-1 prior to starting work, he had no contact with WS-2 prior to starting work, and he worked alone.

Accident Situation	Prior, Ideal, or Accident-Free Situation	Difference	Evaluation of Effect
E-1did not follow his normal routine of stretching exercises at the beginning of the work day. **C-7**	Ideal – E-1 did his normal stretching exercises at the beginning of the work day.	E-1 did not do his stretching exercises.	E-1 may have experienced a loss of dexterity that caused him to misplace his foot on the ladder.
E-1 had limited experience with the circuit tracer needed to complete the job-specific tasks to de-energize the equipment. **C-8**	Ideal – E-1 was proficient with the circuit tracer used to complete the job-specific task of de-energizing the equipment.	E-1 understands the basic functions and operation of the test equipment which was using.	Knowing how the equipment was used (including setup and "calibration") had no effect on the outcome of the accident.
The circuit tracer needed by E-1 to complete the job-specific work task was not in E-1's tool bag. **C-9**	Ideal – The required Pre-start Review meeting identified all the work-specific tasks, and the tools required to complete the work are staged before the work begins.	E-1 did not have (and the work planning process did not assure) the tools required to accomplish the job tasks on-hand at the job site prior to beginning the work.	Taking the circuit tracer to the roof on the first trip up the ladder (hauling up with tool bag) would have reduced E-1's need to make repeated climbs of the ladder.
Building T6179 was a job location new to E-1. **C-10**	Ideal – E-1 was familiar with the job location.	E-1 was unfamiliar with the job location. The day of the accident was the second time E-1 was on the roof and using the circuit tracer for the first time.	Working at new job location and with new tools placed a higher reliance on individual's knowledge skills and experience.
E-1 did not meet with S-1 on the morning of the accident. **C-11**	Prior – E-1 met with S-1 to discuss the days work activities and locations.	E-1 did not discuss work activities and work locations with S-1.	The change in the start of the workday had several effects: E-1 did not complete his stretching exercises, he had no contact with S-1 prior to starting work, he had no contact with WS-2 prior to starting work, and he worked alone. Not meeting with S-1 provided a lost opportunity to be reminded of precautions and for S-1 to assess E1's physical and mental fitness for duty.

Accident Situation	Prior, Ideal, or Accident-Free Situation	Difference	Evaluation of Effect
The Pre-start Review was not conducted in accordance with LLNL requirements. **C-12**	Ideal – WS-2 and all crafts are involved in the Pre-start Review to discuss work activities and confirm that hazard controls were in place prior to beginning work.	All hazards were not identified and the hazard controls were not confirmed by all crafts and WS-2, for the work activities.	Job hazards were not identified (see table) and the hazards were not controlled. Lacking the assurance that the hazard controls were in place, the job was not properly authorized to start by line management in accordance with LLNL procedures.
ES&H Team 1 and ES&H Team 4 management organizational change occurred during the work planning process. **C-13**	Ideal – The same ES&H management teams (organizations) maintain continuity of responsibility for review of the work planning and execution.	The ES&H management teams involved in the review of the work planning were not the same.	Differences in the ES&H management teams may introduce differences of understanding of work activities, identification of hazards and hazards controls. Additionally, there is a potential for incomplete turnover of information.
ES&H was not involved in the work activities sufficiently to identify hazards in the work area and error likely situations during the work performance. (Planning and execution). **C-14**	Ideal – ES&H regularly monitored the work place and work activities to identify and correct hazardous conditions. ES&H was informed this work was being performed outside normal work hours.	ES&H did not identify non-compliant situations present in the work area (ladder compliance) and during the performance of the work (Pre-start review, climbing techniques, work >6 ft, work less than 6 ft from roof edge, lift not completed IAW lift plan).	Increasing the level of involvement of ES&H Team would have provided an opportunity to identify and correct non-compliant conditions and error likely situations.
The roles responsibilities and authorities (RRA) were not well understood by the line management responsible for the work. **C-15**	Ideal – RRAs were clear, understood and enacted by those involved in the work activities. Line management held accountable those involved in the work planning and execution processes to assure complete, accurate and actionable documentation.	The RRAs were left unfulfilled. Accountabilities were not established.	Failure of line management to assure RRAs were clear, understood and acted upon lead to the acceptance of less than accurate and incomplete work planning documentation, proper hazard identification and control of the hazards and unsafe execution of this work activity.

Accident Situation	Prior, Ideal, or Accident-Free Situation	Difference	Evaluation of Effect
The field electricians do not use two-man teams, common to some other trades due to recent staffing cuts. **C-16**	Prior – A second person was present to help with job tasks and re-enforce safe behavior.	A second person was not present to assist with job tasks or re-enforce safe behavior.	Needing another tool, E-1 had to descend and climb the ladder an extra time. A second person could have retrieved the tool and placed it in a bag for E-1 to haul to the roof and corrected E-1's climbing technique when observed.
E-1 did not maintain "3-points contact" while climbing the ladder. **C-17**	Ideal – E-1 maintained "3-points contact" while climbing the ladder.	Improper ladder climbing technique was used when climbing the ladder.	Using improper climbing techniques made E-1 more vulnerable to falling when one point of contact was lost. E-1 fell.
Climbing a ladder higher than six feet was not considered hazard. **C-18**	Ideal – Climbing a ladder higher than six feet was recognized as a hazard and required that hazard controls be in place.	The hazard of climbing higher than six feet was not recognized.	Climbing a ladder higher than six feet was not recognized as a hazard in the work planning process and therefore not controlled. E-1 fell.
Existing ladder deficiencies were not identified by previous inspections. **C-19**	Ideal – Ladder deficiencies were identified and corrected to preclude using defective ladders.	Non-compliant ladder conditions were not identified and the ladder was used E-1.	Existing ladder deficiencies may have contributed to E-1 slipping from the ladder and falling.
Fall protection was not implemented as required in IWS 31.05. **C-20**	Ideal – The fall protection was implemented as required in IWS 31.05 when working at heights above six feet and within six feet of the roof edge.	E-1 (and others) were placed at risk to a fall from the ladder or roof. Recognition of the need for fall protection was left to E-1 during work execution rather than during the work planning.	Failure to identify the fall hazards during the work planning placed workers at increased risk to injury from a fall. **Left up to the worker to decide what hazards they must protect against.**
The Pre-Task Hazards Analysis Worksheet (PTHA) was used by E-1 to self determine task-specific hazards while engaged in this work activity. **C-21**	Prior – E-1 attended "tailgate meetings" to discuss the hazards associated with the work activities.	The individual, vs. group discussion, resulted in the identification of task-specific hazards and the necessary controls.	A single worker has a higher potential to miss some or not recognize all hazards associated with the overall accomplishment of the work activities; in this case working at heights and close to roof edges.
Plastic safety package lost (post accident) **C-22**	Plastic safety package location controlled by "person in charge."	Work documentation not available.	No Effect on Accident. No Documentation of Pre-start Review meeting.

Acronyms

AHJ	Authority Having Jurisdiction
AI	Authorizing Individual
ARO	Assurance Review Office
BU	Business Unit
DAP	Discipline Action Plan
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
DWTF	Decontamination and Waste Treatment Facility
EAO	ES&H Assurance Office
EPD	Environmental Protection Department
ES&H	Environment Safety and Health
FM	Facility Manager
FPOC	Facility Point of Contact
FR	Facility Representative
HAC	Hazard Assessment & Control
HCD	Hazards Control Department
HPI	Human Performance Improvement
ISM	Integrated Safety Management
IWP	Integrated Work Plan
IWS	Integrated Work Sheet
JON	Judgment of Need
LLNL	Lawrence Livermore National Laboratory
LSD	Laboratory Services Directorate
LSO	Livermore Site Office
MPD	Maintenance Production Department
NNSA	National Nuclear Security Administration
OSHA	Occupational Safety and Health Administration
PE	Plant Engineering
PPE	Personal Protective Equipment
PTHA	Pre-Task Hazard Analysis
USQ	Unreviewed Safety Question
RCRA	Resource Conservation and Recovery Act
RHWM	Radioactive Hazardous Waste Management
RI	Responsible Individual
R&Rs	Roles & Responsibilities
SEP	Safety & Environmental Protection
SME	Subject Matter Expert
SS	Shop Supervisor