# TA-53 Arc-Flash Accident Joint Accident Investigation Team (JAIT) Report


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**Release Authorization**

On May 5, 2015, I appointed a National Nuclear Security Administration/Los Alamos National Laboratory Joint Accident Investigation Team (JAIT) to investigate the accident that occurred at the Los Alamos Neutron Science Center, Substation TA-53-0070, on May 3, 2015. The JAIT's responsibilities have been completed with respect to this investigation. The analysis and identification of the contributing and root causes, with the resulting Judgments of Need, were performed in accordance with DOE Order 225.1B, *Accident Investigations.*

[redacted]

July 9, 2015

Don F. Nichols
Cognizant Secretarial Officer for Safety
National Nuclear Security Administration

Date

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

This report neither determines nor implies liability.

## ABSTRACT

An interdisciplinary, learning-focused, and joint Federal and Laboratory team investigated the causes of an electrical accident at Technical Area (TA) 53 at Los Alamos National Laboratory. This event affected nine Los Alamos employees, two of whom required hospitalization. The Joint Accident Investigation Team (JAIT) determined the direct cause of the accident to be cleaning fluid sprayed into the air gap between an energized switchgear bus and the grounded enclosure. The aerosolized fluid created a path to ground, resulting in an arc-flash. The root cause was less-than-adequate management of control implementation. This report identifies relevant facts; determines direct, contributing, and root causes; provides detailed analysis; and establishes conclusions and judgments of need to prevent recurrence.

## ACKNOWLEDGMENTS

The JAIT acknowledges the significant support provided by those directly involved in the accident and response and their shared interest with the JAIT in preventing recurrence of such an incident. Support from key field managers, functional program managers, and union leadership was timely and complete, allowing the JAIT to quickly analyze accident facts and come to conclusions. Emergency Operations Center personnel were most gracious in providing the JAIT physical facilities for our work. Finally, this report could not have been produced without the dedicated and knowledgeable support staff provided to the JAIT from PADOPS/LANL.

# EXECUTIVE SUMMARY

## Background

On May 2, 2015, Los Alamos National Laboratory (LANL) maintenance personnel were conducting 2-Yr breaker preventative maintenance (PM) and 5-Yr PM at 13.8-kV substation Technical Area (TA) 53-0070, which provides power distribution for TA-53. PM included racking out, cleaning, performing conduction and timing measurements, and carrying out high-potential (hi-pot) testing on breakers, as well as cleaning the switchgear cubicles. The entire switchgear was de-energized when these two PM activities commenced on Saturday, May 2, 2015.

Once workers completed some elements of this maintenance on Saturday evening, two of the three buses in the switchgear were re-energized to support TA-53 systems. On Sunday morning, May 3, 2015, work resumed on the one bus that remained de-energized. While cleaning the switchgear cubicles, an employee (designated as E1) entered a cubicle on the energized portion of the switchgear. E1 began to clean the cubicle, using cleaning fluid to spray and wipe down the cubicle walls.

Based on physical evidence, spraying the cleaning solution created a path to ground between the 13.8-kV bus and the grounded cubicle wall, resulting in an arc-flash and -blast. This arc-flash and the resulting blast ejected E1 from the cubicle, resulting in significant burns and a head injury as E1 fell backward and struck test equipment present in the switchgear building. This test equipment was being used to support breaker maintenance work.

On May 5, Dr. Don Nichols, the National Nuclear Security Administration's (NNSA's) Cognizant Secretarial Officer for Safety, tasked Jeffry Roberson, Acting Deputy Associate Administrator for Safety, and Theodore Sherry, Associate Deputy Director at LANL, to convene a Joint Accident Investigation Team (JAIT). The JAIT's objective was to analyze the event and determine direct, root, and contributing causes, and from these provide Judgments of Need (JONs).

The JAIT visited the accident site, reviewed LANL's recent past incidents of a similar nature, conducted interviews, and reviewed relevant documentation. The JAIT formed a Technical Advisory Team (TAT) to support the JAIT with scientific and engineering analysis so that it could better understand the technical elements that contributed to this event. The JAIT also collected benchmarking information related to the processes used at other Department of Energy sites and industry in general. Barrier and change analyses were also performed, along with causal tree mapping, to identify the conclusions that drove the JONs.

This document presents the facts gathered and knowledge gained from the investigation, and includes recommendations that, when implemented, will reduce the probability of a similar event. The table at the end of this executive summary lists all causal factor numbers; the root cause, contributing causes, and JONs; and all JON numbers.

## Summary of Causal Factor Analysis

### *Direct Cause*

> *Direct Cause: Cleaning fluid sprayed into the air gap between the bus bars and the grounded enclosure of an energized cubicle.*

The direct cause of this accident was wireman E1 entering an energized cubicle and spraying cleaning fluid into the air gap between the bus bars and the grounded enclosure. The aerosolized fluid created a path to ground, resulting in an arc-flash.

### *Root Cause*

> *Root Cause: Less-than-adequate management of control implementation.*

Two specific root causes, one related to failure to implement zero-voltage checks and the other associated with lack of establishing physical barriers, were combined into the single root cause of control implementation.

Training and process requirements for electrical work require "zero-voltage" checks on equipment before commencing hands-on work. The crew assigned to this job was a mixed crew composed of lineman (high-voltage workers), breaker maintenance electricians, and wiremen (electricians familiar with lower voltage applications).

During this maintenance activity, the linemen isolated the switchgear and provided safety grounds on the buses in which work was taking place, in accordance with process requirements. This electrical isolation of equipment is known as a clearance. As a result of inconsistent implementation of the zero-voltage check requirement, some wiremen considered the lineman clearance as the zero-voltage check. Other wiremen did not accept the clearance and conducted zero-voltage checks upon entering each cubicle for cleaning. If this zero-voltage check had been conducted on every cubicle, including where the accident occurred, this injury would have been prevented.

Over the two days that this PM was conducted, changes took place in the working environment. During work on Saturday, the switchgear was completely isolated from utility power and only control voltages were present in the switchgear. At the close of work on Saturday, work had been completed on two of the three buses, and these two buses were re-energized to support the Los Alamos Neutron Science Center facility loads.

When work began Sunday morning, 13.8 kV was present in the west portion of the switchgear. This is common for work in switchgear. Status of the energized portion of the switchgear was denoted by one white clearance tag hung on the open tiebreaker at cubicle 18, which indicated the separation of the two energized buses B and C from the de-energized bus A. This is where the PM was to be conducted on Sunday.

The hazard analysis process for this work did not contemplate changes in the work environment from Saturday to Sunday, leaving a mix of lookalike equipment partially energized. Without revisiting the hazard analysis step of work planning, no new controls could be considered to delineate between the energized and de-energized equipment. Conservative work control practices would implement conspicuous barriers to mitigate crew errors of entering energized cubicles. A physical barrier preventing E1 from entering the energized cubicle would also have prevented this accident.

### *Contributing Causes*

The JAIT summarized all causal factors into five contributing causes during its investigation of this event.

> *Contributing Cause: The scope of work at the task[1] level was not adequately defined.*

The Integrated Work Documents (IWDs) did not include tracking processes to validate work required and work completed. Additional work steps to control workflow were not developed to address concurrent maintenance activities. Mixed equipment status was not addressed with process steps to avoid entering energized equipment. Zero-energy verification for each cubicle is required by training and procedure but was not consistently executed.

> *Contributing Cause: Weaknesses in hazard analysis processes resulted in some hazards not being analyzed.*

The hazard analysis process was conducted at the activity[2] level and hence did not require the development of task-level controls. Hazards introduced by working the two PM activities in parallel and changing the operational status of some switchgear in the middle of the work were not considered. The result was inadequate controls for safe execution of concurrent activities and no added effective barrier to separate Bus A from the two energized buses.

> *Contributing Cause: Controls were not effectively implemented to ensure safety on the job.*

A mixed crew of linemen, breaker maintenance electricians, and wiremen were assigned to this job. Linemen rely primarily on the clearance process for utility work, whereas electricians and wiremen rely on Lockout/Tagout. There are substantial common skills and training among this crew; however, the IWD identified both sets of rules without delineating the final control set. No accommodations were made to account for the limited lines of sight and mixed equipment configuration unique to this particular

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[1]Task — A subset of an activity made up of one or more steps and often having different hazards than other tasks within the activity. (P300)

[2]Activity — A subset of a project describing floor-level work, made up of one or more tasks. (P300)

maintenance evolution. The pre-job briefing was interactive between workers, but it did not establish an effective and consistent understanding of the work scope and boundaries for the day's activities. Supervisory direction and oversight were insufficient to limit work activities to the tasks assigned for the workday, allowing a worker to enter energized equipment.

*Contributing Cause: Work was not performed within controls, as envisioned by management and job planners.*

Confusion in the requirements for zero-voltage check resulted in inconsistent implementation of this control. Work activities were not assigned to specific individuals and were informally tracked. Without supervision of assigned tasks, E1 was able to initiate work in energized cubicle 17. Visual work boundaries and work completion status did not clearly indicate that the energized cubicle was outside of the work scope for Sunday.

*Contributing Cause: Feedback and lessons learned were not applied.*

Although other electrical events with similar causal factors are documented at LANL, no evidence existed of lessons learned applied to the hazard analysis used for this work. Task-level controls that could have prevented this accident were not implemented. Lessons learned from other accidents, incidents, and work also were not implemented.

## Final Thoughts

Review of the management processes applicable to this work revealed procedures and policies are in place to govern electrical maintenance work. However, it has been demonstrated by this and other events at LANL in recent history that these procedures and policies are often applied at the minimum level possible to execute work, or in some cases not used at all.

Adequate procedures and policies are in place to prevent this accident and other recent events of this type. However, without correcting the persistent weaknesses in implementing these procedures and policies, it is likely that more events will occur in the future. To avoid this fate, it is crucial that LANL leadership and all levels of responsible management work together cohesively to achieve the level of rigor envisioned for governing hazardous work at LANL. Either a zero-voltage check or a robust barrier to restrict access would have prevented this accident, the former is required by LANL processes and the latter is an industry standard practice.

## TA-53 Electrical Accident Causal Factors

| Causal Factor No. | Conclusions—Root and Contributing Causes | JON No. |
|---|---|---|
| *Root Cause: Less-than-adequate management of control implementation.* | | |
| C12 | E1 did not have zero-voltage verification performed for cubicle 17. | 3, 5 |
| C13 | Processes (zero-voltage checks) were not consistently implemented or understood at the task level. | 3, 5 |
| C20 | The absence of a uniquely marked physical barrier enabled E1 to access cubicle 17 by removing the cubicle door and internal panels. | 3, 4, 11, 13, 2 |
| *Contributing Cause: The scope of work at the task level was not adequately defined.* | | |
| C7 | The yellow caution barricade, intended to demark the hi-pot testing boundary, could have created confusion as to the location of the clearance point boundary, leading E1 to believe cubicle 17 was de-energized. | 2, 3, 4, 6, 11, 13 |
| C15 | Use of clearance tags is not the typical isolation method used by wiremen. | 3, 11 |
| C16 | Trained employees did not identify the lack of required signs, tags, and barriers—a standard industry practice. | 9, 11 |
| C22 | Lack of a formal work-tracking mechanism (in PM documentation) prevented a clear understanding of specific work activities that may have prevented E1 from entering cubicle 17. | 1, 13 |
| C25 | Cluttered workspace, caused by working two jobs concurrently, reduced the ability of the work team and supervisor from observing and preventing E1 from entering cubicle 17. | 7, 9 |
| C29 | Performing two jobs simultaneously inserts additional hazards beyond those addressed for individual tasks. | 1, 7 |
| *Contributing Cause: Weaknesses in hazard analysis processes resulted in some hazards not being analyzed.* | | |
| C3 | The opportunity was missed to establish and implement effective barriers that would have prevented the accident. | 1, 4, 11 |
| C24 | Because of the potential and consequence for human error, the hazard level increases when Bus B and Bus C were re-energized. | 1, 7 |
| C27 | Mixed experience and qualifications caused confusion regarding roles, responsibilities, and control implementation. | 3 |
| C30 | The hazard analysis process did not address the risks and consequences caused by changed conditions between the Saturday and Sunday substation configurations. | 1, 7 |

## TA-53 Electrical Accident Causal Factors (continued)

| Causal Factor No. | Conclusions—Root and Contributing Causes | JON No. |
|---|---|---|
| C31 | Human error had not been fully addressed in terms of "what-if" scenarios. Therefore, robust controls were not implemented. | 1, 4, 11 |
| C33 | Opportunity for craft workers (performing the tasks) to identify concerns for this job was not offered for the hazard analysis process. | 1, 9 |
| C34 | Skill-of-the-craft was used instead of task-level work planning/hazard assessment and controls implementation. | 1, 3 |
| *Contributing Cause: Controls were not effectively implemented to ensure safety on the job.* | | |
| C7 | The yellow caution tape barricade, demarking the hi-pot testing boundary, could have created confusion as to the location of the clearance point boundary, thus leading E1 to believe that Cubicle 17 was de-energized. | 2, 3, 4, 6, 11, 13 |
| C10 | Alerting techniques like safety signs, tags, barricades, and/or attendants were not in place, as would have been standard industry practice. E1 entered lookalike equipment, cubicle 17. | 2, 3, 4, 7, 11 |
| C11 | One foreman (E3) was monitoring the work through frequent work-area passes but did not notice E1 accessing the energized cubicle. | 6 |
| C17 | Reduced worker focus may have contributed to E1's error. | 4, 9 |
| C20 | The absence of a uniquely marked physical barrier enabled E1 to access cubicle 17 by removing the cubicle door and internal panels. | 3, 4, 11, 13, 2 |
| C21 | Lack of a formal work-tracking mechanism prevented positive control and backup by supervision for worker actions that would have prevented E1 from entering cubicle 17. | 2, 6, 13 |
| C27 | Mixed experience and qualifications caused confusion regarding roles, responsibilities, and control implementation. | 3 |
| C28 | Similarity of equipment and congested environment contributed to workers not recognizing E1 was working in cubicle 17. | 4, 7, 9, 10 |
| C32 | Robust controls were not implemented to prevent the consequence of human error. | 2, 4, 9, 10, 11 |
| *Contributing Cause: Work was not performed within controls, as envisioned by management and job planners.* | | |
| C1 | Control afforded by the pre-job briefing was not effective in preventing entry into Bus B, cubicle 17. | 4, 8, 9 |
| C2 | Not all workers had a clear understanding of system/job status and work scope. | 4, 8 |

## TA-53 Electrical Accident Causal Factors (continued)

| Causal Factor No. | Conclusions—Root and Contributing Causes | JON No. |
|---|---|---|
| C4 | Failure to formally track cubicle progress and completion may have resulted in belief that cubicle 17 had not been cleaned on Saturday. | 6, 10, 13 |
| C5 | Work area was congested with people and equipment, contributing to a lack of awareness of other workers. | 1, 4, 7, 9, 10, 13 |
| C6 | The visual boundary (clearance tag) was ineffective in preventing E1 from working outside the intended work scope. | 4, 8, 11 |
| C8 | The absence of blue tape, intended to help identify that cubicle cleaning was complete, possibly contributed to E1 thinking that the cubicle still needed cleaning and was de-energized. | 2, 6, 11, 13 |
| C19 | Opportunity was missed to identify and warn E1 not to open energized cubicle. | 6, 9 |
| C23 | Potential for early completion of the task may have shifted focus away from the task. | 4 |
| C26 | Cluttered workspace may have caused some confusion that led E1 to believe cubicle 17 was de-energized. | 2, 4, 7, 9, 10 |
| *Contributing Cause: Feedback and lessons learned were not applied.* | | |
| C9 | Task-level controls that would have prevented this accident were not identified and implemented. | 7, 12, 13 |
| C14 | Zero-energy verification was not followed, as prescribed in training. | 5, 12 |
| C18 | Lessons learned were not applied to this work activity, resulting in missed opportunities to improve the work process. | 12 |
| **Judgments of Need** | | **Related Conclusions** |
| 1 | Maintenance and Site Services (MSS) and Utility and Institutional Facilities (UI) management need to strengthen expectations regarding work-scope determination, as well as task-level work planning and hazard analysis. These expectations should be reinforced and assessed frequently. | C3, C5, C22, C24, C29, C30, C31, C33, C34 |
| 2 | MSS, Logistics Division (LOG), and UI management need to strengthen expectations regarding rigor in task-level work execution within controls. These expectations should be reinforced and assessed frequently. | C7, C8, C10, C21, C26, C32 |
| 3 | LANL needs to establish uniform and stringent implementation of safety requirements when executing work involving mixed work crews (e.g., different disciplines, experience, and qualifications). | C7, C10, C12, C13, C15, C20, C27, C34 |

## TA-53 Electrical Accident Causal Factors (continued)

| Judgments of Need | | Related Conclusions |
|---|---|---|
| 4 | LANL needs to effectively implement human-performance error-prevention tools in work planning and hazard analysis. | C1, C2, C3, C5, C6, C7, C10, C17, C20, C23, C26, C28, C31, C32 |
| 5 | MSS, LOG, and UI management need to reinforce and clarify expectations and implementation for zero-voltage verification requirements in the course of electrical work at all organizational levels. | C12, C13, C14 |
| 6 | MSS, LOG, and UI management and direct supervision need to reinforce and clarify expectations (training, oversight, and accountability) for Personal Protective Equipment requirements and work practices in the course of electrical work at all organization levels. | C4, C7, C8, C11, C19, C21 |
| 7 | MSS and UI management need to closely evaluate changing conditions when using standing IWDs during the planning process to ensure controls are aligned with actual work activities and site conditions. | C5, C9, C10, C24, C25, C26, C28, C29, C30 |
| 8 | MSS, LOG, and UI management need to strengthen pre-job briefings at the beginning of each shift or when significant changes occur so that worker engagement, focus on important controls, operations integration, and a full understanding by all workers are all assured. | C1, C2, C6 |
| 9 | LANL management needs to ensure workers are encouraged to and are acknowledged for playing an active role in ensuring their own (and work team's) safety and compliance with work rules. | C1, C5, C16, C17, C19, C25, C26, C28, C32, C33 |
| 10 | MSS, LOG, and UI management need to facilitate more direct involvement and ownership by craft in developing the work scope and job planning. | C4, C5, C26, C28, C32, C33 |
| 11 | MSS and UI management need to ensure robust, durable, and visible barriers and signs are appropriately placed and accurately reflect current work conditions, equipment status, and hazards to ensure worker safety. | C3, C6, C7, C8, C10, C15, C16, C20, C31, C32 |
| 12 | LANL needs to improve its ability to implement and verify corrective actions from previous assessments and events. | C9, C14, C18 |
| 13 | MSS and UI management need to evaluate use of informal work practices in the context of potential impact on the effectiveness of safety controls. | C4, C5, C7, C8, C9, C20, C21, C22 |

**CONTENTS**

## ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

| | |
|---|---|
| Activity | A subset of a project describing floor-level work, made up of one or more tasks. (P300) |
| AR | Arc-rated |
| CON | Conclusion |
| CMMS | Computerized Maintenance Management System |
| DARHT | Dual-Axis Radiographic Hydrodynamic Test |
| DOE | U.S. Department of Energy |
| EM | Emergency Management |
| EOC | Emergency Operations Center |
| EOSC | Emergency Operations Support Center |
| ESH | Environmental Safety and Health |
| ESO | Electrical Safety Officer |
| FCA | Facility Centered Assessments |
| FOD | Facility Operations Director |
| HAZMAT | Hazardous Material |
| HAZOP | Hazard and Operability Analysis |
| Hi-pot | high-potential |
| HV | High Voltage |
| ISM | Integrated Safety Management |
| IWD | Integrated Work Document |
| IWM | Integrated Work Management |
| JAIT | Joint Accident Investigation Team |
| JON | Judgment of Need |
| LAFD | Los Alamos Fire Department |
| LAMC | Los Alamos Medical Center |
| LANL | Los Alamos National Laboratory |
| LANS | Los Alamos National Security, LLC |
| LANSCE | Los Alamos Neutron Science Center |
| LL | Lessons Learned |
| LOTO | Lockout/Tagout |
| NA-LA | Los Alamos Field Office |

## ACRONYMS, ABBREVIATIONS, AND DEFINITIONS (continued)

| | |
|---|---|
| MSS | Maintenance and Site Services |
| NFPA | National Fire Protection Association |
| NNSA | National Nuclear Security Administration |
| ORPS | Occurrence Reporting and Processing System |
| PADOPS | Principal Associate Directorate, Operations and Business |
| PERS | Performance Evaluation Reports |
| PIC | Person in Charge |
| PM | Preventative Maintenance |
| PNOV | Preliminary Notice of Violation |
| PPE | Personal Protective Equipment |
| RCO | RadChem Operations |
| RLM | Responsible Line Manager |
| RLUOB | Radiological Laboratory/Utility Office Building |
| RLW | Radioactive Liquid Waste |
| SIWD | Standing Integrated Work Document |
| Step | A subset of a task, typically sequenced into an IWD, procedure, or work instruction, having a discrete set of related hazards and controls. (P300) |
| SME | Subject-Matter Expert |
| STO | Science and Technology Operations |
| TA | Technical Area |
| Task | A subset of an activity made up of one or more steps and often having different hazards than other tasks within the activity. (P300) |
| TAT | Technical Advisory Team |
| TP | Training Plan |
| UI | Utility and Institutional Facilities |
| VPP | Voluntary Protection Program |
| WFO | Weapons Facility Operations |

## PERSONNEL ID KEY FOR REPORT

| ID | Role |
|---|---|
| E1 | Wireman (in substation) |
| E2 | Wireman (in substation) |
| E3 | Foreman Wireman (in substation) |
| E4 | Wireman (in substation) |
| E5 | Lineman (in substation) |
| E6 | Wireman (in substation) |
| E7 | Wireman Apprentice (in substation) |
| E8 | Wireman (in substation) |
| E9 | General Foreman Wireman (outside substation) |
| E10 | Wireman (inside substation) |
| EM1-3 | Emergency Management Personnel |
| S1 | Electrical Superintendent (outside substation) |
| L1 | Lineman (in and out of substation) |
| L2 | General Foreman Lineman (ESO) |
| O1 | Electric System Operator |
| FP1 | Fire Protection |
| FP2 | Fire Protection |
| FP3 | Fire Protection |
| G1 | Groundsman |
| G2 | Groundsman |
| L5 | Lineman Apprentice (outside substation) |
| L6 | Lineman Apprentice (outside substation) |
| L7 | Lineman Apprentice (outside substation) |

As a convention in this report, medium-voltage and <600V electricians will be designated as wiremen. High-voltage electricians will be designated as linemen.

# 1.0 INTRODUCTION

## 1.1 Background

*National Nuclear Security Administration/Los Alamos Field Office*

Created by the National Defense Authorization Act for Fiscal Year 2000, Pub. L. No. 106-65 (1999), the National Nuclear Security Administration (NNSA) serves as a semiautonomous organization under the U. S. Department of Energy (DOE). NNSA focuses on DOE's mission of operating the U.S. nuclear weapons enterprise and associated facilities nationwide. Within NNSA, Los Alamos National Laboratory (LANL) supports this mission through weapons-system maintenance, non-nuclear testing, advanced computer modeling, and development and applied science and engineering. NNSA relies upon the Los Alamos Field Office (NA-LA) to interface with the LANL management team and its operations contractor, Los Alamos National Security, LLC (LANS).

Key responsibilities of the NNSA Field Office include safety oversight, contract management, strategic planning, project management, and budget execution. These functions are carried out in close coordination with LANS management and staff members. To help ensure the desired level of contractor performance, NNSA uses a formal oversight system that leverages LANL's Contractor Assurance System (CAS). This system breaks down LANL operations and mission execution into key functional areas. Federal and contractor staff members focus on monitoring and coordinating work and evaluation of these areas.

Federal staff members achieve safety oversight in four specific areas: Nuclear Safety Basis, Safety System Oversight, Facility Representatives, and Safety Programs. The first three areas focus on nuclear facilities operations, with safety programs crosscutting all LANL operations and programs. Electrical safety at LANL is monitored part-time as part of industrial safety oversight. Such safety is supplemented on a case-by-case basis by the electrical systems engineer from Safety System Oversight.

*Los Alamos National Laboratory*

LANL was established in 1943 under the Manhattan Project and has grown substantially since that time in terms of both size and its diversity of mission functions. Today, this NNSA facility is widely recognized as a vital national institution for supercomputing, basic science, nuclear stockpile stewardship, advanced engineering science, and material science.

The accident took place at the Los Alamos Neutron Science Center (LANSCE), a large facility at LANL. LANSCE consists of a linear accelerator approximately three-quarters of a mile long that generates high-energy subatomic particles for a variety of science and

*Figure 1-1. The 13.8-kV substation was the site of the electric-arc accident on May 3, 2015.*

*Figure 1-2. The switchgear is located near Building 1 at TA-53.*

nuclear engineering applications. Examples include medical isotope production, materials analysis, subatomic physics, and advanced imaging technologies.

LANSCE operates on regular annual cycles of continuous beam operation for several months at a time. Beam operations are typically conducted 24 hours a day, seven days a week. This operation is followed by planned long-term outages that can last several months. It is during such outages that workers perform maintenance and testing of the myriad specialized equipment required for operations.

During these planned outages, personnel maintain ancillary equipment designed to avoid interruption of beam operations, which is very undesirable. Such maintenance includes the 13.8-kV switchgear station, which is fed by incoming 115-kV utility power lines. Collectively, this gear provides power to the entire TA-53 area and houses all distribution breakers for TA-53, which includes LANSCE (Figure 1-1). The switchgear is located in a dedicated and fenced switching yard near Building 1 (Figure 1-2), which is west of the accelerator beam facilities.

### 1.2 Facility Description

The electrical substation TA-53-0070 is located in Technical Area (TA) 53 (Figure 1-3) and serves the adjacent LANSCE. The substation receives 115-kV utility power to two transformers that step the voltage down to 13.8 kV, which is supplied to buses A and B. Additionally, 13.8 kV from distribution circuit EA-06 is connected to Bus C as an alternate power source. There are alternate configurations for power line-up. The incoming power is distributed through the switchgear to multiple administrative and experimental facilities across TA-53.

*Figure 1-3. An aerial view of TA-53, looking west.*

Figure 1-4 shows an aerial view of Building 70 (substation at TA-53-0070) and Building 1


*Figure 1-4. An aerial view of Building 70 and Building 1.*

The substation at TA-53-0070 consists of 28 cubicles that contain distribution breakers, tiebreakers, and power-system metering instrumentation. These cubicles are all closely adjoined, beginning with number 1 on the west end. They can be electrically segmented by opening tiebreakers in cubicles 8 and 18 as needed, thus isolating them into separate buses. Bus C powers cubicles 1 to 8, Bus B powers cubicles 8 to 18, and Bus A powers cubicles 18 to 28. Transformer TR-2 feeds Bus B and TR-1 feeds Bus A. Bus C can be connected to alternate power via circuit EA-6, fed into cubicle 3.

**1.3 Scope, Conduct, and Methodology**

The Joint Accident Investigation Team (JAIT) established a charter consistent with the Appointing Official’s letter and DOE Order 225.1B, *Accident Investigations*. This charter outlined the following approach:

- Identify relevant facts
- Analyze the facts to determine direct, contributing, and root causes for the event
- Develop judgments of need to prevent recurrence
- Investigate DOE programs and oversight
- Review previous electrical incidents at LANL for common causes/weaknesses
- Maintain team confidentiality
- Do not cast blame

The JAIT consisted of both NNSA and LANL representatives, as well as related contractor personnel. The JAIT was co-chaired by senior management from both NNSA and LANL, as identified by the Appointing Official's memorandum, dated May 5, 2015. Both chairmen provided separate appointment memos to the federal and contractor members of the team.

Members of the JAIT included personnel with significant leadership and subject-matter expertise in high-rigor operations, human factors, failure analysis, high-voltage electrical safety, as well as safety culture and work process and control. The memoranda from the Appointing Official and the chairs identified that those assigned to the team were relieved of all other duties while participating on the JAIT. The federal co-chair appointed a trained accident investigator.

Technical advisors were identified to provide support to the JAIT members. These advisors worked closely with the JAIT to identify and review evidence, determine the appropriate facts, execute analysis and draw conclusions, and provide input and judgments of need for this report. Technical advisors brought with them relevant experience in emergency response and accident investigations.

All team members signed a nondisclosure agreement. These forms were collected and are included in the JAIT's evidence folders. Team participants were dedicated to the team for the duration of the investigation.

Team Members and technical support personnel all worked seamlessly and closely to understand the events leading up to the accident, as well as the emergency response that followed the accident. Team Members followed the structure for conducting accident investigations, as identified in DOE-HDBK-1208-2012, *Accident and Operational Safety Analysis.* Members gathered evidence; identified facts; performed analysis of the facts by developing an events and causal factors chart, as well as barrier and change analyses; and developed causal factors, conclusions, and judgments of need using the processes and forms identified in the Handbook.

The JAIT met daily as a group to discuss the collected information, key issues identified during the day, questions raised during the day, needed support, and issues of interest to other JAIT members. Co-Chairs held a daily briefing with the Appointing Official, as well as senior NA-LA and LANL management. Written daily updates of JAIT activities were provided to LANL personnel each afternoon.

Establishing a JAIT with members from both NNSA and LANL enabled a common understanding of the federal and contractor sides of the issues surrounding the accident, as well as a better understanding of the basis for improvements to avoid this type of accident ever happening again. This joint effort also ensured that the JAIT could call upon local resources with historical knowledge of the process and the basis of the JAIT's results.

# 2.0 THE ACCIDENT

## 2.1 Accident Description

During May 2–3, 2015, workers performed scheduled preventative maintenance (PM) operations at Substation Building 70 (TA-53-0070). Figure 2-1 shows substation TA-53-0070, looking from north-by-northeast.

Workers were simultaneously executing two separate work orders at TA-53-0070: (1) a 5-Yr Switchgear PM and (2) a 2-Yr Air Circuit Breaker PM. Engaged in the PM work were a mixed crew of workers consisting of Maintenance and Site Services (MSS) wiremen and linemen (both groups are deployed from Logistics Division), with various levels of substation and switchgear experience. In general, a composite crew of linemen and wiremen were assigned to both efforts. At least one lineman, however, was available to support the wiremen for both zero-voltage checks and attaching grounds.

The substation provides 13.8-kV distribution services to LANSCE through the following three segments: Bus A, Bus B, and Bus C. Bus C powers cubicles 1 through 8, Bus B powers cubicles 8 through 18, and Bus A powers cubicles 18 through 28. Tiebreakers in cubicles 8 and 18 connect the segments as needed. During normal use, the three buses can be connected by closing the tiebreakers in cubicles 8 and 18. Tiebreakers can be opened to isolate parts of the switchgear.

On May 2, 2015, all three buses were de-energized so that workers could perform maintenance tasks (Figure 2-2). Breaker maintenance and cleaning operations for Bus B and Bus C were completed, and both were re-energized by linemen, using the approved switching procedure, at the end of shift (1904 MDT), so that electrical service could be restored to some facilities within TA-53 to minimize outage impacts. Personnel attached a clearance tag (Figure 2-3) to the cubicle-18 tiebreaker. This tag indicated a demarcation between energized and de-energized cubicles. A lineman was available for zero-energy checks.

On Sunday, May 3, 2015 (the second day of scheduled PM), a crew of ten employees (identified as E1–E10 in this report), who had all supported PM operations the previous day, returned to complete the remaining maintenance and cleaning work required for Bus A, which remained de-energized. The Saturday Person in Charge (PIC) and two other linemen who had worked on Saturday did not return on Sunday due to off-site training. One of the Alternate PICs, E9, was designated the Sunday PIC, was on site and attended the pre-job briefing. (LANL PIC duties and training are similar to those of the Work Supervisor described in DOE-HDBK-1211-2014, *Activity Level Work Planning and Control Implementation*.)

*Figure 2-1. A north-by-northeast view of Substation Building 70 at TA-53.*

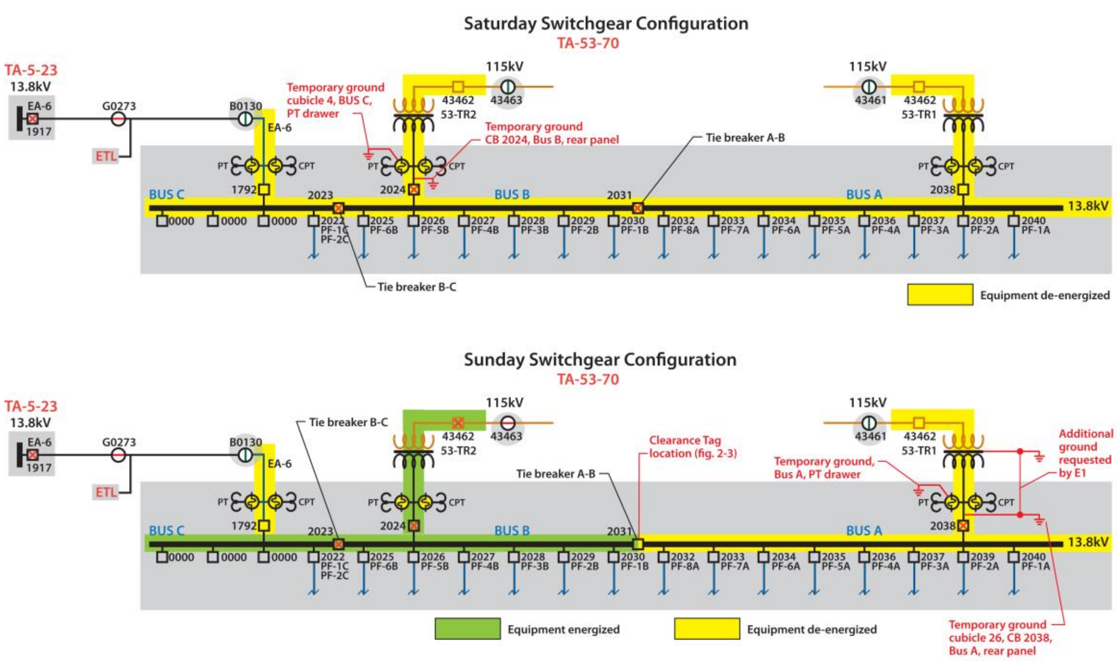


*Figure. 2-2. Substation TA-53-0070 clearance configuration on Saturday, May 2, 2015 (top) and on Sunday, May 3, 2015. On Saturday, energy isolation breakers of disconnect blades (yellow) were opened to achieve the desired boundary. TA-53-0070 buses A, B, and C were all de-energized.*


*Figure. 2-3. The Clearance Tag hangs from the cubicle 18 tiebreaker.*

Work began at 0700 with a pre-job briefing, which included a reading of the work scope by the designated foreman, E3, as well as a detailed briefing on the associated hazards, mandatory mitigation measures, and personnel safety requirements. The crew received the brief from E3 directly in front of the tiebreaker (cubicle 18), where they were reminded again that Bus B and Bus C were now energized and that all work on this day was to be performed only on Bus A (cubicles 19–28), which was not energized.

The clearance tag hung on the cubicle 18 tiebreaker the night before was verified as still in place as part of the power dispatch authorization process to allow entry into Bus A cubicles.

**No other physical barriers or barricades between the energized cubicles (1–18) and de-energized cubicles (19–28) were installed to identify the separation of the *energized* from the *de-energized* cubicles.**

However, yellow caution barricade tape was placed across the aisle at the junction between cubicles 8 and 9, as well as the junction between cubicles 16 and 17. This tape designated the area where hi-pot testing would occur as part of the 2-Yr breaker-testing activity, and was not associated with marking energized buses.

During the pre-job briefing, E1 inquired about the status of the personnel safety ground. It was then determined that a ground had not been installed, but that it would be a good additional control. At this point, E1, together with a lineman (E5), installed and verified this ground before continuing work.

All ten employees associated with this activity acknowledged their understanding of the work scope and safety requirements. Nine employees proceeded with their assigned duties inside the switchgear while the tenth, E9 (General Foreman), went to an adjacent building (Control Building 53773) to complete paperwork and documentation. Figure 2-4 shows the location of employees E1 through E10 at the time of the accident.

At approximately 1100, E1 walked past the clearance tag that was fixed to cubicle 18 and opened the door to cubicle 17, which was part of the energized Bus B segment. E1 was wearing personal protective equipment (PPE) consisting of nitrile gloves and an arc-rated (AR) shirt, and other clothing including non-arc-rated overalls, and a baseball cap.

E1 positioned a four-foot fiberglass stepladder along the inside of cubicle 17 (Figure 2-5.). He removed the side-by-side internal steel protective-cover panels to expose the bus bars and associated switchgear, apparently to allow cleaning of the internal surfaces, components, and assemblies.

Bus B and Bus C were energized at the end of the shift on the previous day, so the action of E1 unbolting and removing these protective covers inside this cubicle exposed the energized bus bars. Based on physical evidence at the scene and system-monitoring data, at 1108 E1 hand sprayed a commercial liquid cleaner into the air gap between the energized switchgear bus and the grounded enclosure inside cubicle 17 (Figure 2-5).

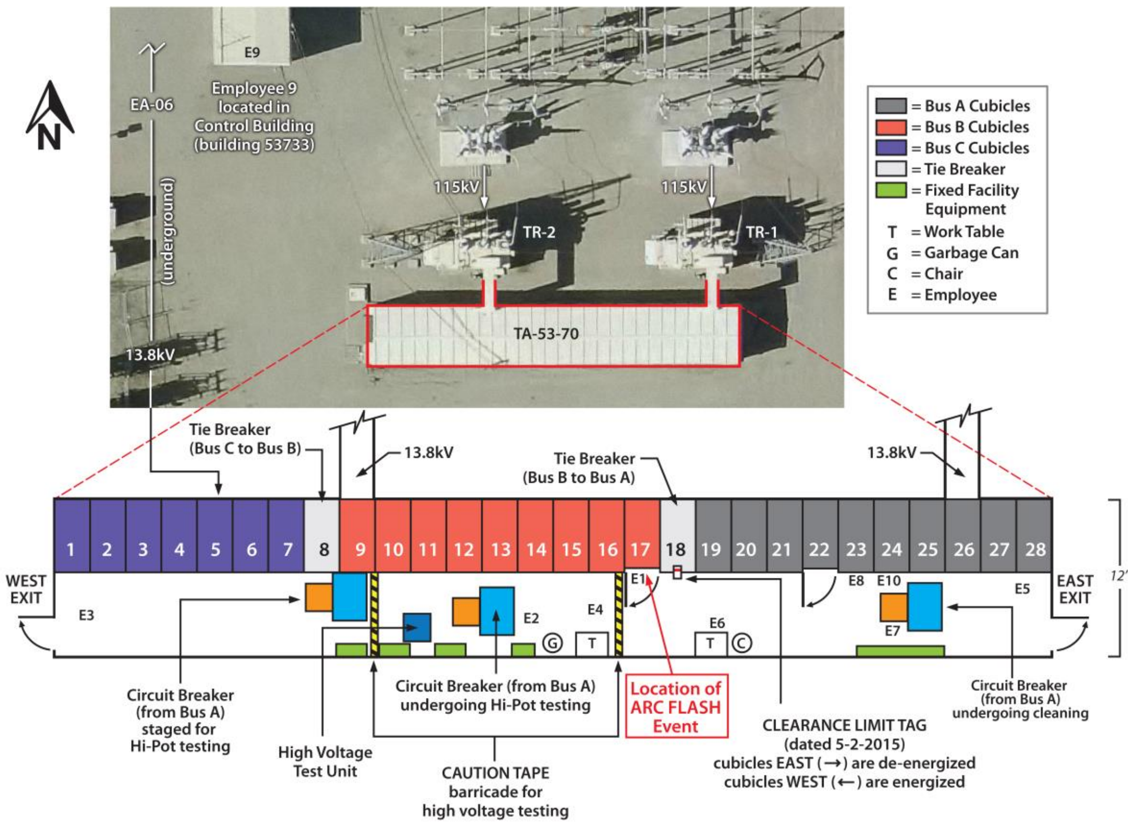


*Figure 2-4. Substation TA-53-0070 configuration at time of accident on Sunday, May 3, 2015*

*Figure 2-5 Position of E1 just before the accident.*

The JAIT verified this assumption based on the post-event condition of the spray container, which indicated that it had been extremely close to a high heat source (Figure 2-6). In addition, post-event waveform analysis of the arc-flash event supports the conclusion that the liquid was sprayed in very close proximity to the energized C-phase bus. The initial fault measured as a C-phase-to-ground arc transitioning quickly to a B-phase-to-ground arc, followed by multiple phase-to-phase faults as plasma flooded the cubicle.

The spray cleaner used is a commercially available household cleaner with no established dielectric characteristics, which means it has no insulating properties to prevent the conducting of electrical current. This spray's intended use for this application was to clean non-energized surfaces.

**The presence of this conductive, aerosolized fluid in the dielectric airspace between the energized bus bar components and the grounded cubicle sidewall surface resulted in an immediate arcing fault, which rapidly transitioned to an arc-flash event.**

The above conclusion is based on the waveforms captured from the monitoring systems and the physical damage on the cubicle wall and bus bars. The low-current leader of the fault is hidden by the very high currents following the initial flash, with the arc fault sustained by the establishment of highly conductive plasma. This energy discharge burned the bus bars and vaporized the copper and other metal parts in the vicinity, resulting in an arc-blast.

The resultant explosion impacted E1 directly. Figure 2-7 shows an example of an arc-flash event.

Within the relatively confined cubicle space, it is assumed that E1 placed his hands, forearms, chest, and face in close proximity to the energized components of all three phases within Bus B at the time of the accident. Medical assessment of the resulting injuries determined no evidence of direct electrical contact to any skin surface; all burns were caused by exposure to the extreme thermal energy of the arc-flash.

Post-event analysis of E1's clothing (Figure. 2-8) indicates no sign of combustion below chest level.

**The rapid release of thermal energy from the flash event resulted in serious burns to E1's hands, forearms, chest, face, head, and left rear upper torso. The subsequent pressure wave forced him backward and downward onto the floor, where his head struck a micro-ohm testing instrument.**

*Figure 2-6. Post-even condition of the spray bottle's bottom (top image) and sprayer (bottom image) on the floor outside cubicle 17.*

*Figure 2-7. This photo shows the energy released from thermal, pressure, sound, and light modes during a typical arc-flash event.*

*Figure 2-8. Clothing recovered from E1 after the arc-flash event.*

*Figure 2-9. What cubicle 17 looked like after the arc-flash event.*

As a result of this strike, E1 suffered a laceration to the back of his head. Figure 2-9 shows cubicle 17 after the arc-flash event. Figure 2-10 shows the position of E1 after the arc-flash event.


*Figure. 2-10. Position of E1 after the arc-flash event.*

*Figure. 2-11. This fire extinguisher was brought to the scene but not used to extinguish the fire on E1 at the arc-flash accident scene.*

## 2.2 Accident Response

Immediately following the event, E2 and E4 observed E1 lying on the floor in front of cubicle 17. E3 called for everyone to evacuate the switchgear. E4 moved toward the west exit door and informed E3 that E1 was down and on fire. E2 reached E1 first and began to manually pat out the flames on E1's shirt and sleeves after donning leather gloves.

E3 had retrieved the closest fire extinguisher from the west entry door to assist with extinguishing the fire on E1. However, because E2 had already put out the fire, the extinguisher was not required. Post-event status of the extinguisher gage and safety pin verified that it had not been used or discharged (Figure 2-11).

E1 was initially responsive, but became unresponsive after several seconds. E2 took action to revive him, and E1 was then able to walk out of the east exit with the help of E2. E1 was escorted to the southeast corner inside the substation fence enclosure to await arrival of emergency response.

Facility management assessed the TA-53-0070 substation to ensure that the high-voltage source power remained de-energized. The immediate accident scene inside the switchgear was made secure and red "DANGER" barricade tape was installed to isolate the boundaries of the arc-flash event, as well as exterior areas of the switchgear.

Access to the remainder of the substation building was restricted to only those that required access. The substation complex itself, which is already protected by a perimeter fence and locked gates, was locked down to prevent any unauthorized access, pending the arrival of the JAIT.

## 2.3 Summary of the Medical Report

Nine individuals were transported by emergency vehicles to the Los Alamos Medical Center (LAMC, a local hospital) as the result of the arc-flash. The general foreman, E9, who was in an adjacent building at the time of the arc-flash, did not require medical attention. As a result of the arc-flash, E1 suffered a burn injury to his hands, wrists, face, neck, and torso. E1 also received a minor laceration to the back of the head. After evaluation and treatment, E1 was identified as critical and transferred by CareFlight to the regional burn center for ongoing treatment. There was no evidence of injury to hearing or vision.

E2 was referred for admission to the LAMC for ongoing observation and treatment related to inhalation exposure, then subsequently released two days later. All others were evaluated, treated, and released.

Behavioral Health Services was also mobilized and offered their services to all employees on the day of the event. The support remains ongoing and continues to be offered or provided to any impacted employees.

## 2.4 Event Chronology

Table 2-1 summarizes the events and actions associated with TA-53-0070 before the accident described in Section 2.1, Accident Description. This table is designed to assist with putting context around events on the day of the accident. A detailed description of the timeline associated with this accident is provided in the Event and Causal Factors Chart in Appendix G.

**Table 2-1. Summary of Events and Actions Pre-accident.**

| **Date** | **Action** |
|---|---|
| ~2010 | 5-Yr Switchgear Cleaning PM performed. |
| ~2011 | 2-Yr Air Circuit Breaker PM performed. |
| ~2013 | 2-Yr Air Circuit Breaker PM performed. |
| 1/14/2015 | 5-Yr Switchgear Cleaning PM Work Order generated. |
| 1/14/2015 | 2-Yr Air Circuit Breaker PM Work Order generated. |
| ~March 2015 | Hazard Analysis Process for both PMs utilized a document generated the prior year on 4/4/2014. |
| 3/21/2015 | Initial work on Air Circuit Breaker PM commenced with a Pre-Job Brief and work on breakers that did not require individual buses to be de-energized. |
| 4/22/2015 | The combined 5-Yr Switchgear Cleaning PM and 2-Yr Air Circuit Breaker PM were planned to work the weekend of 5/16/2015. |
| 4/27/2015 | After consultation amongst groups involved, the combined PMs were moved to the weekend of 5/2/2015 to accommodate facility and resource schedules. |
| 4/27/2015 | An outage request for TA-53 was requested for all of TA-53-0070 to be de-energized on 5/2/2015 (Saturday) and 5/3/2015 (Sunday). |
| 4/28/2015 | A decision by LANSCE and maintenance was made to re-energize Buses B and C on Saturday evening, 5/2/2015, after the work on those buses was complete. |
| 5/1/2015 | Switching procedure authorized to control de-energizing all buses, then re-energizing Buses B & C on Saturday evening. |
| 5/2/2015 | The combined PMs were performed on Buses B and C, with the entire switchgear de-energized. |
| 5/2/2015 | After work was complete for the day, Buses B and C were re-energized to minimize outage impacts on LANSCE. |
| 5/3/2015 | All crewmembers except the PIC and two other linemen return to TA-53-0070 to complete the cleaning. Wiremen and one lineman inside, other linemen demobilize equipment from outside work. |
| 5/3/2015 | At about 1108, the Arc-Flash Accident occurred. |

# 3.0 FACTS AND ANALYSIS

## 3.1 Emergency Response

*Facts*

Emergency Operations Response

At 1109, the Los Alamos Fire Department (LAFD) received an alarm notification for a possible electrocution burn. At 1115, the LAFD arrived on scene and began providing initial treatment to E1 and the other eight employees involved with the event. After initial assessment of E1, LAFD requested that CareFlight be dispatched to LAMC.

**At approximately 1118, E1 was transported to LAMC by ambulance and subsequently transported by a CareFlight helicopter to the Albuquerque Medical Center Burn Center at the University of New Mexico Hospital in Albuquerque.**

The eight other members of this work crew were transported via ambulance to LAMC. Two individuals were evaluated for potential smoke inhalation. Seven of these employees were later released, with one (E2) remaining at the hospital for further observation before being released two days later.

At 1110, the LANL Emergency Operations Support Center (EOSC) within the Emergency Operations Center (EOC) copied the LAFD radio call dispatching of medical units to TA-53-0070. Emergency Management Duty Officer (EM3) arrived at the scene at 1141. Additional LAFD assets arrived on scene and established EOC/LAFD Unified Command at 1148.

At 1206, the EOSC requested that management and technical support personnel report to the EOC at 1300 or sooner. The HAZMAT team was placed on standby for support. The Unified Command post was relocated to TA-53-0044 because of lightning warnings in the area. On-Scene Command post was terminated at 1236.

At 1243, EM3 turned the substation over to the Facility Superintendent. EM3 declared the incident as Non-Emergency-Significant Event at 1402. At 1432, EM3 and the LAFD terminated unified command.

Medical Response

Immediately following the accident, E2 and E3 responded to assist E1, who was initially responsive. E2 patted E1 down and extinguished the fire that was on E1's clothing. At the same time E3 went to get a fire extinguisher but it was not needed. E1 became unresponsive and was revived by E2 who helped E1 remove burnt clothing, applied cool wet rags to E1, and assisted E1 out of TA-53-0070 while E3 went and called 911. Other individuals on the scene also called 911.

At 1109, the Los Alamos Fire Department (LAFD) received an alarm notification for a possible electrocution burn and initial emergency units were dispatched to the scene at 1110. At 1115, Medic 1 and other LAFD units arrived on scene. Site personnel had opened the gates to allow the arriving emergency units direct and unencumbered access to the accident scene. Personnel in Medic 1 began providing initial treatment to E1 and the other eight employees involved with the event. Medic 1 personnel took the lead for treating E1 and personnel from other LAFD units assisted in evaluating and treating the other eight employees, and LAMC is notified to expect mass casualties from the accident.

After initial assessment of E1, Medic 1 personnel requested that CareFlight be dispatched to LAMC. Medic 1 leaves the site with E1 at 1118 and arrives at LAMC at 1125. E1 is assessed at LAMC, where he is prepared for his trip to the University of New Mexico Hospital's (UNMH) Level 1 Trauma Unit via helicopter. At 1228 E1 is transported to the Los Alamos High School (LAMC's normal helicopter pad was unavailable) to be placed into the helicopter. The helicopter with E1 aboard leaves Los Alamos for UNMH at approximately 1235.

The eight other members of this work crew were transported via ambulance to LAMC at approximately 1145. All eight individuals were evaluated for potential injury. Five individuals were evaluated and released, two were treated and released, and one (E2) remains at the hospital for further observation before being released two days later.

*Analysis*

The involved personnel reacted effectively and appropriately to ensure that workers were successfully evacuated from the switchgear and moved to a safe location. Appropriate first aid was given to E1.

The ability of the workers to react quickly despite the trauma involved in this type of event may have prevented additional injury to E1. The call to 911 was placed shortly after the event and LAFD responded to the scene within the required response time. LAFD and LAMC provided appropriate first aid and medical treatment. The decision to airlift E1 to the New Mexico Burn Center at the University of New Mexico in Albuquerque, NM, was timely and appropriate.

Proper and timely incident notifications were made to the EOC, UI Facility Operations Director (FOD), LANSCE FOD, and LANL management. The LAFD effectively secured the scene and the lineman crew ensured the switchgear was in a safe and stable configuration. The EOC coordinated the recall of support personnel in a timely manner. The EOC and the LAFD established a Unified Command Structure and managed the scene until it was released back to the UI FOD. The EOC properly staffed and classified the event as a "Non-Emergency-Significant Event."

The overall emergency response by those individuals at the scene, the responding fire and medical staff, LAMC and Albuquerque hospitals, and the LANL EOC was timely and appropriate. The actions of E2 and E3 to ensure other employees evacuated the switchgear and to render aid to E1 were commendable. Also commendable was the LAFD response to the scene to provide aid, assist in emergency transportation, and support to all involved workers.

### 3.2 Post-Event Accident Scene Preservation and Management Response

*Facts*

Emergency Management employee 3 (EM3) released the scene at 1243 to the Electrical Superintendent (S1), per LANL SEO-3 EM Incident Record for Incident 15-066.
S1 instructed L1 and E9 to de-energize Bus B and Bus C by isolating TR2 and executing standard high-voltage isolation actions, involving operating the necessary 13.8-kV breakers and the voltage-isolating switches.

S1 instructed all linemen to leave the yard because of an approaching lightning storm.

Nothing was removed or altered inside TA-53-0070 until early in the week of May 3, when hazard signs were placed on the cubicle doors to identify energized cubicles.

S1 instructed all personnel inside TA-53-0070 and inside the fence line to depart. LANL provided hotel accommodation for all affected employees to avoid the need to drive home. S1 used his camera to document the status of TA-53-0070.

The Videx electronic locking system controls all access to TA-53-0070, whether it is a fence door, gate, or TA-53-0070 door. The key for these locks is authorized only by S1. This key is available only to the HV linemen. EM (fire and protective forces) does not have a key.

No post-event drug or alcohol testing was performed on any members of this work crew as required by LANL Procedures. It is recognized that the priority was treatment of the injured employee, but other involved workers in the accident could have been available for testing.

*Analysis*

Scene preservation satisfied the need of the JAIT to maintain the direct link to the accident for pertinent facts.

Lack of drug and alcohol testing post-event prevented the JAIT from ruling out impairment as a contributor. Implementation of LANL drug and alcohol testing policy is inadequate to ensure that these tests are conducted in a timely manner. Laboratory management has reviewed and is updating execution mechanisms for future accidents.

## 3.3 Assessing Prior Events and Accident Precursors

*Facts*

The JAIT performed a review to identify historical precursors by reviewing and summarizing LANL's recent and historical electrical safety and related Integrated Work Management (IWM) experience. This effort included reviews and results from multiple sources.

Facility Centered Assessments

Institutional Facility Centered Assessments (FCAs) that incorporated assessment criteria for electrical safety and Integrated Safety Management (ISM)/IWM implementation were evaluated. Assessments cited include DARHT (2012), Weapons Facility Operations (WFO, 2011), RadChem Operations (RCO, 2014), Science and Technology Operations (STO, 2010), Radioactive Liquid Waste (RLW, 2013), and Utilities and Institutional Facilities (UI, 2013). Results varied slightly across the operations yet reported electrical and ISM/IWM implementation as meeting the review criteria, with a few exceptions. Some common observations and opportunities for improvement from the assessments included the following:

- Engagement of subject-matter experts (SMEs) and workers in scoping and work planning to improve hazard analysis and implementation of clearly defined controls.
- Improve work-package consistency and formality to help minimize confusion and worker error.

Special Assessments

Two special assessments of LANL electrical safety events were also evaluated. This evaluation included a team review (2011 IWM Team Report) of five events, four of which were electrical, that occurred over a short period of time and another more recent assessment (April 2015) of an electrical shock event and facility-related experience at the Radiological Laboratory/Utility/Office Building (RLUOB) facility. Data from the assessments identified common precursors, including factors associated with the following:

- Work scoping and bounding to include risk assessments, Integrated Work Document (IWD) boundaries, two-person rule, PPE, etc.
- Changing work conditions and distractions to workers and supervision.
- Clarifying and communicating roles and responsibilities, chain-of-command and involvement of workers, SMEs, planners, foremen and supervisors.
- Working outside of the IWD or failure to implement described controls.
- Pre-job briefing lacking or inadequate.

Lessons Learned Records

Lessons Learned (LL) since 2009 addressing specific high- and low-voltage events at LANL were reviewed for content highlighting and communicating information regarding specific electrical events. LL were from troubleshooting a failed vacuum pump at LANSCE (July 2010), multiple electrical events summary (fall of 2010 to spring of 2011), and scoping of subcontracted repair work (October 2012).

These LL Records highlighted the need to engage SMEs and personnel in work planning, scoping, and assessments. Additional Electrical safety and/or IWM-related recommendations for ensuring safe conduct of electrical work included the following:

- Daily task reviews
- Conducting zero-energy checks and powering down equipment as a positive barrier
- Addressing changes in work scope, equipment, material, or techniques that differ from previous work

DOE Occurrence Reports

Select ORPS reports and history associated with electrical events were reviewed for common issues and precursors. Specific events were associated with acceptance testing of a vacuum pump disconnect (WFO, February 2015); construction subcontractor support activities for a programmatic upgrade project (WFO, October 2014); unauthorized repair of programmatic equipment (STO, October 2014); and facility electrical system tracing

(TA-55, February 2015). From a review of these recent events, common precursors were again identified, including the following:

- Engagement of SMEs and workers in work planning
- Work scoping and IWD development to clearly define and plan work processes, tasks, and steps sufficient to support hazard identification and implementation of controls
- Clear definition of roles, responsibilities, and expectations for all workers
- Communication across the Program, Responsible Line Manager (RLM), PIC and craft workers of work conditions
- Identification and implementation of controls such as Lockout/Tagout (LOTO), zero-voltage testing, and PPE
- Changes in the scope of work

Office of Enforcement Reports

A review of historical DOE Enforcement activities was also conducted for work activity and compliance factors as they related to event precursors. This was limited to an investigation resulting in a PNOV issued to LANL in October 2012. The scope of the enforcement action covered four electrical events involving LANL and LANL subcontractors. One occurred in October 2010, one in December 2010, and two others in January 2011. Similar precursors from the event investigations and enforcement action summary included the following:

- Weaknesses in work planning to analyze hazards and develop controls
- Monitoring and assessment of work practices
- Using a safety watch or qualified electrical worker to monitor work
- Implementing required work permits
- Employing practices to eliminate or reduce employee exposure to electrical energy by applying physical controls or using barricades and signs to exclude workers from hazards

*Analysis*

The JAIT analyzed LANL's past experience associated with electrical safety and related IWM implementation. This included an analysis of information from multiple sources, including LANL assessments, LL, occurrence reports, and enforcement actions.

Analysis of the key precursor data and improvement opportunities showed the precursors grouped within eight general categories. There is a strong correlation to the causal factors observed in this event investigation. Precursors were identified in historical information as follows:

- Engagement of SMEs and workers in scoping and work planning was identified in three of five sources
- Improving work package consistency and formality was in one source
- Defining and communicating roles and responsibilities were in two of five sources
- Work scoping and effective hazard analysis and implementation of controls were in three of five sources
- Pre-Job Briefing or communicating work conditions were in three of five sources
- Changing work conditions was in three of five sources
- Working outside the IWD or failure to implement controls was in one of five sources
- Assessing Work Practices (Feedback) was in one source

LANL had previously identified the precursors and established corresponding corrective actions, improvement plans, and integrated activities with goals and objectives. In some cases actions have demonstrated commitment by management and workers with progress as demonstrated through VPP worker involvement and *Strategic Plan for Improving Integrated Work Management*. Others have not yet been completed, but those completed were not sustained or effective at the task level as shown by this historical analysis.

| |
|---|
| JON-12: LANL needs to improve its ability to implement and verify corrective actions from previous assessments and events. |

### 3.4 ISM/Work Planning and Controls

*Facts*

The overarching upper-level document for LANL work planning and control is procedure P300, *Integrated Work Management*. Based on ISM's core functions, P300 has been established so that it is possible to perform work in a way that protects people, the environment, property, and the security of the nation.

P950, *Conduct of Maintenance* along with AP-Work-002, *Work Planning*, document and provide a detailed planning process for maintenance/construction activities identified through the work request, screening, and acceptance process.

LANL's Computerized Maintenance Management System (CMMS) and IWM processes were used to plan the LANSCE electrical switchgear PM outage. Using the IWM process, the Responsible Line Manager (RLM) determined that work at TA-53-0070 was considered a moderate-hazard activity. The outage planning included a detailed switching order and associated IWD.

A typical work-planning development process takes approximately eight weeks. LANSCE's outage scheduling led to the integration of the 5-Yr PM activity and the 2-Yr PM activity well in advance of the typical eight-week planning period.

The TA-53-0070 switchgear was initially planned to be de-energized over the entire weekend of May 2–3. However, on April 28, a proposal was made by MSS personnel to re-energize Bus B and Bus C while leaving Bus A de-energized at the end of the day on Saturday, May 2. This decision was approved by the UI and LANSCE FODs, and followed discussions that had begun as early as April 21. Re-energizing Bus B and Bus C enabled LANSCE to transfer vacuum pump and other equipment power from temporary generators back to line power. LANSCE uses vacuum pumps to keep the accelerator beam cavity evacuated and the facility was prepared to support a two-day shutdown without bringing vacuum pumps back on line. Re-energizing Bus B and Bus C also allowed UI to bring power back to local sanitary lift stations.

The clearance procedure to re-energize Bus B and Bus C on Saturday evening was requested by the Planner on April 28, but no additional hazard analysis was initiated. The PIC and work crew were also informed after the April 28 decision.

Because these two activities are performed every two and five years, two model work-order packages were created for TA-53-0070 switchgear maintenance. These two model work-orders were created years before the work, and had been successfully performed independently in previous evolutions. Both model work orders were reviewed by the Planner as part of the work package development process.

The JAIT reviewed both work packages. The 2-Yr PM package involved maintenance for the air circuit breakers. The 5-Yr PM was for cleaning the cubicles. Both packages included a Work Order Task section; Form 2103 (IWD Part 3, *Validation and Work Release*); Form 2101 (IWD Part 2, *FOD Requirements and Approval for Entry and Area Hazards and Controls*); Form 2100-WC (AP-Work-002: Attachment 15- *Facility Maintenance Activity Specific Information*); and AP-Work-002: Attachment 11– Maintenance and Site Services Work Completion Form. The following sections describe the results of the JAIT review.

### Define the Scope of Work

Within the standing IWD is the scope of work for both PM work packages. Form 2100-WC contains an Activity Description/Overview statement. The 5-Yr PM Activity Description/Overview statement reads as follows: "PERFORM 5YR. PREVENTATIVE MAINTENANCE ON SWITCHGEAR. OUTAGE REQUIRED FOR AFFECTED ELECTRICAL SWITCHGEAR, TRANSFORMER AND BLDGS.  WIPE, CLEAN, AND INSPECT. MAKE NECESSARY REPAIRS ONLY IF ELECTRICAL SYSTEM IS COMPROMIZED.

**The scope of work for the 5-Yr PM and the work package steps did not include information associated with work on a partially energized switchgear.**

Analyze the Hazards

The IWD process uses several tools and approaches to analyze work hazards. Once work is identified and the scope of work is defined, the first step to identify hazards is to determine hazard level by using the online Hazard Grading Table. An automated hazard-screening tool is also available on the LANL network. The TA-53-0070 Substation PM screened as a moderate-hazard activity.

According to P300, a work activity that screens at the moderate-hazard level, must use a hazard analysis method, "such as 'what-if' or Hazard and Operability Analysis (HAZOP)," to determine the hazards associated with potential accidents or incidents and how harm might be caused. This generally requires each of the tasks and work steps with an activity to be identified, defined, and planned so the associated hazards can be adequately mitigated. P300 states that: "The analysis may be graded based on the complexity of the moderate-hazard activity ranging from a relatively quick 'brainstorming' for simple activities to a documented 'what if' or 'HAZOP' for more complicated ones." The result of tabletop hazard analysis is incorporated into the Precautions/Limitations/Prerequisite, General Hazards and Work Step sections of AP-WORK-002: Attachment 15 – Form 2100-WC.

Also included into maintenance IWD work packages is IWD Part 2, Form 2101, "FOD Requirements and Approval for Entry and Area Hazards and Controls." This form is similar to the traditional Job Hazard Analysis, although it serves a different purpose. Besides its use as rudimentary high-level facility hazard screening, this form is mostly used to coordinate entry into LANL facilities and to identify site hazards.

Develop and Implement Controls

P300 provides information regarding the expectations on how to develop and implement controls, including details associated with a hierarchy of controls to mitigate hazards. The process also includes information related to IWD work-package documentation, peer review before approval, the expectation for a "validation walk down" and worker authorization. IWD forms used to document these expectations and additional more detailed procedure steps are found in MSS Work Control - Conduct of Maintenance (P950) Administrative Procedure AP-WORK-002, R14 *Work Planning*, as well as forms associated with that procedure.

Although there are slight differences among controls listed on the various forms in the two PM work packages, the following are common to both:

- Mode 0, Class 1.5 PPE is the minimum required during the work: Hard Hat, Safety Glasses, Nomex Long Sleeve Shirt, and Leather Gloves.
- A "VERIFY zero voltage" step that reads:
  - "Confirm no voltage or residual electrical present in circuit with an adequately rated voltage detection instrument to test each phase conductor or circuit part to verify that they are de-energized."
- A "ENSURE when performing Preventive Maintenance Work" step that reads:
  - "All affect(ed) equipment between clearance points is checked for zero voltage and grounded (if multiple equipment is being worked on in stages personal grounds may be applied and logged into Switching Procedure with dispatch)."
  - "Use a second person to verify zero voltage when testing (lineman, electrician, or apprentice)."

<u>Perform Work within Controls</u>

The IWM process and the IWD (Part 3, Work Validation and Work Release) describe the minimum content of pre-job briefs. Specifically, the following questions are to be asked as part of the pre-job:

- How can we make a mistake at this point?
- What is the worst thing that can go wrong?

The LANL Electrical Safety Program, (P101-13) also has requirements for pre-job brief content. Section 6.2.6 Pre-Job Briefing requires 12 subjects to be discussed for electrical work. Requirements applicable to this event include the following:

- Procedures that must be followed (e.g., two-person rule or safety watch)
- Special tools or test equipment to be used when executing the work task
- Any special precautions that are required by the working conditions
- Required PPE and protective clothing
- Other work being performed in the immediate physical area

<u>Provide Feedback and Improvement</u>

According to MSS Work Control - Conduct of Maintenance (P950) Administrative Procedure AP-WORK-002 R14 *Work Planning*, maintenance work activities that use IWD work packages, feedback is performed using AP-WORK-002: Attachment 11, Maintenance and Site Services Work Completion Form, as well as the Lessons Learned process.

*Analysis*

Define the Scope of Work

The scope of work in the switchgear-cleaning IWD work package [Work Order Task 00489196 01] was written at a broad activity level to enable the greatest flexibility of work execution.

**As a result, hazards at the task work level were not sufficiently identified, analyzed, or mitigated.**

Specifically, the IWD task steps involved bus de-energizing, cleaning, and re-energizing. This approach allowed the work package to be used for Saturday's work, when all three buses were de-energized, as well as for Sunday's work, when Bus B and Bus C were energized and Bus A remained de-energized.

JON-1: MSS and UI management need to strengthen expectations regarding work-scope determination, as well as task-level work planning and hazard analysis. These expectations should be reinforced and assessed frequently.

JON-10: MSS and UI management need to facilitate more direct involvement and ownership by craft in developing the work scope and job planning.

Analyze the Hazards

The IWD analysis did not evaluate the hazards and their associated effects of the following:

- Concurrently performing two PMs, which contributed to workplace clutter and a crowded environment
- Initiating a changing work configuration, when on Saturday all buses were de-energized but on Sunday such a configuration was changed to only a partial de-energization
- The possibility of human error by accidently entering and performing work on an energized cubicle

**Failure to perform this analysis resulted in a missed opportunity to include task-level controls, such as specific work-scope boundaries intended to demarcate between the energized and de-energized equipment.**

JON-7: MSS and UI management need to closely evaluate changing conditions when using standing IWDs during the planning process to ensure controls are aligned with actual work activities and site conditions.

Develop and Implement Controls

A work package developed at the task level may have prevented the human error that led to E1's injury.

**The specific failure was that the IWD did not evaluate hazards associated with changing conditions from Saturday to Sunday, when the switchgear went from completely de-energized to partially energized. The JAIT concluded that this omission constituted a missed opportunity, particularly when it came to identifying the need for an additional physical barrier that identified the boundaries of the de-energized Bus A.**

Such a barrier would have decreased the likelihood of the occurrence of human error that led to E1's injury.

Perform Work within Controls

The broad nature of the work-package planning meant that the work package neither acknowledged nor provided specific hazard-control information regarding the controls for working with partially energized equipment. The linemen used a rigorous and detailed switching procedure that provided step-by-step instructions to configure the switchgear for Sunday's work, so that Bus B and Bus C were energized while Bus A was de-energized. However, the IWD that the wiremen used did not provide a level of detail that addressed the hazards associated with the changed work configuration.

One work package was used to perform similar work on the switchgear on Saturday and Sunday, despite the fact that the switchgear configuration had changed, thereby introducing additional hazards from energized buses in adjacent lookalike cubicles.
The work package Form 2100-WC (Facility Maintenance Activity-Specific Information) did not address the possibility of a worker mistakenly opening and beginning work on an energized cubicle.

**The work package did not identify the elevated hazard associated with continuing the work on Sunday with a portion of the switchgear energized. This hazard was not recognized or addressed in the IWD, so no additional controls were in place to prevent human error.**

The additional hazard inserted due to the partial re-energization could have been mitigated had all workers implemented the zero-voltage check requirements in the IWD. A lineman capable of conducting zero-voltage checks on high voltage equipment was available on Sunday, though he was not always utilized for these checks. In interviews, several workers stated that they had conducted zero-voltage checks to satisfy their own personal safety concerns.

JON-5: MSS and UI management need to reinforce and clarify expectations and implementation for zero-voltage verification requirements in the course of electrical work at all organizational levels.

In 2013, LANL accepted NFPA 70E 2012, *Standard for Electrical Safety in the Workplace*, which specifically addresses the caution necessary around lookalike equipment in section 130.7(E)(4) **Look-Alike Equipment**, where work performed on equipment that is de-energized and placed in an electrically safe work condition exists in a work area with other energized equipment that is similar in size, shape, and construction, one of the alerting methods in 130.7(E)(1), (2), or (3) shall be employed to prevent the employee from entering lookalike equipment. In summary, these methods involve clear signage, physical barricades, or an attendant (safety watch).

The LANL Chief Electrical Safety Officer has indicated that this particular standard from 70E was not in effect due to the exclusion in 70E granted to installations that are under the "exclusive control of an electrical utility." While this exclusion may be valid, it has not been effectively implemented or proceduralized to provide adequate compensatory measures for instances when mixed crews, trained in 70E and 1910.269 are working together in such an installation. It is also noted that the JAIT benchmarking effort found other DOE facilities who utilize the 70E exclusion have implemented robust barriers as standard industry practice.

JON-11: MSS and UI management need to ensure robust, durable, and visible barriers and signs are appropriately placed and accurately reflect current work conditions, equipment status, and hazards to ensure worker safety.

Concurrent with the switchgear PM work to clean the cubicles, a separate PM was performed on the switchgear breakers. As part of this breaker PM, on Sunday morning workers removed breakers from the de-energized Bus A. The breakers were staged to move to the opposite end of the switchgear so they could undergo hi-pot testing. This testing necessitated additional equipment, tools, and personnel to complete the work.

**The JAIT concluded that the congested work area, additional personnel, and equipment might have contributed to an error-likely situation in which E1 chose to open cubicle 17 and work on an energized bus.**

High-voltage hazards in the hi-pot testing area—under the second PM— necessitated that yellow caution tape be hung to establish a boundary around the testing area. As discussed in other sections of this report, the JAIT concluded that the location of the yellow caution tape could have provided a confusing visual cue that influenced E1 to choose to work on energized cubicle 17.

The IWM process and the IWD (Part 3, Work Validation and Work Release) describe the minimum content of pre-job briefs. Specifically, the following questions are to be asked as part of the pre-job:

- How can we make a mistake at this point?
- What is the worst thing that can go wrong?

Although it is unclear if these questions were asked, it is clear that the pre-job did not anticipate the possibility of a worker mistakenly opening and beginning work on an energized cubicle. In addition to this IWD Part 3, it is also unclear if any of the required subjects for electrical work presented in the LANL Electrical Safety Program (P101-13) were incorporated into the pre-job briefs.

JON-8: MSS and UI management need to strengthen pre-job briefings at the beginning of each shift or when significant changes occur so that worker engagement, focus on important controls, operations integration, and a full understanding by all workers are all assured.

JON-9: LANL management needs to ensure workers are encouraged to and are acknowledged for playing an active role in ensuring their own (and work team's) safety and compliance with work rules.

The IWD process did identify hazards and develop controls for the cubicle cleaning that involved the use of PPE. However, the JAIT, through a review of physical and photographic evidence, found that not all workers used the identified PPE, and this expectation was neither communicated nor enforced by supervision or co-workers.

JON-6: MSS and UI management and direct supervision need to reinforce and clarify expectations (training, oversight, and accountability) for PPE requirements and work practices in the course of electrical work at all organization levels.

Provide Feedback and Improvement

**The work package's "Work Completion Form" was not completed because the PM was interrupted by the arc-flash event. Regardless, the JAIT evaluated previous efforts to review and improve LANL's Work Planning and Control process. One particularly applicable self-assessment was completed in 2013. The self-assessment identified Hazard Identification and Control as a "dominant weakness."**

Factors contributing to this conclusion that are relevant to this accident investigation include the following:

- ESH personnel were not consistently involved in work planning or when changes occurred to work
- IWDs and Exposure Assessments did not always consider co-located workers
- IWDs did not always define the work in sufficient detail to adequate identify and analyze hazards.
- Hazard controls were not always adequate for the identified hazards; sometimes controls were missing altogether

Analysis also identified observations chronicled in the Health, Safety, and Security Investigation Reports (January 2012) involving four Hazardous Control Events at LANL. These observations included a potential violation of NPFA 70E, Section 120.1 "Process of Achieving an Electrically Safe Work Condition." The specific applicable requirement that links to this event is the following requirement: "Use an adequately rated voltage detector to test each phase conductor or circuit part to verify they are de-energized." This accident could have been prevented if LANL's corporate feedback and improvement process had driven corrective actions adequately from this 2012 event. Such actions would ensure an electrically safe work environment, particularly when it came to the verification of zero energy before starting work.

### 3.5 Conduct of Operations

*Facts*

In July 1990, DOE issued DOE Order 5480.19, *Conduct of Operations Requirements for DOE Facilities*. This Order's guidelines were designed to form a compendium of good management practices and describe key elements that support excellence in operation. In 2001, this Order was added to the Prime Contract. In June 2010, DOE Order 422.1, *Conduct of Operations*, superseded DOE Order 5480.19 and was added to LANL's contract in January 2011. The requirements in P315, the LANL *Conduct of Operations Manual,* are applicable to all Laboratory workers.

Training & Qualification and Control of Equipment and System Status are two key Conduct of Operations elements applicable to this accident and are discussed below.

Training & Qualification

Members of the medium-voltage-breaker maintenance crew and linemen crew are both under rigorous training and qualification programs. Each program requires thousands of hours of experience and hundreds of hours of formal training all of which produces licensed journeymen electricians qualified to work within the LANL environment. A key aspect of this training and experience is to be proficient at recognizing a variety of electrical hazards and detailed knowledge of implementing associated controls. These controls come from several national standards and are implemented at LANL through training identified in P 101-13, *Electrical Safety Program.*

Applicable national standards, LANL P 101-13, formal training and demonstrated proficiency requirements all focus heavily on how to identify and quantify hazards. Workers must demonstrate that they know the proper instruments to test for a given voltage for all work they are trained to perform. They are also required to demonstrate that they know and understand PPE requirements for this work. This stage of electrical work is considered the most critical line of defense. Working on energized equipment is rarely permitted within DOE facilities and requires senior management approval, per P 101-13, *Electrical Safety Program*. (In this accident, there was no intention to work on energized equipment.) Linemen, however, do regularly work on energized overhead equipment and power lines.

There are two institutional training plans that apply to electrical craft work at LANL. TP 2559, *Electricians/Apprentice Electricians and Facility Engineers* and TP2911, *Linemen & Utility Engineers.* Additionally, although not required, some workers have completed training plan 810, *Electrician Sub-station Electrical Worker.*

TP 2911 is assigned to all linemen crewmembers. This plan contains the following:

- training on the LANL electrical safety program for electrical craft,
- electrical transmission and distribution safety (OSHA 1910.269),
- personal protective equipment and signage (NFPA 70E),
- National Electrical Safety Code (NESC) (focuses on utility work),
- First Aid, and
- Annual CPR/AED certification.

TP 810 was previously assigned only to crew members dedicated to breaker maintenance and contains two classes delivered by AVO, a subcontractor to LANL:

- Course 33964, Circuit Breaker Testing Certification
- Course 3967, Substation Maintenance Certification

TP 2559 is assigned to all wiremen and electrical breaker maintenance crewmembers. This plan contains the following:

- training on the LANL electrical safety program for electrical craft,

- personal protective equipment and signage (NFPA 70E),
- First Aid,
- Annual CPR/AED certification, and
- NEC Update Training (Tri-Annual).

*Analysis*

Training & Qualification for Electrical Work

Training Plans (TP) and Electrical Worker Qualification Forms are both tracked using electronic databases to maintain the status of each electrical worker at LANL.

Training and qualification programs and the associated requirements for all involved workers were reviewed in depth and were deemed to be well designed and implemented with *two caveats:*

- *Though both linemen and wiremen are trained in 70E, there was no evidence presented that wiremen were trained to recognize the exclusion from 70E requirements while working in the Substation and switchgear, asserted to be under the "exclusive control of the electrical utility," i.e., the linemen.*
- *Subcontracted technical training offered to the breaker maintenance crew, mostly wiremen, has not been offered for several years. This training increases skills for working on breakers and in switchgear. It is recommended LANL evaluate whether this training should be provided in the future.*

Control of Equipment and System Status

The work packages to execute both the 2- and 5-Yr PM activities required for 13.8-kV switchgears at LANL were developed during previous evolutions for this particular set of equipment. They were retained in the CMMS as standing work orders to facilitate scheduling routine work and work history. The 2-Yr breaker maintenance work order was triggered in the scheduling system in January of 2015. This work order contains an IWD that identifies the key work steps, precautions, and controls from P 101-13, *Electrical Safety Program* to conduct the work safely. The 5-Yr switchgear maintenance work order was initiated in the same timeframe. Individually, these two packages have both been conducted safely.

On this switchgear maintenance evolution, breaker work began two months before the accident. Individual breakers were isolated, removed, and tested under smaller power outages. This process reduced the overall work required the weekend of May 2 and 3.

**The status of the switchgear maintenance was informally tracked by applying tape to cubicles as they were completed. Red tape indicated breaker completion while blue tape indicated cleaning completion.**

This process was used as an Operator Aid, but was not formally approved. In addition to this informal process, no task-level assignments were made to complete the defined work scope.

JON-13: MSS and UI management need to evaluate use of informal work practices in the context of potential impact on the effectiveness of safety controls.

### 3.6 Supervision and Oversight of Work

*Facts*

Work was performed on substation TA-53-0070, which is under the control of UI Division Office, a part of UI-FOD.

Supervision Interaction during the Event

The line of supervision during the two IWDs being executed was as follows:

- E3, a wireman foreman, was present in the area when the event occurred. E3 conducted the job pre-brief and was monitoring the crew on the day of the event.
- E9, a general foreman assigned as an Alternate PIC. E9 was located in an adjacent building working on paperwork.
- L1 was also assigned as an alternate PIC on Sunday, and he briefed the linemen working on the outside of the switchgear.
- S1, a superintendent who served as RLM assigned to this work. S1 was also designated as facility and outage point of contact. S1 was not present in the area the day the event occurred.
- O1, a UI Electric Systems Operator. Located in the control center, O1 interacted via radio with lineman L1 at the beginning of shift.

There was interaction between L1 and O1 via radio to declare beginning of work activities inside substation TA-53-0070 at 0710 on May 3, 2015.

Hazard Analysis and Controls by Supervision

IWDs part 2, FOD *Requirements and Approval for Entry and Area Hazards and Controls,* were in place to address TA-53-0070 facility hazards. The form is a coordinating document between the facility tenant and non-tenant work crew and identifies general facility hazards. It is not intended to provide work-activity or task-level hazard analysis and controls.

The IWD form 2100-WC contains the hazard analysis at the work activity and task level. This form indicates the work steps developed by S1 and L2, both of whom are qualified ESOs, in conjunction with a planner. The form was approved by all three, as well as by a

FOD designee, who in this case was a UI-OPS person. The form contains several notes, cautions, and warnings not embedded in the work steps. Because the controls are written generically, the IWDs do not mandate that the crew performing the work go back and read/comply with the notes, cautions, and warnings every time the work is re-started after a pause.

There is a hold point before step 1 of the work order for the 5-Yr PM that requires that equipment be evaluated for additional AC/DC electrical hazards present from another source and evaluate appropriate controls prior to commencing work, but there are no sign-offs to indicate who releases such a hold point.

Work Control Supervision

*Pre-Job Brief*. IWD part 3, form 2103, for the 5-Yr PM, which contains the PIC designation and the pre-job brief attendance, documents the assignment of the primary PIC and two authorized alternate PICs. The 2-Yr PM form 2103 named E9 as a PIC.

E3 conducted the pre-job brief in the switchgear before work started on May 3, 2015. This brief accurately described the boundaries of the clearance that was issued for the work to be performed on that day.

The pre-job brief, conducted in front of cubicle 18 (Tiebreaker Bus A and Bus B), explained to all crewmembers that the clearance tag located on cubicle 18 was the electrical boundary to isolate Bus A from the energized Bus B and Bus C. This tag also indicated that the tiebreaker inside cubicle 18 had been racked out of the circuit and physically locked in that position. Forms 2103 for both IWDs have a pre-job brief attendance roster but do not have a method to track daily attendance.

*Housekeeping and Conduct*. The available work area inside the switchgear building is small. The corridor was crowded with two breakers in front of the energized Bus B and Bus C. This corridor was enclosed with yellow caution tape because of hi-pot testing, in addition to the actual hi-pot test set and respective cables, which hung from the ceiling (Figure. 3-1). In front of Bus A were another breaker in the corridor, a bench, and several stools. There was a piece of test equipment on the floor against the wall across from cubicle 17, where E1's head would strike. Two doors were open in cubicles from Bus A that somewhat limited the line of sight across the corridor (Figure 3-2).

The JAIT found a half-burned cigarette on the floor in front of cubicle 17 (Figure 3-3). *Danger-No Smoking* signs were visible in the switchgear. There is no evidence that this cigarette was from E1, or even that it had been deposited on the day of the accident.

It was noted that E1 was wearing a baseball cap—not a hard hat, as required by the IWD. Moreover, E1 had his AR shirt's long sleeves rolled up at the time of the accident.


*Figure 3-1. This photo shows the area in front of energized Bus B and Bus C, both of which power the LANSCE area. Note how close the breakers under test were set to the operating equipment. There is an open cubicle door on the operating area. The blue device is the hi-pot test set. The area is so crowded that it almost blocks the east side exit door.*

*Figure 3-2. This photo shows the front of de-energized Bus A. Note the one air breaker on the floor, as well as a bench, trash, and extension cord, and scattered tools.*

*Figure 3-3. This close-up shot shows the area in front of cubicle 17. Note the "ductor" test set, tools, a class-2 glove, a cigarette butt, and a bench.*

*Work Execution*. The JAIT found no individual cubicle sign-off for the maintenance activity for the 5-Yr PM.

It is important to note that the switchgear cleaning/inspection process is performed at the front and at the back of the cubicle. The front part is accessible from inside the switchgear and is cleaned/inspected by wiremen (electricians). The back part is accessible from outside the switchgear and is cleaned/inspected by linemen.

An informal process employing blue tape and red tape to track the completion of the cleaning process and circuit breaker testing was used. Blue indicated that the cubicle cleaning had been completed. Red indicated the completion of breaker testing and cleaning. The tape was adhered to each cubicle as the crew reported activities as complete. Cubicle 17, which is part of Bus B cleaned Saturday, did not have any blue tape installed.

*Analysis*

Supervision Interaction during the Event.

The following supervision layers had opportunities, but did not make changes in hazard controls on Sunday to account for the energized buses: E3 (foreman), E9 (General Foreman and PIC), S1 (Superintendent), and UI-FOD representative. However, E3 was clear as to the area to be worked on Bus A, and where not to work, during the pre-job brief. No additional resources were identified to better monitor the work area on the day of the accident.

The UI-FOD representative did not visit the area on Sunday, and as a result an opportunity was missed to have another set of eyes to point out additional control measures at partially energized switchgear. The following is a section of the IWM P300 manual, which provides guidance in a situation like the one on Sunday:

> "If multiple activities within a project or work area must be coordinated to ensure safety, security, or environmental protection, the FOD must designate an individual to provide that coordination and must inform the other participating RLMs and PICs of that individual's identity and authority. Information regarding "Negotiating Shared Space/Shared Activities" is available in the IWM Toolbox in the *Guidance Documents* section."

However, there were no physical area control measures mandated by UI-FOD or UI-OPS to prevent traffic or access to the corridor in front of energized Bus B and Bus C that were restored on Saturday night for LANSCE operation. Area control measures like plastic barricades are typically installed to divide the area that contains equipment in operation and equipment out for maintenance (Figure. 3-1).

JON-4: LANL needs to effectively implement human-performance error-prevention tools in work planning and hazard analysis.

Hazard Analysis and Controls by Supervision

IWDs did not sufficiently recognize the unique characteristics of combining the two maintenance activities with partially energized switchgear. In addition to the added challenges posed by mixed experience and qualification levels of the work crew, the increased risk of human error was not recognized.

The hazards analysis took place at the activity level, rather than at the task level. As a result, no new controls were added to mitigate new hazards. The PIC (L2), the wireman foreman (E3), and the craft workers had no input into the hazard analysis process.

The following considerations from IWM P300 were not taken into account during the hazard analysis for Sunday activities and could have been helpful to prevent the accident: "Consideration should also be given to facility-related conditions that may adversely affect the safety of an activity such as the loss of electrical power, and operational upsets in shared facilities." The facility-related conditions of congestion and partially-energized switchgear should have led supervision to determine that more controls or additional hazard analysis was required.

Supervision of Work Control

*Pre-Job Brief*. The PIC did not carry out the pre-job brief on Sunday. Because there had been such a change in hazards, the PIC should have carried out another pre-job brief. However, he was in attendance during the Sunday pre-job brief that was presented by E3.

Although the PIC did not conduct the pre-job brief, the crew was clear that E3 was supervising work inside the switchgear. It was also clear that both job activities were being monitored by E3. This also allowed the PIC to catch up on paperwork in a building directly adjacent to the switchgear.

During the pre-job brief, there was a missed opportunity to mitigate the additional risk introduced by partially energizing the switchgear. There was no discussion about extra precautions that may need to be taken, especially since the previous day's work had taken place with all components completely de-energized.

If a pre-job brief is conducted daily, P300 Form 2103 does not have a requirement or place to track the daily attendance. This means that it is not possible to validate worker agreement and confirmation of his or her authorization, qualifications, and fitness to perform work, as mandated by the IWM P300 process. This particular IWD had been first used on March 21 and a pre-job brief was performed on multiple days as work progressed.

It is noted that Standing IWDs (SIWDs) can be used for repetitive, moderate-hazard work activities in single or multiple facilities, in accordance with the IWM P300 manual. This document consists of a standardized, previously developed and approved Part 1, combined with an appropriate Part 2 for each facility that lists the specific facility entry and coordination requirements and work-area hazards. In each case, the PIC must ensure the activity-specific and work-area requirements do not conflict.

Activities covered by SIWDs require the PIC to walk down the actual system or equipment and conduct a pre-job brief before beginning work. Only one pre-job brief is required if the work (1) is performed repetitively at the same location with the same workers and (2) when periodic reviews are performed to detect changes in the work, work site, and hazards. The second stipulation did not apply for work on Sunday because there were significant changes in the work conditions from Saturday. Instead, a new pre-job brief form should have been signed.

*Housekeeping and Conduct*. Figures 3-1, 3-2, and 3-3 show that housekeeping in the switchgear was less than adequate, a factor that could have contributed to the accident. Management and supervision at all levels need to reinforce and clarify expectations for the implementation of IWM P300.

*Work Execution.*

**Supervision did not implement a formal work-tracking mechanism for the 5-Yr PM.**

The JAIT found that form JS00009—provided in the IWD—is not adequate to record details and to provide an accurate record of the maintenance activity. An individual record-per-cubicle, with places for both front and back side cleaning/inspection, would have been helpful so that the supervisor could track completion and perhaps even prevent E1 from entering a previously cleaned cubicle.

Not tracking or giving out cubicle assignments meant that work activity and scope were left to the discretion of the individual workers. This approach prevented positive control and peer check by supervision for worker actions that could have prevented E1 from entering cubicle 17.

**Zero-voltage and positive-energy control was not enforced/not performed when cubicle 17 was opened on Sunday.**

E1 opened and began work in an energized cubicle. No one noticed that E1 was working in cubicle 17 and did not recognize that it was in fact outside the clearance boundary. The JAIT estimated that E1 had the door to cubicle 17 open for at least 10 minutes before he commenced work.

JON-2: MSS and UI management need to strengthen expectations regarding rigor in task-level work execution within controls. These expectations should be reinforced and assessed frequently.

The JAIT also has photographic and other evidence that PPE specified by the IWDs was not worn in all cases inside the switchgear work area, and supervision took no action to correct these deficiencies on either Saturday or Sunday, the day of the accident.

JON-6: MSS and UI management and direct supervision need to reinforce and clarify expectations (training, oversight, and accountability) for PPE requirements and work practices in the course of electrical work at all organization levels.

### 3.7 NNSA/Los Alamos Field Office Oversight

*Facts*

The NNSA/NA-LA is the onsite federal organization responsible for routine oversight of LANL. NA-LA conducts its oversight in accordance with an annual assessment plan, which follows DOE/NNSA policy and directives for line oversight. This assessment plan is integrated with internal LANL activities and other outside agency assessments for efficiency and complete coverage. Development of the plan requires an assessment of risk and oversight options in each area.

Safety oversight is accomplished by federal staff in four specific areas: Nuclear Safety Basis, Safety System Oversight, Facility Representatives, and Safety Programs. The first three areas are focused on nuclear facility operations, with the safety programs crosscutting all LANL operations and programs.

Program oversight for relevant Safety Programs, including Electrical Safety and Maintenance, is conducted by a group of nine SMEs. Although there is no designated Electrical SME NA-LA, Electrical Safety at LANL is monitored on a part-time basis as part of industrial safety oversight and supplemented on a case-by-case basis by the electrical systems engineer from Safety System Oversight.

The Maintenance Program has been reviewed at the required periodicity. Although there is no requirement for a programmatic assessment of the Electrical Safety Program, a programmatic assessment of Electrical Inspections, which included some elements of electrical safety, was performed in 2012. Members of the SME team are actively involved in oversight of programmatic activities, and frequently shadow LANL employees performing assessments.

The Facility Representative Team is comprised of a team leader and seven facility representatives, with one vacancy. Three of the eight members of the team are retirement-eligible and there were 12 facility representatives as recently as 2011. Due to limited available staffing, no targeted safety assessments were scheduled in 2014, and none are planned for 2015. No facility representatives are assigned to non-nuclear facilities, including UI or LANSCE.

Contractor Performance Evaluation Reports (PERs) produced by the federal field office for 2014 and 2013 indicate issues with LANL formality of operations, self-discovery of operational issues, and effective corrective action processes.

*Analysis*

NA-LA and other external entities perform a significant number of assessments and other oversight activities at LANL each year. These assessments are integrated with LANL internal assessments, a good practice that generates both efficiencies and opportunities for partnering on assessments.

Industrial Safety SMEs are very active in shadowing LANL assessments, and they are active in appropriate safety committees at LANL. Without a formally appointed Electrical Safety SME, however, there is reduced opportunity for NA-LA to follow up on corrective actions from previous incidents. Development of a set of roles and responsibilities for an Electrical Safety SME would be beneficial as a checklist for anyone acting in the position, even temporarily. An Electrical Safety Program Assessment, such as those performed at many sites around 2009, would also be beneficial.

Federal oversight of safety management programs at LANL is heavily focused on implementation through work control processes. No federal staff member has been assigned to focus on these processes since initial development of the IWM Process in the 2002 timeframe. This initial effort was driven both by the DOE-wide effort to implement ISM and a series of serious accidents at LANL resulting in a temporary stand down of all work at LANL.

Several concerted efforts since 2004 by LANL to improve IWM have been undertaken, mainly driven by serious accidents and near-miss events. Electrical work-related events are a dominant theme in this data, in spite of the fact that the LANL electrical safety program has shown improvement. This improvement was achieved through a deliberate joint improvement effort between the LANL and NA-LA from 2005 to 2011. Also, historical data indicate that the IWM improvement efforts were more effective at improving safety in scientific work than facility work.

Efforts by NA-LA over the last decade to improve work control have had limited lasting impact. The vision of the DOE ISM System for executing hazardous work at LANL has not been fully achieved. This outcome is largely caused by ineffective processes to ensure lessons learned drive sustained improvement by both LANL and DOE, as documented in numerous assessments.

Focused electrical safety oversight by NA-LA was initiated in response to the NNSA Administrator's demand in 2004 to improve electrical safety complex-wide. Once this objective was achieved, federal resources were substantially pared back. Today, there are few active electrical safety professionals in DOE.

Based on these analyses, federal oversight and the contractor evaluation processes have not been effective in driving the necessary improvements in work control at LANL, with emphasis added on implementation of the documented processes.

PERs conducted in previous years have noted problems associated with self-discovery and formality of operations. To help focus on improvement efforts, it is important that additional assets be provided to enable targeted assessments and oversight. This oversight can provide needed assurance to the NA-LA Manager that repeat issues are being corrected.

### 3.8 Human-Performance Analysis and Interfaces

*Facts*

A team made up of linemen and wiremen was assembled to work overtime on May 2–3, 2015. This team's objective was to clean the TA-53-0070 switchgear and complete circuit breaker maintenance. Each team member clearly understood the objectives stipulated for the weekend work. Appendix H indicates tasks assigned and experience level of personnel.

Up to twenty-eight hours of overtime was requested for the weekend work, and the workers had completed a forty hour work week by Friday. Because the work was expected to be completed before the end of the day on Sunday, all the overtime requested would not have been used. This overtime was requested and worked in accordance with LANL policy.

The work package for the TA-53-0070 switchgear PM used a 5-Yr-old-model work package. This work package was created at the activity level, not at a task level. When work conditions (status of buses being energized or de-energized) changed from Saturday to Sunday, the work package did not include detailed hazard controls necessary to prevent E1 from entering cubicle 17.

**The activity-level work packages also did not evaluate the impact and potential hazards introduced by working two PMs concurrently in a small workspace.**

Four team members normally did other electrical work and did not work with the switchgear team, and one was doing this sort of work for the first time. Note that E1 was familiar with switchgear work. It is not clear how training and qualification was verified for these team members.

**PPE worn by the team members did not match the requirements of the work packages. *See 3.4.***

Several team members did comment that working two PMs concurrently was unusual and did contribute to workplace congestion.

On May 2, the PIC conducted a pre-job brief for the entire crew. This brief was followed by three additional briefs: (1) one for the crew working the switchgear, (2) one for the linemen outside, and (3) one for the fire-protection crew.

The crew worked 14 hours on May 2. LANL provided hotel accommodations for the crew to afford the members maximum downtime by avoiding the traveling of great distances. Three members of the work crew did not take advantage of the accommodations because they lived close to Los Alamos.

Work on May 2 ended with Bus B and Bus C re-energized. Linemen had completed cleaning all cubicles from the outside of the switchgear.

Information obtained from worker interviews revealed that all employees were well rested and felt good upon returning to work at 0630 on May 3. The progress made on the previous day was such that they felt there was a good chance that work on May 3 would be completed early. In interviews, it was stated that there were conversations to suggest E1 did not want to be at work any longer than necessary on May 3 so that he could attend a personal event later in the day.

On May 3, three pre-job briefs were held: (1) one for the crew assigned to work inside the building, (2) one for the linemen working outside, and (3) one for the fire-protection crew. The crew assigned to work inside the building received a comprehensive brief at Cubicle 18 of what specifically had been re-energized (cubicles 1-18). The tag on cubicle 18, marking a clearance point, was explained to all workers. There was an opportunity for questions and clarification in all the briefs.

During the switchgear-room brief, E1 asked about extra safety grounding on the 13.8-kV side of transformer TR-1, which is located outside the building. The crew agreed that such extra grounding would provide an extra safety measure. It was also agreed that work would be carried out with E1 observing the ground placement.

**The interviews revealed that some of the employees expressed concern over some equipment being re-energized, though these concerns were not noted at the pre-job brief.**

To track work progress, an informal system that is neither proceduralized nor formalized was used to signify that breaker work and cubicle cleaning were completed. Blue tape indicated that the cubicle cleaning had been completed. Red tape indicated the completion of breaker testing. After the event, red and blue strips of tape were found on cubicles for work completed on May 2. Tape was also found on one cubicle from work performed earlier in the month.

Cubicle 17 (where the accident took place) should have been marked with blue tape only, as it contains no breaker, and it had been cleaned on Saturday.

**Photographic evidence (Figure 3-4) and subsequent JAIT inspection revealed that cubicle 17 did not have tape of any color on it and there had never been any colored tape placed there.**

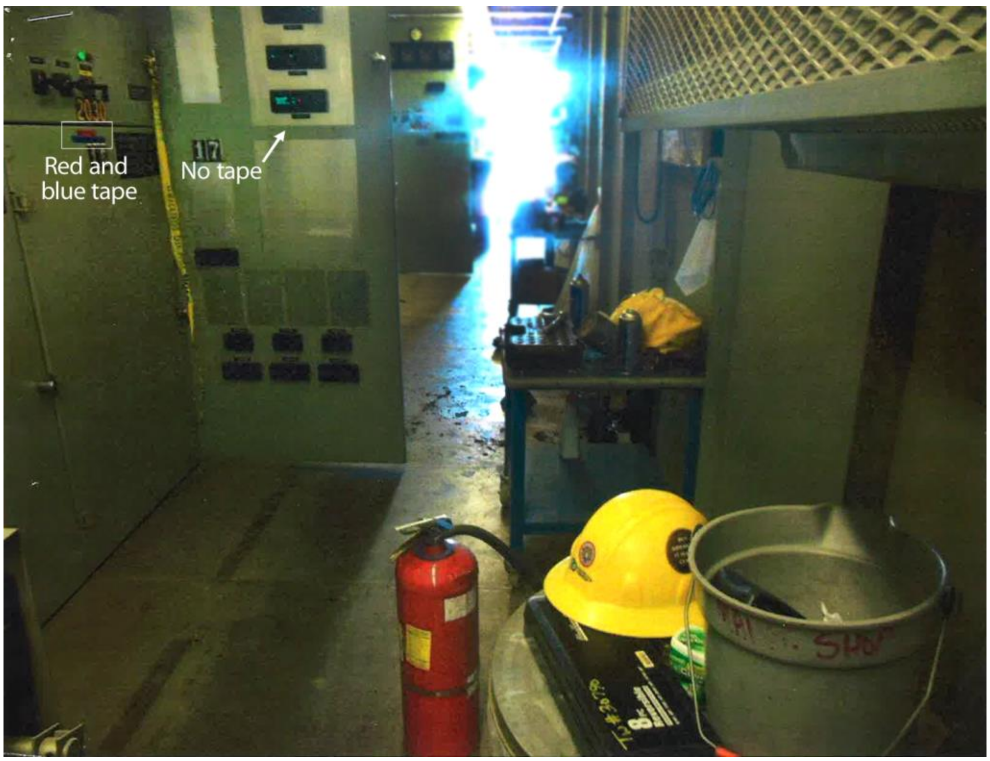


*Figure. 3-4. No tape was found on cubicle 17.*
*Note the red and blue tape on the adjacent cubicle.*

No crewmember remembers noticing the cubicle-17 door open leading up to the accident. However, E6 remembers seeing the cubicle-17 door open as he walked past immediately before the accident. E4 was aware that the door was open immediately before the accident, but he cannot remember seeing anyone there. Both employees saw and heard the arc-flash immediately after they became cognizant of the open door. No one remembers seeing E1 open the door or working in the cubicle.

Figure. 3-5. *Yellow caution tape was used as a barrier for hi-pot testing.*

The work carried out on May 3 involved a significant number of people (8-9) and equipment in a relatively confined space. Yellow caution tape—identified after the accident—was used as a barrier for the hi-pot testing. The tape (Figure 3-5), along with a verbal protocol, was used to establish an exclusion zone while testing took place. This process was clearly stated and understood at the pre-job brief.

During the post-Accident interview process, some employees expressed concern that this was the first time they had worked near energized cubicles. These concerns were not raised during the pre-job brief.

Other employees countered that such work was common practice. This split was further highlighted by differences in expectations when it came to LOTO. Linemen knew that the clearance tag was the norm, whereas the wiremen were accustomed to LOTO as the norm, but trained to recognize the clearance process.

Some members of the crew pointed out that this was the first time they had worked on two concurrent PMs (cleaning cubicles and breaker testing). Practice before this evolution had been to complete cleaning with the switchgear fully isolated. Then at some later date, execute limited outages to allow cleaning and testing of a few breakers at a time. This was actually done to several breakers a month before the accident.

**Interviews also revealed that there was confusion about whether zero-voltage checks should be performed on each cubicle. Some workers did not know who should perform the checks, if they were to be performed at all. Testimony states that some cubicles were checked, but not all.**

There were no physical barriers or deterrents to prevent work in cubicle 17. Instead, workers had to rely on the clearance tag, a problem for workers not accustomed to performing work with such a tag.

All employees interviewed understood clearly who the foreman and general foreman were for the entire job. Interviewed workers stated that no one saw the event take place. However, E2 stated that he saw a body ejected from cubicle 17. E2 further stated that he saw E1 on the floor immediately after the arc-flash, as did E4, who then informed E3.

Many of the interviewed workers say that they heard E1 say things after the accident happened that implied that E1 had not expected the cubicle to be energized. E1 was described as hardworking and driven employee.

No drug or alcohol testing was performed post-event, as specified in Procedure P732, Section 3.6.4:

*Drug and/or alcohol testing is/are required when*

- *a non-vehicular incident or accident that resulted in a serious injury or had the potential for serious injury occurs at work.*

It is recognized that the priority was treatment of the injured employee, but other involved workers in the accident could have been available for testing.

*Analysis*

Table 3-1 indicates there were a significant number of error precursors present prior to this event.

<u>Familiarity with Work Tasks and Location with Mixed Teams</u>

Several assigned crewmembers did not typically work with the switchgear crew. These members joined the work crew to support available breaker crewmembers and as a result of overtime polling. The resultant crew was mixed, with some members accustomed to this work (routine) and others possessing little or no experience. Additionally, one individual was performing this type of work for the first time. Significant work experience may breed overconfidence on one extreme and little to no experience in the detailed safety precautions required on the other. Such characteristics are particularly noted when it came to zero-grounding requirements, in which interviews revealed that there were many variations of what should be done and what was perceived to be done, with no consistency through the answers.

| |
|---|
| JON-3: LANL needs to establish uniform and stringent implementation of safety requirements when executing work involving mixed work crews (e.g., different disciplines, experience, and qualifications). |

Work control demonstrated several human-factor issues in terms of concerns (such as partial re-energization and combining work packages) raised by various team members assigned to carry out the work.

**Table 3-1. Human Performance Error Precursors.**

| Task Demands | Individual Capabilities |
|---|---|
| **Time considerations**<br>Need to re-energize B&C Saturday Night<br>Need to be finished by Sunday night<br>May get finished early | **Lack of knowledge (faulty mental mode)**<br>Loss of bearings and missed visual demarcation<br>Lack of PPE adherence<br>Numbers of workers non routine to Substation work<br>One person first time ever on the job |
| **Repetitive actions**<br>Clean a cubicle mark it move on to another unmarked cubicle | **Illness or fatigue**<br>14-hour day on Saturday |
| **Irreversible actions**<br>Opened cubicle 17 and cleaning started<br>E1 sprayed cleaning fluid into cubicle 17 | |
| **Interpretation of requirements**<br>Only clean to the East Side of the clearance tag on cubicle 18<br>West of the clearance is energized | |
| **Work Environment** | **Human Nature** |
| **Unclear goals roles or responsibilities**<br>Clean cubicle should not have led to an energized cubicle being opened | |
| **Changes/departure from routine**<br>For some, doing two PM's simultaneously<br>Working beside re-energized equipment<br>Not completing the job without de-energization the whole time | **Assumptions**<br>If the cubicle needs cleaned it is de-energized<br>If cubicle does not have colored tape it needs cleaning |
| **Confusing displays or controls**<br>Red/blue tape signifies complete, missing from cubicle 17 (which is energized)<br>Clearance tags more normal for linemen, not wiremen<br>E1 is an wireman<br>Yellow caution tape directly next to cubicle 17 | **Mindset (intentions)**<br>E1 is a hard worker and does not like to sit around<br>Desire to help the team get finished |
| **Unexpected equipment conditions**<br>Cubicle17 had no colored tape to signify it had been completed, implication therefore it needed cleaning and must be de-energized | |
| **Lack of alternative indication**<br>No physical deterrent from opening an energized cubicle | |

Activity-level planning using standing work orders allowed an assumption that two packages normally worked separately would not introduce new hazards when both were worked together. Work was planned at the activity level, so combining two PMs did not trigger a new analysis. Each work package was looked at separately.

<u>Conflicting Visual Cues</u>

A high-voltage clearance tag was placed on cubicle 18 to indicate the separation point between energized systems from de-energized systems. Linemen traditionally use such tags, but it is not part of the normal process used by wiremen. The pre-job brief clearly identified and pointed out the tag, as well as which side of the tag was energized and which side was de-energized. The difficulty is that wiremen use a different LOTO process. Although wiremen are trained to recognize clearance tags, such recognition is not routine practice (they do not see such tags every day).

| |
|---|
| JON-4: LANL needs to effectively implement human-performance error-prevention tools in work planning and hazard analysis. |

An informal process was used with red and blue tape to identify when work is complete (Fig. 3-6). Red tape on the cubicle indicates the breaker is finished and the blue tape means that the cubicle is clean. This process is not documented or developed in formal job planning. While a process is helpful to prevent duplication and provide visual status of work, if it is not well understood and formalized, it can cause errors. The cubicle where the event took place should have had blue tape, as it was cleaned on Saturday.


*Figure 3-6. Cubicle 19 showing both the breaker testing and cleaning is complete, in contrast to Cubicle 17 with no tape on Sunday, even though Cubicle 17 is on a re-energized bus.*

However, because the process was informal, there was no verification step to ensure all cubicles cleaned Saturday were labeled. The absence of tape may have caused confusion among the crewmembers. Cubicle 17 has no breaker so the door would not have red tape, which may have also confused E1 when looking at the door to determine what work was left to complete.

Hi-pot testing took place in front of the energized cubicles. As a precaution, visible yellow caution tape was used to prevent access to the hi-pot testing work area. Testing took place just past the cubicle where the arc-flash event occurred. By placing yellow caution tape at the junction between cubicle 16 and 17, this highly visible aid may have unintentionally placed energized cubicle 17 into what could have been perceived as a "safe" area to work.

Recognizing and Addressing Personnel Performance Issues

Informality of wearing PPE and apparent lack of recognition by supervision indicates that standards and safety culture had slipped in the wiremen work team.

JON-9: LANL management needs to ensure workers are encouraged to and are acknowledged for playing an active role in ensuring their own (and work team's) safety and compliance with work rules.

May 2 proved to be a long day, and it had become apparent that an early finish was a possibility for May 3. Although this is not an issue in its own right, it is a distraction from the work being performed, as the focus was on getting everything done as soon as possible. Everyone had been working in a relatively small and congested area. Employees focused on getting the work done, so much so that situational awareness by each worker may have been impacted, thus, no one saw E1 open the door and start working in cubicle 17.

# 4.0 CAUSAL ANALYSIS AND RESULTS

The JAIT used the following to conduct causal analysis: event charting, barrier analysis, and change analysis. Once causal analysis was completed, the JAIT identified conclusions, which were further grouped into contributing causes and a root cause.

## 4.1 Direct Cause

The direct cause of this accident was wireman E1 entering an energized cubicle and spraying cleaning fluid into the air gap between the bus bars and the grounded enclosure. The aerosolized fluid created a path to ground, resulting in an arc-flash.

## 4.2 Contributing Causes

The JAIT identified five contributing causes during its investigation of this event.

*Contributing Cause: The scope of work at the task level was not adequately defined.*

Although the two PM work packages each comprised relatively straightforward activities, a more detailed plan at the task level should have been performed. When both PMs were combined, they were performed within a cramped work space. These activities were further complicated by energizing two of the three buses in the switchgear. A new work plan should have recognized the physical and energy-source interfaces between the two groups, and the small and cramped work environment, and could have utilized a formally controlled and documented work status, thus enabling supervisory personnel to apply more oversight during critical times.

*Contributing Cause: Weaknesses in hazard-analysis processes resulted in some hazards not being analyzed.*

Additional hazards were introduced that were not covered by the general industrial hazard-analysis process because of the cramped workspaces and the interaction between the two PMs. When the work scope's definition was further changed by energizing two of the three buses in the switchgear, additional hazards of working in the vicinity of such energized equipment were not adequately evaluated.

*Contributing Cause: Controls were not effectively implemented to ensure safety on the job.*

Zero-voltage checks are the recognized method used before entering and interacting with new equipment. However, its application within two different groups who have varying standards and expectations, injected an element of risk for all the workers involved. The general hazard controls implemented in this event were not rigorously enforced inside the switchgear, thus resulting in inconsistent application of PPE and so on. The workspace's cramped nature necessitated the use of yellow caution tape as barriers for some of the work. The caution tape could have given false visual cues regarding the boundary between the energized and de-energized portions of the switchgear. The cramped nature of the switchgear made it difficult for supervision and other workers to routinely observe and question the performance of their co-workers.

*Contributing Cause: Work was not performed within controls, as envisioned by management and job planners.*

The informal work-status tracking mechanism used during this job meant that not all workers understood well the true status of all work. Inconsistent application of zero-voltage checks, as envisioned by management, was not caught by supervisors or questioned by co-workers.

*Contributing Cause: Feedback and lessons learned were not applied.*

Task-level controls that could have prevented this accident were not implemented. Lessons learned from other accidents, incidents, and work also were not implemented.

### 4.3 Root Cause

This accident's root cause lies in the management of control implementation. Such management was less than adequate, resulting in E1 accessing an energized cubicle without performing a zero-voltage check. These checks were applied inconsistently across the involved work groups.

When the decision was made to work with the switchgear partially energized, a clearance tag was used as the only barrier preventing entry to an energized panel. A more robust physical barrier or barriers with controls would have prevented human error by precluding entry to an energized area.

# 5.0 CONCLUSION AND JUDGMENTS OF NEED

Tables 5-1 and 5-2 list the JAIT's conclusions (root and contributing causes) and Judgments of Need (JONs). The contributing causes discussed in the previous section follow ISM's core process (such as defining the scope of work, analyzing hazards, developing and implementing controls, performing work, and providing feedback and improvement). LANL work control policies and procedures establish a framework consistent with ISM's core processes and principles. However, implementing these work-planning and executions procedures was inadequate for the two PM jobs being performed at the time of the accident.

In defining the scope of work, the planning process did not evaluate the added complexities associated with (1) performing two jobs concurrently and (2) working in a partially energized environment on May 3. Work packages developed years ago for each individual job were used without evaluating these changes in condition. Therefore, analyzing the hazards meant that such changes (combining the jobs and working in a partially energized environment) were not recognized. There was not an evaluation of possible human error as an initiator for a potential accident.

The absence of such an analysis meant that the development of robust controls (such as a physical barrier or safety watch) was not contemplated. During work execution, an environment was created in which a mistake resulted in an employee injury as a result of (1) a lack of robust controls, (2) a cluttered/congested work environment, (3) a lack of a formal work-tracking mechanism, and (4) possibly confusing visual cues to all employees, but in particular to E1.

Although this accident involved an electrical arc-flash, the shortfalls that contributed to the accident reside in work control implementation. A review of past assessments, events, and incidents reveal that LANL has experienced a number of similar work control negative trends and related corrective actions. If these lessons and corrective actions had been fully implemented in the work planning effort for the weekend of May 2, 2015, the likelihood of the accident would have been significantly reduced.

Table 5-1 lists the JAIT's specific conclusions. Conclusion numbers reference specific causal factors derived from applying both barrier and change analyses performed by the JAIT and its technical advisors. Table 5-2 lists the JONs identified by the JAIT. The JAIT strongly recommends critical thought be applied to corrective action development in response to the JONs, particularly when contemplating the addition of procedures, policies, or requirements. Simply adding more documentation will not necessarily address the issues experienced during this particular event. Instead, place more focus on finding ways to ensure proper implementation, clearly understood expectations, and effective verification of implementation. Also consider reviewing current processes to remove inefficiencies and distractions to effective implementation.

**Table 5-1**

| Causal Factor No. | Conclusions—Root and Contributing Causes | JON No. |
|---|---|---|
| *Root Cause: Less-than-adequate management of control implementation.* | | |
| C12 | E1 did not have zero-voltage verification performed for Cubicle 17. | 3, 5 |
| C13 | Processes (zero-voltage checks) were not consistently implemented of understood at the task level. | 3, 5 |
| C20 | The absence of a uniquely marked physical barrier enables E1 to access Cubicle 17 by removing the cubicle door and internal panels. | 3, 4, 11, 13, 2 |
| *Contributing Cause: The scope of work at the task level was not adequately defined.* | | |
| C7 | The yellow caution barricade, intended to demark the hi-pot testing boundary, could have created confusion as to the location of the clearance point boundary and thus led E1 to believe Cubicle 17 was de-energized. | 2, 3, 4, 6, 11, 13 |
| C15 | Use of clearance tags is not the typical isolation method used by wiremen | 3, 11 |
| C16 | Trained employees did not identify the lack of required signs, tags, and barriers, a standard industry practice. | 9, 11 |
| C22 | Lack of a formal work-tracking mechanism (in PM documentation) prevented a clear understanding of specific work activities that may have prevented E1 from entering Cubicle 17. | 1, 13 |
| C25 | Cluttered workspace, caused by working two jobs concurrently, reduced the ability of the work team and supervisor from observing and preventing E1 from entering Cubicle 17. | 7, 9 |
| C29 | Performing two jobs simultaneously inserts additional hazards beyond those addressed for individual tasks. | 1, 7 |
| *Contributing Cause: Weaknesses in hazard analysis processes resulted in some hazards not being analyzed.* | | |
| C3 | The opportunity was missed to establish and implement effective barriers that would have prevented the accident. | 1, 4, 11 |
| C24 | Because of the potential and consequence for human error, the hazard level increases when Bus B and Bus C were re-energized. | 1, 7 |
| C27 | Mixed experience and qualifications caused confusion regarding roles, responsibilities, and control implementation. | 3 |
| C30 | The hazard analysis process did not address the risks and consequences caused by changed conditions between the Saturday and Sunday substation configurations. | 1, 7 |

**Table 5-1 (continued)**

| Causal Factor No. | Conclusions—Root and Contributing Causes | JON No. |
|---|---|---|
| C31 | Human error had not been fully addressed in terms of "what-if" scenarios and therefore robust controls were not implemented. | 1, 4, 11 |
| C33 | Opportunity for craft workers (performing the tasks) to identify concerns for this job was not offered for the hazard analysis process. | 1, 9 |
| C34 | Skill-of-the-craft was used instead of task-level work planning/hazard assessment and controls implementation. | 1, 3 |
| *Contributing Cause: Controls were not effectively implemented to ensure safety on the job.* | | |
| C7 | The yellow caution tape barricade, demarking the hi-pot testing boundary, could have created confusion as to the location of the clearance point boundary, thus leading E1 to believe that Cubicle 17 was de-energized. | 2, 3, 4, 6, 11, 13 |
| C10 | Alerting techniques like safety signs, tags, barricades, and/or attendants were not in place as would have been standard industry practice. E1 entered lookalike equipment, cubicle 17. | 2, 3, 4, 7, 11 |
| C11 | One foreman (E3) was monitoring the work through frequent work-area passes but did not notice E1 accessing the energized cubicle. | 6 |
| C17 | Reduced worker focus may have contributed to E1's error. | 4, 9 |
| C20 | The absence of a uniquely marked physical barrier enabled E1 to access Cubicle 17 by removing the cubicle door and internal panels. | 3, 4, 11, 13, 2 |
| C21 | Lack of a formal work-tracking mechanism prevented positive control and backup by supervision for worker actions that would have prevented E1 from entering Cubicle 17. | 2, 6, 13 |
| C27 | Mixed experience and qualifications caused confusion regarding roles, responsibilities, and control implementation. | 3 |
| C28 | Similarity of equipment and congested environment contributed to workers not recognizing E1 was working in Cubicle 17. | 4, 7, 9, 10 |
| C32 | Robust controls were not implemented to prevent the consequence of human error. | 2, 4, 9, 10, 11 |

**Table 5-1 (continued)**

| Causal Factor No. | Conclusions—Root and Contributing Causes | JON No. |
|---|---|---|
| *Contributing Cause: Work was not performed within controls, as envisioned by management and job planners.* | | |
| C1 | Control afforded by the pre-job briefing was not effective in preventing entry into Bus B, Cubicle 17. | 4, 8, 9 |
| C2 | Not all workers had a clear understanding of system/job status and work scope. | 4, 8 |
| C4 | Failure to formally track cubicle progress and completion may have resulted in belief that Cubicle 17 had not been cleaned on Saturday. | 6, 10, 13 |
| C5 | Work area was congested with people and equipment, contributing to a lack of awareness of other workers. | 1, 4, 7, 9, 10, 13 |
| C6 | The visual boundary (clearance tag) was ineffective in preventing E1 from working outside the intended work scope. | 4, 8, 11 |
| C8 | The absence of blue tape, intended to help identify that cubicle cleaning was complete, possibly contributed to E1 thinking that the cubicle still needed cleaning and was de-energized. | 2, 6, 11, 13 |
| C19 | Opportunity was missed to identify and warn E1 not to open energized cubicle. | 6, 9 |
| C23 | Potential for early completion of the task may have shifted focus away from the task. | 4 |
| C26 | Cluttered workspace may have caused some confusion that led E1 to believe Cubicle 17 was de-energized. | 2, 4, 7, 9, 10 |
| *Contributing Cause: Feedback and lessons learned were not applied.* | | |
| C9 | Task-level controls that would have prevented this accident were not identified and implemented. | 7, 12, 13 |
| C14 | Zero-energy verification was not followed, as prescribed in training. | 5, 12 |
| C18 | Lessons learned were not applied to this work activity, resulting in missed opportunities to improve the work process. | 12 |

**Table 5-2**

| Judgments of Need | | Related Conclusions |
|---|---|---|
| 1 | MSS and UI management need to strengthen expectations regarding work-scope determination, as well as task-level work planning and hazard analysis. These expectations should be reinforced and assessed frequently. | C3, C5, C22, C24, C29, C30, C31, C33, C34 |
| 2 | MSS and UI management need to strengthen expectations regarding rigor in task-level work execution within controls. These expectations should be reinforced and assessed frequently. | C7, C8, C10, C21, C26, C32 |
| 3 | LANL needs to establish uniform and stringent implementation of safety requirements when executing work involving mixed work crews (e.g., different disciplines, experience, and qualifications). | C7, C10, C12, C13, C15, C20, C27, C34 |
| 4 | LANL needs to effectively implement human-performance error-prevention tools in work planning and hazard analysis. | C1, C2, C3, C5, C6, C7, C10, C17, C20, C23, C26, C28, C31, C32 |
| 5 | MSS and UI management need to reinforce and clarify expectations and implementation for zero-voltage verification requirements in the course of electrical work at all organizational levels. | C12, C13, C14 |
| 6 | MSS and UI management and direct supervision need to reinforce and clarify expectations (training, oversight, and accountability) for PPE requirements and work practices in the course of electrical work at all organization levels. | C4, C7, C8, C11, C19, C21 |
| 7 | MSS and UI management need to closely evaluate changing conditions when using standing IWDs during the planning process to ensure controls are aligned with actual work activities and site conditions. | C5, C9, C10, C24, C25, C26, C28, C29, C30 |
| 8 | MSS and UI management need to strengthen pre-job briefings at the beginning of each shift or when significant changes occur so that worker engagement, focus on important controls, operations integration, and a full understanding by all workers are all assured. | C1, C2, C6 |
| 9 | LANL management needs to ensure workers are encouraged to and are acknowledged for playing an active role in ensuring their own (and work team's) safety and compliance with work rules. | C1, C5, C16, C17, C19, C25, C26, C28, C32, C33 |
| 10 | MSS and UI management need to facilitate more direct involvement and ownership by craft in developing the work scope and job planning. | C4, C5, C26, C28, C32, C33 |
| 11 | MSS and UI management need to ensure robust, durable, and visible barriers and signs are appropriately placed and accurately reflect current work conditions, equipment status, and hazards to ensure worker safety. | C3, C6, C7, C8, C10, C15, C16, C20, C31, C32 |

**Table 5-2 (continued)**

| Judgments of Need | | Related Conclusions |
|---|---|---|
| 12 | LANL needs to improve its ability to implement and verify corrective actions from previous assessments and events. | C9, C14, C18 |
| 13 | MSS and UI management need to evaluate use of informal work practices in the context of potential impact on the effectiveness of safety controls. | C4, C5, C7, C8, C9, C20, C21, C22 |

## 6.0 JOINT ACCIDENT INVESTIGATION TEAM MEMBER SIGNATURES

Signed ______________________________

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Los Alamos National Laboratory

Signed ______________________________

Nathan Morley, Joint Accident Investigation Team, Accident Investigator
Department of Energy, National Nuclear Security Administration, Albuquerque Complex

Signed ______________________________

Alexander Tasama-Escobar, Joint Accident Investigation Team, Member
Bechtel National, Washington

Signed ______________________________

Jeffrey Williams, Joint Accident Investigation Team, Member
Los Alamos Field Office

# APPENDIX A
# TEAM MEMBERS, ADVISORS, CONSULTANTS, AND STAFF

| | |
|---|---|
| Co-Chair | Jeffry Roberson, Joint Accident Investigation Team<br>Acting Deputy Associate Administrator for Safety<br>Department of Energy, National Nuclear Security Administration |
| Co-Chair | Theodore Sherry, Joint Accident Investigation Team<br>Associate Deputy Director, Los Alamos National Laboratory |
| Board Members | Michael Briggs, Accident Investigation Team<br>The Babcock & Wilcox Company |
| | Richard Caummisar, Accident Investigation Team<br>Department of Energy, National Nuclear Security Administration |
| | Gary Dreifuerst, Accident Investigation Team<br>University of California, Office of the President |
| | Michael Johnson, Accident Investigation Team<br>AECOM |
| | John McNeel, Accident Investigation Team<br>Los Alamos National Laboratory |
| | Nathan Morley, Accident Investigation Team<br>Accident Investigator, Department of Energy, National Nuclear Security Administration, Albuquerque Complex |
| | Alexander Tasama-Escobar, Accident Investigation Team<br>Bechtel National, Washington |
| | Jeffrey Williams, Accident Investigation Team<br>Los Alamos Field Office |
| Technical Advisors | James (Chris) Cantwell, Bechtel National Corporation |
| | Jeffrey Vincoli, Bechtel Global Logistics, Houston |
| Medical Advisor | Sara Elizabeth Pasqualoni, M.D., Los Alamos National Laboratory |
| Legal Advisors | David Sosinski, Los Alamos National Laboratory |
| | Sean T. Counce, Department of Energy, National Nuclear Security Administration |
| Administrative Coordinators | Christina Archuleta, Los Alamos National Laboratory |
| | Patrick Trujillo, Los Alamos National Laboratory |
| Technical Writer-Editor | Octavio Ramos. Los Alamos National Laboratory |
| Administrative Support | Linda K. Salazar, Los Alamos National Laboratory |

## APPENDIX B
## ACCIDENT INVESTGATION BOARD APPOINTMENT MEMO

**Department of Energy**
**National Nuclear Security Administration**
**Washington, DC 20585**

MAY 5 2015

MEMORANDUM FOR: JEFFRY L. ROBERSON
ACTING DEPUTY ASSOCIATE ADMINISTRATOR FOR SAFETY
NATIONAL NUCLEAR SECURITY ADMINISTRATION

THEODORE D. SHERRY
ASSOCIATE DEPUTY DIRECTOR
LOS ALAMOS NATIONAL LABORATORY

FROM: DON F. NICHOLS
COGNIZANT SECRETARIAL OFFICER FOR SAFETY
NATIONAL NUCLEAR SECURITY ADMINISTRATION

KIMBERLY D. LEBAK
MANAGER, LOS ALAMOS FIELD OFFICE
NATIONAL NUCLEAR SECURITY ADMINISTRATION
5/5/2015

U1501191

SUBJECT: Investigation of May 3, 2015, Accident at an Electrical Substation Supporting the Los Alamos Neutron Science Center

In accordance with the requirements of Department of Energy (DOE) Order 225.1B, *Accident Investigations*, we are authorizing you to co-chair and establish a joint Accident Investigation Board (AIB) team to investigate the May 3 accident at an electrical substation supporting the Los Alamos Neutron Science Center. Together, your experience in safety, investigations, and training in Departmental accident investigation processes qualify you for this task.

The composition of this investigation team will be modeled after the highly successful joint accident investigation that was conducted at Sandia National Laboratories in 2014. The investigation team will be composed of Federal members who meet the full requirements of DOE O 225.1B for an AIB, teamed with personnel selected by the Management and Operating (M&O) partner. To maximize learning, Federal and M&O team members are expected to conduct the investigation as a single, integrated effort, and produce an integrated report. All members of the AIB team are to be released from their normal, regular duty assignment to serve on the team during the period the AIB is convened. Federal and M&O team members must be independent of the direct line management chain responsible for day-to-day operation or oversight of the facility, area, or activity involved in the accident.

The scope of the investigation is to include, but not be limited to: identifying all relevant facts, determining direct, contributing, and root causes of the event, developing conclusions, and determining the judgments of need to prevent recurrence. Also, the scope of the investigation is to include relevant DOE programs and oversight activities. Please include a review of previous electrical incidents at Los Alamos over the last few years, to the extent that they may reveal a common underlying cause or weakness.

If you deem it necessary, you may convene a Technical Advisory Team, with membership that may overlap that of the AIB team, to assist in reconstructing and determining the direct technical cause of the accident.

You are to provide us with periodic reports on the status of the investigation. Please submit draft copies of the factual portion of the investigation report to James McConnell, Charles McMillan, and us for factual accuracy review prior to finalization.
A final draft report should be provided to me no later than June 5, 2015. Discussion of the investigation and copies of the draft report will be controlled until we authorize release of the final report.

cc:
Frank Klotz, Administrator, Under Secretary for Nuclear Security
Madelyn Creedon, Principal Deputy Administrator
Charles McMillan, Director, Los Alamos National Laboratory
James McConnell, Associate Administrator for Safety, Infrastructure and Operations
Joseph McBrearty, Deputy Director for Field Operations, Office of Science
Robert Poole, Contracting Officer, Los Alamos Field Office
Gary Staffo, Office of Analysis, Department of Energy
Stephen Wallace, Office of Safety

# APPENDIX C
# NNSA MEMBER APPOINTMENT LETTER

**Department of Energy**
**National Nuclear Security Administration**
**Washington, DC 20585**

MAY 1 1 2015

MEMORANDUM FOR DISTRIBUTION

FROM: JEFFRY L. ROBERSON
ACTING DEPUTY ASSOCIATE ADMINISTRATOR FOR SAFETY NATIONAL NUCLEAR SAFETY ADMINISTRATION

SUBJECT: Accident investigation into the May 3, 2015, Accident at an Electrical Substation Supporting the Los Alamos Neutron Science Center

REFERENCES: DOE Memorandum from Don F. Nichols and Kimberly D. Lebak Authorizing Convention of an Accident Investigation Board

In accordance with the requirements of Department of Energy (DOE) Order 225.1B, *Accident Investigations*, the Cognizant Secretarial Officer (CSO) for Safety National Nuclear Security Administration and Los Alamos Field Office Manager have directed me to co-chair an Accident Investigation Board (AIB) to investigate the May 3, 2015, Accident at an Electrical Substation Supporting the Los Alamos Neutron Science Center. Federal membership on the Board is:

- Jeffry L. Roberson, Co-chair
- Nathan Morley, member
- Jeffrey Williams, member
- Richard Caummisar, member

As a member of the AIB, in accordance with the requirements of DOE Order 225.1B, you are released from your normal regular duty assignment to serve on the AIB during the period of the AIB is convened.

The scope of the AIB's investigation is to include, but not be limited to: identifying all relevant facts, determining direct, contributing and root causes of the event, developing conclusions, and determining the judgements of need to prevent recurrence. Also, the scope of the investigation is to include the DOE's programs and oversight activities. Further, the team will review previous electrical incidents at Los Alamos over the last few years, to the extent that they may reveal a common underlying cause or weakness. The AIB is to provide the CSO for Safety and the Los Alamos Field Office Manager with periodic reports on the status of the investigation. A final draft report should be provided to James McConnell, Charles McMillan, and Michael Lansing no later than June 5, 2015. Discussion of the investigation and copies of the draft report will be controlled until this group authorizes release of the final report.

The onsite portion of the investigation will commence on May 6, 2015 and last through June 5, 2015. Additional details of the review schedule will be forthcoming.

Distribution:
Charles McMillan, LANL
James McConnell, NA-50
Don F. Nichols, NA-50
Kimberly Lebak, LAFO
Gary Staffo, AU-23
Stephen Wallace, NA-51
Nathan Morley, NA-512
Jeffrey Williams, NA-LA
Richard Caummisar, NPO

# APPENDIX D
# CONTRACTOR MEMBER APPOINTMENT MEMO

Los Alamos NATIONAL LABORATORY EST. 1943
Office of the Director

*To/MS:* Distribution
*From/MS:* Theodore D. Sherry, DIR, A100
*Phone/Fax:* (505)695-4318
*Symbol:* AIB-15-001
*Date:* May 13, 2015

**REFERENCE:** ***DOE Memorandum from Don F. Nichols and Kimberly D. Lebak, Authorizing Convention of an Accident Investigation Board***

**SUBJECT:** **Accident Investigation into the May 3, 2015, Electrical Event at TA-53, Building 70**

In accordance with the requirements of Department of Energy (DOE) Order 225.1B, *Accident Investigations*, the Cognizant Secretarial Officer for Safety National Nuclear Security Administration and the Los Alamos National Laboratory Director have directed me and Jeffry Roberson, NNSA, to co-chair an Accident Investigation Team to investigate the May 3, 2015, accident at an electrical substation supporting the Los Alamos Neutron Science Center at TA-53, Building 70.

The Laboratory AI Team Membership is:

- Theodore D. Sherry, Co-Chair
- Mike Briggs, Member
- Chris Cantwell, Technical Advisor
- Gary Dreifuerst, Member
- Michael Johnson, Member
- John McNeel, Member
- Alexander Tasama-Escobar, Member
- Jeff Vincoli, Technical Advisor

As a member of the AI Team, in accordance with the requirements of DOE Order 225.1B, you are released from your normal regular duty assignment to serve on the AI Team during the period of the AI Team is convened.

The scope of the AI Team's investigation is to include, but not be limited to:

- Identifying all relevant facts, determining direct, contributing and root causes of the event, developing conclusions, and determining the judgements of need to prevent recurrence.
- Also, the scope of the investigation is to include the Department of Energy's (DOE) programs and oversight activities.
- Further, the team will review previous electrical incidents at Los Alamos over the last few years, to the extent that they may reveal a common underlying cause or weakness.
- The AI Team is to provide the Cognizant Secretarial Officer for Safety, the Los Alamos Field Office Manager Director, and the Los Alamos National Laboratory Director with periodic reports on the status of the investigation.
- A final draft report should be provided to James McConnell, Charles McMillan, and Michael Lansing no later than June 5, 2015.

Discussion of the investigation and copies of the draft report will be controlled until this group authorizes release of the final report. The onsite portion of the investigation will commence on May 6, 2015, and last through June 5, 2015. Additional details of the review schedule will be forthcoming.

Cy: Charles McMillan, Director, Los Alamos National Laboratory
James McConnell, Associate Administrator for Safety, Infrastructure and Operation
Don F. Nichols, Principle Dep Associate Administrator for Safety, Infrastructure & Ops
Kimberly Lebak, Manager, Los Alamos Field Office
Gary Staffo, Office of Analysis, Department of Energy
Stephen Wallace, Office of Safety
SI-RMS, A150

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Williams, Jeffrey, jawilliams@lanl.gov
Vincoli, Jeff, jwvincoli@lanl.gov

## APPENDIX E
## BARRIER-ANALYSIS WORKSHEET

| Hazard: **13.8 KV** | | Target: **Electrician 1** | | |
|---|---|---|---|---|
| What were the barriers? | How did each barrier perform? | Why did the barrier fail? | How did the barrier affect the accident? | Context: ISM/HPI |
| Cubicle 17, Door | Door was bypassed | Identification of barrier ineffective, no unique signs or additional physical measures implemented as part of work control to distinguish energized cubicles from de-energized cubicles. | If the cubicle door had stayed in place E1 would not have had access to the energized equipment. | ISM:<br>▪ CF 4 – Perform work within controls<br>▪ GP 1 – Line Management responsible for safety<br>▪ GP 5 – Hazards evaluated and controlled<br>HPI:<br>▪ TD #6 – Interpretation of requirements<br>▪ HN #3 – Assumptions<br>▪ HN #5 - Mindset |
| Cubicle 17, internal enclosure panels | Panels were removed | The barrier failed when the panels were removed. | If the panels had not been removed E1 would not have had access to the energized equipment | ISM:<br>▪ GP-1 Line Management responsible for safety<br>▪ GP-5 Hazards evaluated and controlled<br>▪ GP-6 Controls shall be tailored to work performed and hazards<br>▪ CF-3 Develop and implement controls<br>▪ CF-4 Perform work within controls |

| Hazard: **13.8 KV** | | Target: **Electrician 1** | | |
|---|---|---|---|---|
| What were the barriers? | How did each barrier perform? | Why did the barrier fail? | How did the barrier affect the accident? | Context: ISM/HPI |
| Pre-job briefing | Pre-job briefing generally identified hazards and controls for the job, but did not specifically identify task level controls (e.g., zero voltage checks in each cubicle, "what could go wrong" discussion) per IWD. | All areas of IWD pre-job brief content not covered. Task level controls were not identified or discussed.<br><br>The documentation to positively reflect understanding by workers is inadequate.<br><br>Initial pre-job briefing was delivered in March and worker acknowledgment spans the time from March through May.<br><br>UI practice is that individuals are only required to sign IWD once, versus signing daily. | Control afforded by pre-job briefing was not effective to prevent entry into Bus B, cubicle 17.<br><br>C-1<br><br>Not all workers had a clear understanding of system/job status and work scope.<br><br>C-2<br><br>By not requiring daily signatures for the pre-job briefing an opportunity was missed to verify worker understanding of system status and controls. | ISM:<br>▪ GP-5 Hazards evaluated and controlled<br>▪ CF 4 – Perform work within controls<br><br>HPI:<br>▪ IC #5 - Imprecise communication habits |

| Hazard: **13.8 KV** | | Target: **Electrician 1** | | |
|---|---|---|---|---|
| What were the barriers? | How did each barrier perform? | Why did the barrier fail? | How did the barrier affect the accident? | Context: ISM/HPI |
| IWDs | IWDs did not sufficiently address work on a partially energized substation and switchgear. | IWDs did not specify change in conditions that produced an unaddressed hazard<br><br>The IWDs level of detail and implementation was less than adequate at the task level.<br><br>Work package was intentionally created in the broadest terms to allow flexibility in job execution.<br><br>Specifically cubicles were not identified individually in the 5-Yr PM IWD (to record completion of each cubicle). | The opportunity was missed to establish and implement effective barriers that would have prevented the accident.<br><br>C-3<br><br>Failure to formally track cubicle progress and completion may have resulted in belief that cubicle 17 had not been cleaned Saturday.<br><br>C-4 | ISM<br>▪ GP-5 Hazards evaluated and controlled<br>▪ GP- 6 Controls tailored to work and hazard<br>▪ CF-4 Perform work within controls |
| Workers being aware of the work going on within their surroundings. | Personnel were concentrating on their individual work. | Other workers did not recognize that E1 was working in an energized Bus B cubicle.<br><br>This was outside of the scope of work for that day. No one prevented him from entering the energized Bus B cubicle.<br><br>The work area was small and congested. | No one noticed work taking place on the wrong side of the clearance tag.<br><br>No one prevented E1 for working in energized Bus B cubicle on May 3.<br><br>Work area was congested with people and equipment contributing to lack of awareness of other workers.<br><br>C-5 | ISM:<br>▪ CF 4 – Perform work in within controls<br>▪ GP 2 – Clear roles and responsibilities<br>▪ GP-3 Competence commensurate with responsibilities |

| Hazard: **13.8 KV** | | Target: **Electrician 1** | | |
| --- | --- | --- | --- | --- |
| What were the barriers? | How did each barrier perform? | Why did the barrier fail? | How did the barrier affect the accident? | Context: ISM/HPI |
| Positive energy control | Positive energy control was established for the intended work scope. | The visual boundary (clearance tag) was ineffective in preventing E1 from working outside the intended work scope.<br><br>C-6 | It was not effective at maintaining the work scope boundary. | ISM:<br>▪ GP-3 Competence commensurate with responsibilities<br>▪ GP-1 Line management responsible for safety |
| Clearance Tag on Cubicle 18 | Barrier did not prevent E1 from entering Cubicle 17. | E1 entered cubicle 17, potentially being confused by the existence of yellow caution barricade tape hung between 16 and 17 as marking the de-energized boundary.<br><br>Blue adhesive tape was not applied to cubicle 17, possibly adding to E1's assumption that this cubicle still required cleaning.<br><br>There was no specific signage on cubicle 17 to indicate to E1 that he was accessing an energized cubicle. | The yellow caution barricade, demarking hi-pot testing boundary, could have created confusion as to the location of the clearance point boundary, and led E1 to believe cubicle 17 was de-energized.<br><br>C-7<br><br>The absence of blue tape, intended to help identify that cubicle cleaning was complete, possibly contributed to E1 thinking the cubicle still needed cleaning and was de-energized.<br><br>C-8 | ISM:<br>▪ CF 3 – Develop and Implement Hazard Controls<br>▪ GP 6 – Hazard controls tailored to the work being performed<br>▪ GP 1 – Line Management responsible for safety |

| Hazard: **13.8 KV** | | Target: **Electrician 1** | | |
|---|---|---|---|---|
| What were the barriers? | How did each barrier perform? | Why did the barrier fail? | How did the barrier affect the accident? | Context: ISM/HPI |
| Hazard Analysis and Control Development | JHA is conducted at the generic job-scope level, therefore, did not develop controls at the task level. | The hazardous analysis and control development process was not applied at the task level for this job.<br>There is no difference in controls between the de-energized work on Saturday and mixed work (partially energized) on Sunday.<br>The unique aspects of working two PMs concurrently in a small space were not analyzed. | The Hazard Analysis process and control development bounded the job scope but did not detail controls for task level hazards.<br>Task level controls are left to "skill- of-the-craft."<br>Task level controls that would have prevented this accident were not identified or implemented.<br>C-9<br>Alerting techniques like safety signs & tags, barricades and/or attendants were not in place as required, E1 entered look-alike equipment, cubicle 17.<br>C-10 | ISM:<br>▪ GP-1 Line management responsible for safety<br>▪ GP-5 Hazards evaluated and safety standards agreed<br>▪ GP-6 Controls tailored to the work and the hazards<br>▪ CF-2 Analyze Hazards<br>▪ CF-3 Develop and Implement hazard controls |
| Clear Roles and Responsibilities | Up to three Persons in Charge (PICs) identified; crew unsure exactly who was in charge. | Two different crews with two different PICs. | One Foreman (E3) was monitoring the work through frequent work area passes, but he did not notice E1 accessing energized cubicle.<br>C-11 | ISM:<br>▪ GP-2 Clear lines of authority and responsibility for safety established<br>▪ GP-3 Competence commensurate with responsibility |

| Hazard: **13.8 KV** | | Target: **Electrician 1** | | |
|---|---|---|---|---|
| What were the barriers? | How did each barrier perform? | Why did the barrier fail? | How did the barrier affect the accident? | Context: ISM/HPI |
| Zero-Voltage Verification | Zero-Voltage Verification not conducted on cubicle 17 prior to E1 entering. | E1 did not perform Zero-Voltage Verification for cubicle 17.<br>C-12<br>Processes (zero-voltage checks) were not consistently implemented or understood at the task level.<br>C-13 | Without voltage present, there would be no dielectric breakdown resulting in an arc-flash due to E1 spraying cleaner. | ISM:<br>▪ GP-3 Competence commensurate with responsibility<br>▪ CF-4 Perform work within controls |
| Training, Qualifications, and Experience | All workers, the planner, PIC and foremen were qualified and experienced for this job. | Zero-energy verification was not followed as prescribed in training.<br>C-14<br>Use of clearance tags is not the typical isolation method used by Wiremen.<br>C-15 | Weak implementation of training requirements by the crew contributed to E1 not detecting the hazard present.<br>Trained employees did not identify the lack of required signs, tags, and barriers, a standard industry practice.<br>C-16 | ISM:<br>▪ GP-3 Competence commensurate with responsibility<br>▪ GP-1 Line management responsible for safety<br>▪ GP-7 Operations Authorization |
| Fitness for Work | Long work hours from the week through the weekend may have reduced fitness for work. | Excessive work hours. | Reduced worker focus may have contributed to E1's error.<br>C-17 | ISM:<br>▪ GP-3 Competence commensurate with responsibility<br>▪ CF-4 Perform work within controls<br>▪ GP-7- Operations Authorization |

| Hazard: **13.8 KV** | | Target: **Electrician 1** | | |
|---|---|---|---|---|
| What were the barriers? | How did each barrier perform? | Why did the barrier fail? | How did the barrier affect the accident? | Context: ISM/HPI |
| Feedback and Lessons Learned | Barrier was not used. | AP-Work-002: Attachment 11 MSS Work Completion Form from previous work not reviewed by the planner as part of work package development.<br><br>AP-Work-002 was being completed by PIC for the job. e.g., "Summarize the Work Performed" section was being partially completed. No issues had been identified. | Lessons learned not applied to this work activity resulting in missed opportunities to improve the work process.<br><br>C-18 | ISM:<br>▪ CF-5 Provide feedback and Continuous Improvement |
| Team Safety Awareness | Questioning attitude by coworkers was not demonstrated throughout the job. | Workers were focused on accomplishing their individual task. | Opportunity was missed to identify and warn E1 to not open energized cubicle.<br><br>C-19 | |

**APPENDIX F**
**CHANGE-ANALYSIS WORKSHEET**

| Factors | Accident Situation | Prior, Ideal or Accident Free Situation | Difference | Evaluation of Effect |
|---|---|---|---|---|
| WHAT<br>conditions, occurrences, activities, equipment | Yellow caution tape not marked as the hi-pot activity boundary. | Yellow caution tape marked as hi-pot boundary. | Purpose of yellow caution tape not marked. | May have caused some confusion that led E1 to believe cubicle 17 was de-energized. |
| | Physical boundary not in place to limit access to energized equipment and cubicle doors. | Physical boundary in place to limit access to energized equipment and cubicle doors. | Physical boundaries were not in place and clearly understood. | The absence of a uniquely marked physical barrier allowed E1 to access cubicle 17, by removing the cubicle door and internal panels.<br>C-20 |
| | Clearance tag used to identify boundary. | Physical boundary in place to limit access to energized equipment and cubicle doors. | Physical boundaries were not in place and clearly understood. | The absence of a physical boundary allowed E1 to access cubicle 17. |
| | Blue and red adhesive tape informally used to track work progress and tape was absent from cubicle 17. | Formal process used and implemented to clearly track work progress. | An informal system was being used to signify cleaning complete.<br>No blue adhesive tape present on cubicle 17 to indicate it had been cleaned (no red tape required as cubicle 17 had no breaker). | May have caused some confusion that led E1 to believe cubicle 17 was part of Sunday's work-scope.<br>This prevented a clear understanding of specific work activities that may have prevented E1 from entering cubicle 17. |

| Factors | Accident Situation | Prior, Ideal or Accident Free Situation | Difference | Evaluation of Effect |
|---|---|---|---|---|
| | Supervision did not implement a formal work tracking mechanism. | Supervision implemented a formal work tracking mechanism. | Work activity and scope left to individual worker discretion. | Lack of a formal work tracking mechanism prevented positive control and backup by supervision for worker actions that would have prevented E1 from entering cubicle 17.<br><br>C-21 |
| | Work plan did not include a tracking mechanism for work at the individual task level for cleaning. | Work plan did include a tracking mechanism for work at the individual task level for cleaning. | Work task and scope left to individual worker discretion. | Lack of a formal work tracking mechanism (in PM documentation) prevented a clear understanding of specific work tasks that may have prevented E1 from entering cubicle 17.<br><br>C-22 |
| | Buses B and C were energized on Sunday. | All Buses de-energized on Sunday. | Decision was made to complete the 2 and 5-Yr maintenance evolutions with the switchgear partially re-energized on Sunday. | The decision to re-energize Buses B and C raised the risk of someone working on an energized cubicle.<br><br>The hazard analysis did not capture the change between Saturday and Sunday. |
| | Employee working in energized cubicle. | Employee working in de-energized cubicle. | Work took place in partially re-energized switchgear.<br><br>Work took place in an energized cubicle. | The decision to re-energize Buses B and C raised the risk of someone working on an energized cubicle. |

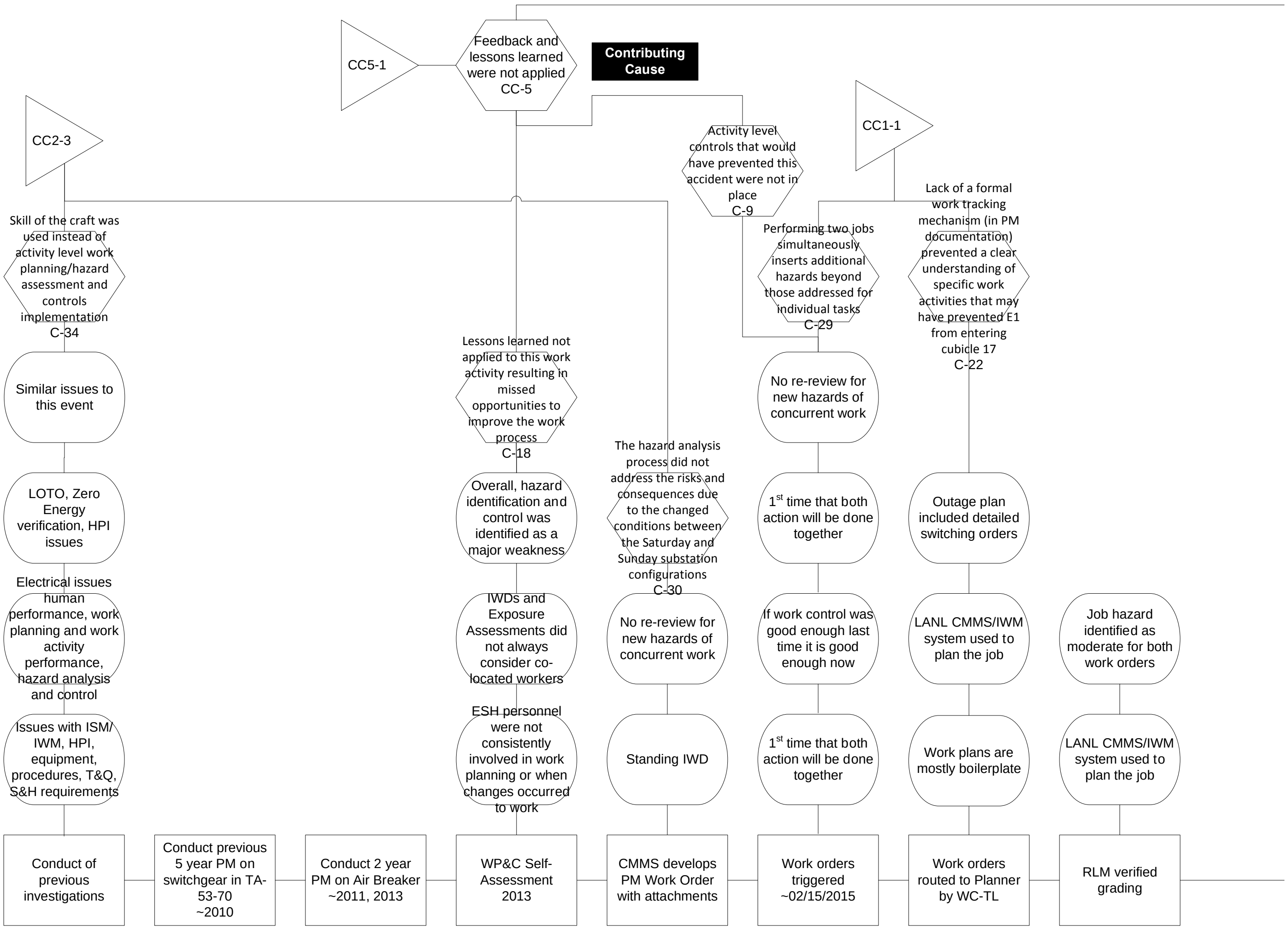
| Factors | Accident Situation | Prior, Ideal or Accident Free Situation | Difference | Evaluation of Effect |
|---|---|---|---|---|
| | | | | E1 was not prevented from entering and beginning work in an energized cubicle. |
| | Zero Voltage and positive energy control was not performed when cubicle 17 was opened on Sunday. | Zero Voltage checks conducted when cubicle 17 was opened on Sunday. | Electrical safety training and demonstrated proficiency requirements applicable to this job were not followed in all cases.<br><br>Neither the electrician nor a lineman conducted a zero voltage check on cubicle 17 prior to work. | This control is the last line of defense to avoid injury. If this were rigorously executed on the job, no accident would have occurred.<br><br>It was not recognized the cubicle 17 was energized. |
| WHEN<br><br>Occurred, identified, facility status, schedule | Crew focus on finishing job early. | Crew focused on safe work performance. | Focus had begun to shift towards the expectation of finishing early after a long day Saturday. | Potential for early completion of the task may have shifted focus away from the task.<br><br>C-23 |
| | Decision to reenergize Bus B and Bus C for Sunday work. | Complete work with all Buses de-energized | Due to the potential and consequence for human error, the hazard level increased when Buses B & C were re-energized<br><br>C-24 | Worker potential exposure and consequences due to hazardous energy from human error increased. |
| WHERE<br><br>Physical location, environmental conditions | Hallway was crowded with equipment and people because two work packages were worked concurrently. | Workspace had sufficient room for all work scheduled. | Cluttered workspace with associated industrial hazards (trips, cuts, etc.) as a result of two jobs concurrently. | Cluttered workspace, due to working two jobs concurrently, reduced the ability of work team and supervisor from seeing and |

| Factors | Accident Situation | Prior, Ideal or Accident Free Situation | Difference | Evaluation of Effect |
|---|---|---|---|---|
| | | | Line of sight to E1 and other workers was restricted by equipment and configuration. | preventing E1 from entering cubicle 17.<br>C-25<br>Cluttered workspace may have caused some confusion that led E1 to believe cubicle 17 was de-energized.<br>C-26 |
| WHO<br>Staff involved, training, qualification, supervision | Mixed experienced and qualification levels of the work crew. | Controls and compensatory measures instituted to address mixed experienced and qualification levels of the work crew. | No evidence that special provisions or measures instituted for less experienced workers. | Mixed experienced and qualifications caused confusion on roles and responsibilities and control implementation.<br>C-27 |
| | No one noticed E1 working in cubicle 17 and recognized that it was outside the clearance boundary. | Someone noticed E1 working on cubicle 17 and took action to prevent E1 from entering or working in an energized cubicle. | Congestion in the workplace may have contributed to workers not recognizing E1's working on cubicle 17.<br>Workers lost situational awareness. | Similarity of equipment and congested environment contributed to workers not recognizing E1 was working in cubicle 17.<br>C-28 |
| | Confusion as to who was the PIC. | PIC is known by all personnel conducting the work. | Lack of clear roles, responsibilities, authorities and accountability. | From interviews of workers in the switchgear there was no confusion regarding who was in charge and therefore this effect was not significant. |

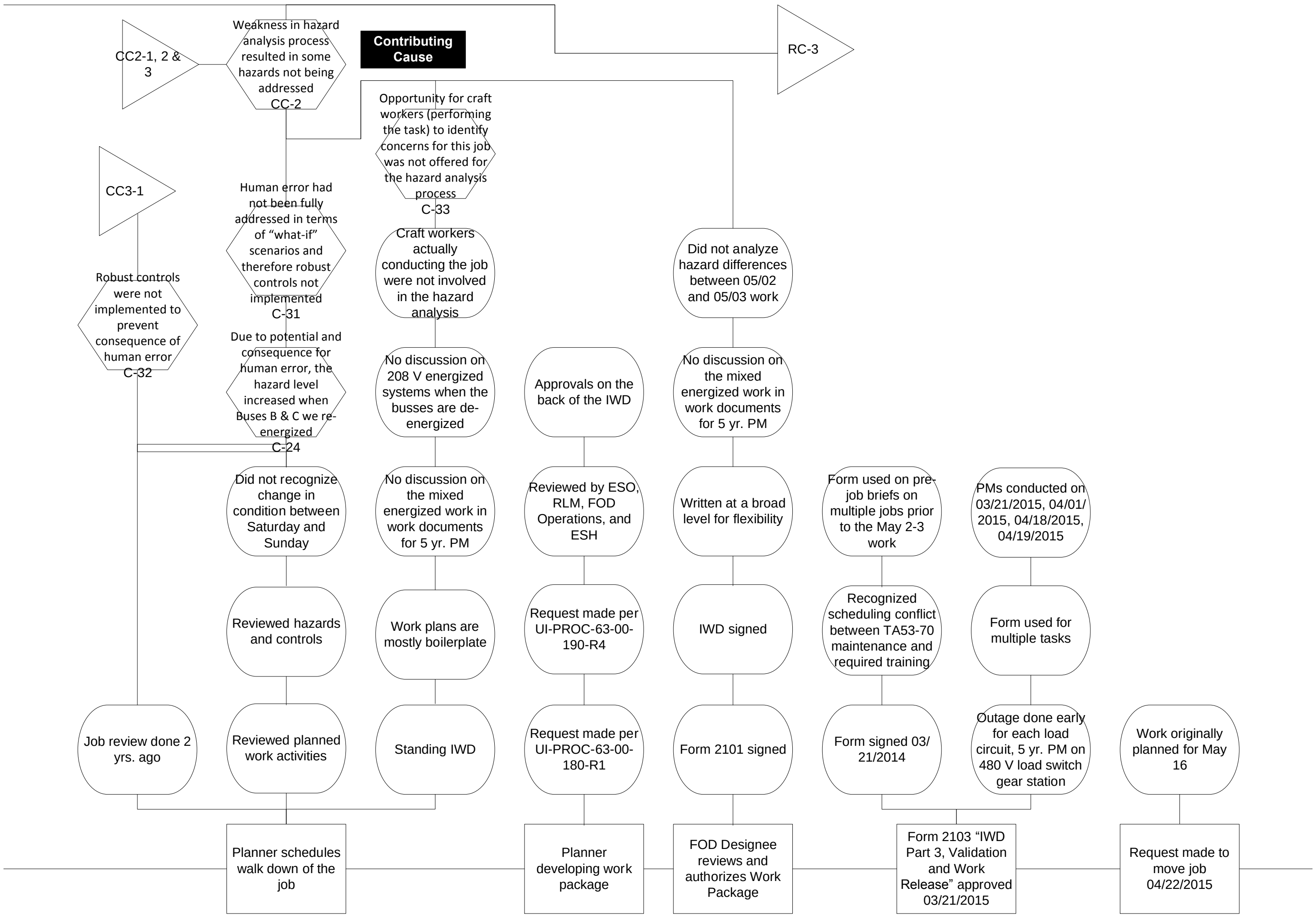
| Factors | Accident Situation | Prior, Ideal or Accident Free Situation | Difference | Evaluation of Effect |
|---|---|---|---|---|
| | Situational awareness of work status broke down at the time of the accident. | Supervision and crew had a clear understanding of work status. | Lack of awareness allowed for undesired access to energized equipment.<br>Confusion, undesired actions, and subsequent injuries. | This prevented a clear understanding of specific work activities that may have prevented E1 from entering cubicle 17. |
| HOW<br>Control chain, hazard analysis monitoring | The IWDs did not sufficiently recognize the unique aspects of combining the two maintenance activities. | The IWDs are sufficiently developed to recognize the unique aspects of combining the two maintenance activities. | Performing two jobs simultaneously inserts additional hazards beyond those addressed for individual tasks.<br>C-29 | Work proceeded without proper recognition of all hazards. |
| | Risk of human error was not recognized. | The hazard analysis process recognized risk of human error and developed controls. | The hazard analysis process did not address the risks and consequences due to the changed conditions between the Saturday and Sunday switchgear configurations.<br>C-30<br>Human error had not been fully addressed in terms of "what-if" scenarios and therefore robust controls not implemented.<br>C-31<br>The scenario that took place was not considered in the hazard analysis process since it was assumed the clearance tag was a sufficient control. | Consideration of human error and the development/ implementation of associated controls may have prevented the accident. |

| Factors | Accident Situation | Prior, Ideal or Accident Free Situation | Difference | Evaluation of Effect |
|---|---|---|---|---|
| | Employee opened and began work in an energized cubicle | Employee did not open and begin work in an energized cubicle. | Human error had not been fully addressed in terms of “what-if” scenarios.<br><br>Robust controls were not implemented to prevent the consequence of human error.<br><br>C-32 | The implemented controls (e.g., clearance tag, pre-job briefing) did not prevent E1 from entering cubicle 17. |
| | Craft Workers did not have input into the hazard analysis process. | Craft workers did have input into the hazard analysis process. | Opportunity for craft workers (performing the task) to identify concerns for this job was not offered for the hazard analysis process.<br><br>C-33<br><br>Skill-of-the-craft was used instead of task level work planning/hazard assessment and controls implementation.<br><br>C-34 | There was a missed opportunity to further identify hazards and establish controls that may have prevented the accident. |
| OTHER | Drug and Alcohol testing not conducted per Laboratory policy | Drug and Alcohol testing was effectively conducted | There is no way of determining if either drugs or alcohol is a determining factor. | Evidence never obtained to determine if this impacted the accident. |

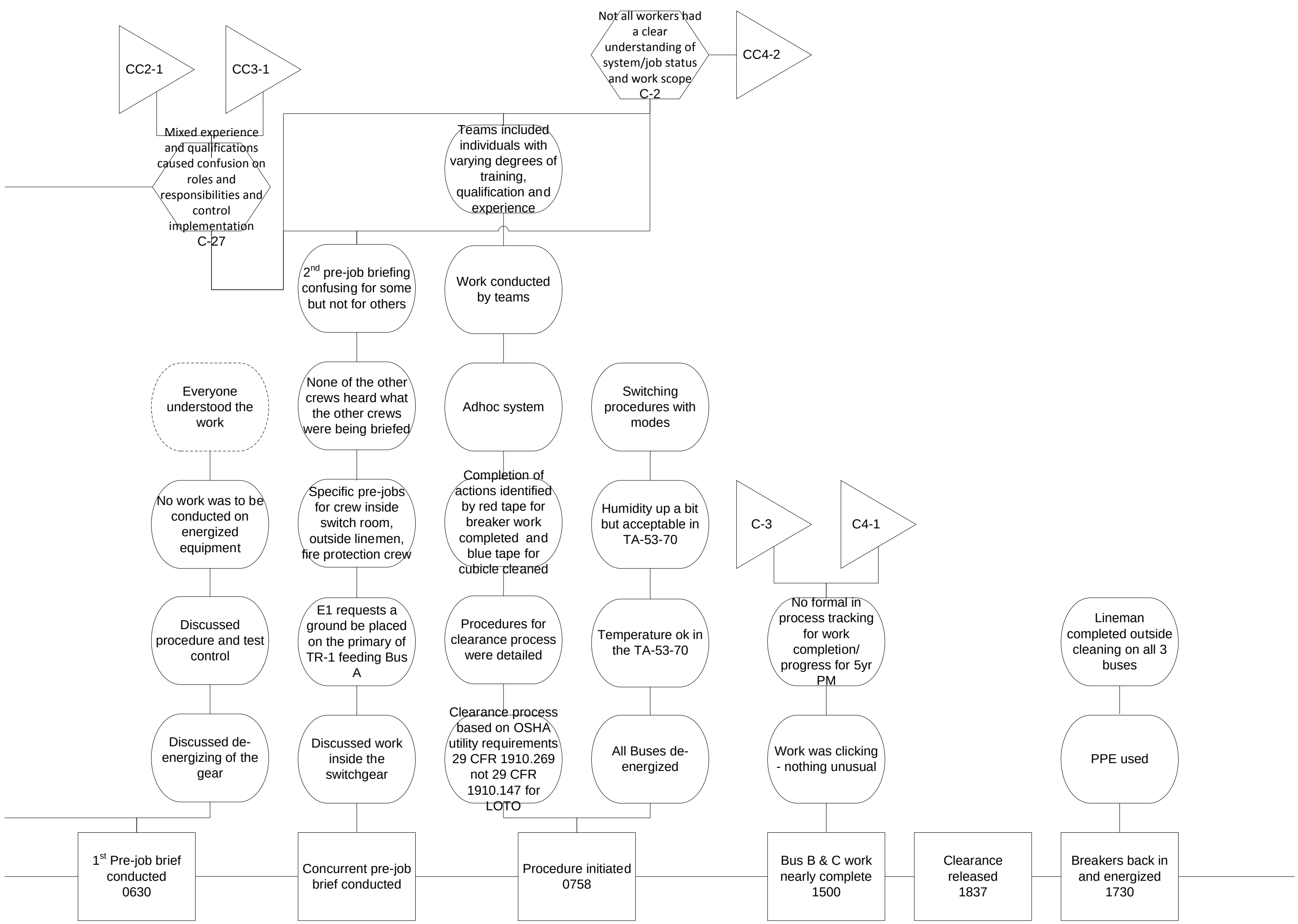
# APPENDIX G
# EVENTS AND CAUSAL FACTORS CHART



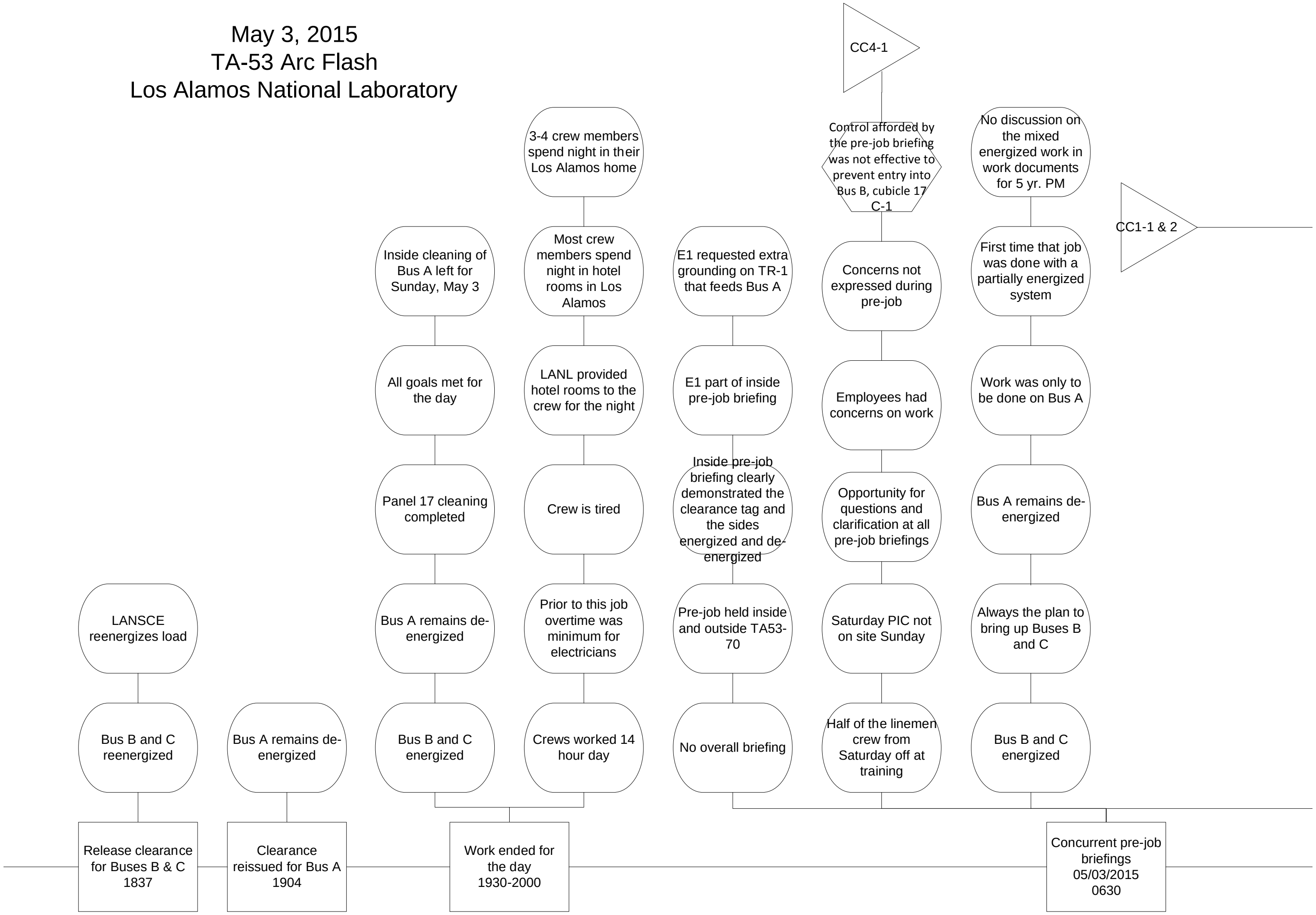
CC5-1
Feedback and lessons learned were not applied CC-5
Contributing Cause
CC2-3
Activity level controls that would have prevented this accident were not in place C-9
CC1-1
Lack of a formal work tracking mechanism (in PM documentation) prevented a clear understanding of specific work activities that may have prevented E1 from entering cubicle 17 C-22
Skill of the craft was used instead of activity level work planning/hazard assessment and controls implementation C-34
Performing two jobs simultaneously inserts additional hazards beyond those addressed for individual tasks C-29
Lessons learned not applied to this work activity resulting in missed opportunities to improve the work process C-18
Similar issues to this event
No re-review for new hazards of concurrent work
The hazard analysis process did not address the risks and consequences due to the changed conditions between the Saturday and Sunday substation configurations C-30
LOTO, Zero Energy verification, HPI issues
Overall, hazard identification and control was identified as a major weakness
1st time that both action will be done together
Outage plan included detailed switching orders
Electrical issues human performance, work planning and work activity performance, hazard analysis and control
IWDs and Exposure Assessments did not always consider co-located workers
No re-review for new hazards of concurrent work
If work control was good enough last time it is good enough now
LANL CMMS/IWM system used to plan the job
Job hazard identified as moderate for both work orders
Issues with ISM/ IWM, HPI, equipment, procedures, T&Q, S&H requirements
ESH personnel were not consistently involved in work planning or when changes occurred to work
Standing IWD
1st time that both action will be done together
Work plans are mostly boilerplate
LANL CMMS/IWM system used to plan the job
Conduct of previous investigations
Conduct previous 5 year PM on switchgear in TA-53-70 ~2010
Conduct 2 year PM on Air Breaker ~2011, 2013
WP&C Self-Assessment 2013
CMMS develops PM Work Order with attachments
Work orders triggered ~02/15/2015
Work orders routed to Planner by WC-TL
RLM verified grading

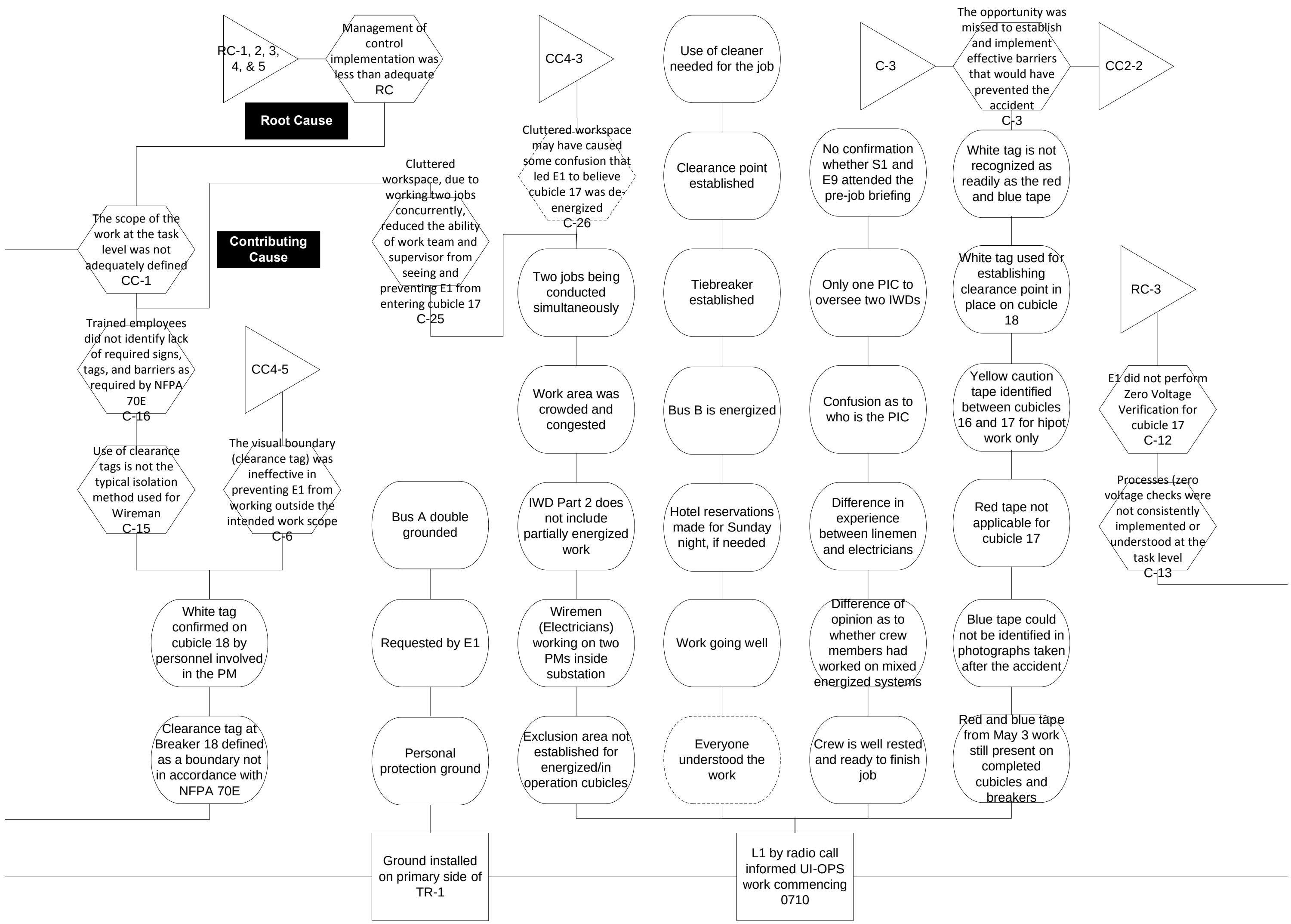

CC2-1, 2 & 3
Weakness in hazard analysis process resulted in some hazards not being addressed CC-2
Contributing Cause
RC-3
Opportunity for craft workers (performing the task) to identify concerns for this job was not offered for the hazard analysis process C-33
CC3-1
Human error had not been fully addressed in terms of "what-if" scenarios and therefore robust controls not implemented C-31
Craft workers actually conducting the job were not involved in the hazard analysis
Did not analyze hazard differences between 05/02 and 05/03 work
Robust controls were not implemented to prevent consequence of human error C-32
Due to potential and consequence for human error, the hazard level increased when Buses B & C we re-energized C-24
No discussion on 208 V energized systems when the busses are de-energized
Approvals on the back of the IWD
No discussion on the mixed energized work in work documents for 5 yr. PM
Did not recognize change in condition between Saturday and Sunday
No discussion on the mixed energized work in work documents for 5 yr. PM
Reviewed by ESO, RLM, FOD Operations, and ESH
Written at a broad level for flexibility
Form used on pre-job briefs on multiple jobs prior to the May 2-3 work
PMs conducted on 03/21/2015, 04/01/2015, 04/18/2015, 04/19/2015
Reviewed hazards and controls
Work plans are mostly boilerplate
Request made per UI-PROC-63-00-190-R4
IWD signed
Recognized scheduling conflict between TA53-70 maintenance and required training
Form used for multiple tasks
Job review done 2 yrs. ago
Reviewed planned work activities
Standing IWD
Request made per UI-PROC-63-00-180-R1
Form 2101 signed
Form signed 03/21/2014
Outage done early for each load circuit, 5 yr. PM on 480 V load switch gear station
Work originally planned for May 16
Planner schedules walk down of the job
Planner developing work package
FOD Designee reviews and authorizes Work Package
Form 2103 "IWD Part 3, Validation and Work Release" approved 03/21/2015
Request made to move job 04/22/2015

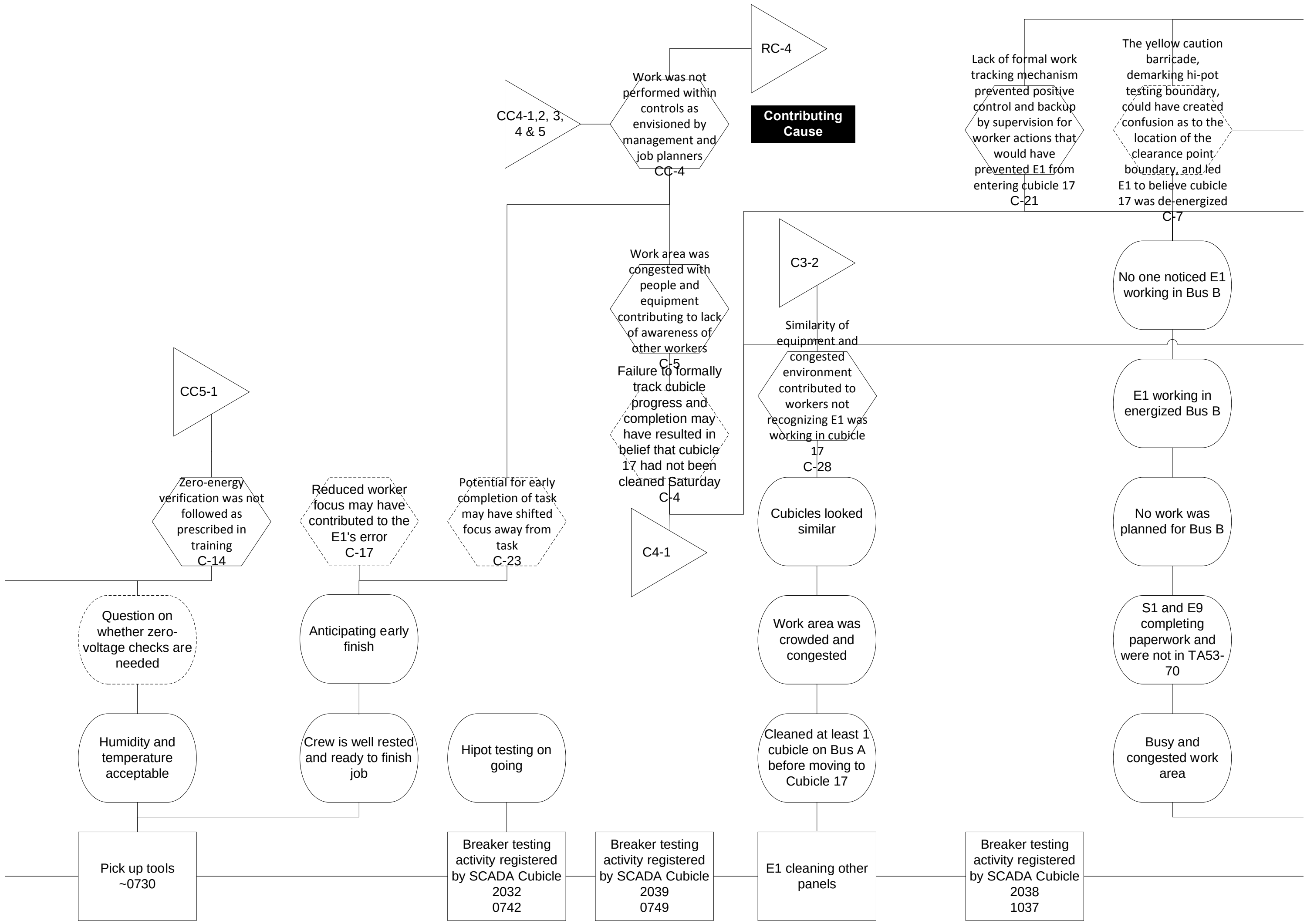
Legend
Events
Conditions
Causal Factors
Connector
Assumed Events
Assumed Conditions
Assumed Causal Factors
Request to move job date discussed with Supervisor 04/23/2015
Request to reschedule job finalized 04/27/2015
Job now scheduled to start May 2
Determination made to energize Bus B & C on Saturday evening 04/28/2015
LANSCE prepared for 2-day outage
No one disagreed with the decision
LANSCE had generators ready
Switching procedures for both PMs approved
Includes reenergizing Bus B & C on 05/02
FOD Designee Release work at the POTD 05/02/2015
Began 5-year and 2-year PM activities in TA-53-70 0658
Clearance of entire substation to support work
2-yr cabinet cleaning and 5-yr breaker maintenance combined for first time
Previous 5 year review was reviewed
Buses A, B, and C were involved in the activity
Buses A, B, and C de-energized
Saturday was to end with re-energization of Busses B & C
No operational pressure to reenergize
Overtime work
Using 29 CFR 1910.269 to control hazardous energy
Electrician who normally does traffic lights given OJT for the switch gear
Included entire crew
E1 is journeyman electrician
Crew was a combination of Lineman, Medium Voltage and “borrowed” electricians

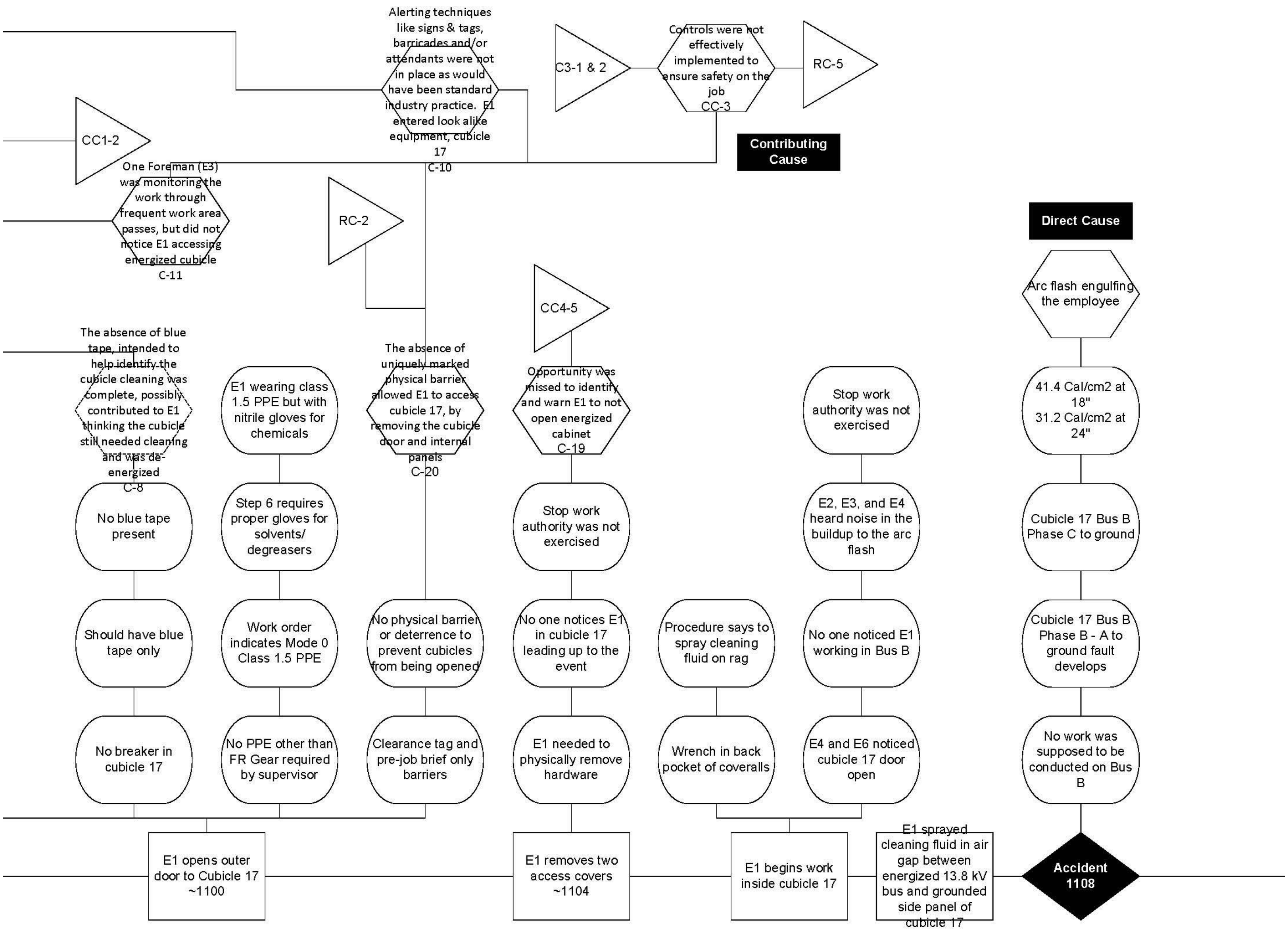

CC2-1
CC3-1
Not all workers had a clear understanding of system/job status and work scope C-2
CC4-2
Mixed experience and qualifications caused confusion on roles and responsibilities and control implementation C-27
Teams included individuals with varying degrees of training, qualification and experience
2nd pre-job briefing confusing for some but not for others
Work conducted by teams
Everyone understood the work
None of the other crews heard what the other crews were being briefed
Adhoc system
Switching procedures with modes
No work was to be conducted on energized equipment
Specific pre-jobs for crew inside switch room, outside linemen, fire protection crew
Completion of actions identified by red tape for breaker work completed and blue tape for cubicle cleaned
Humidity up a bit but acceptable in TA-53-70
C-3
C4-1
Discussed procedure and test control
E1 requests a ground be placed on the primary of TR-1 feeding Bus A
Procedures for clearance process were detailed
Temperature ok in the TA-53-70
No formal in process tracking for work completion/ progress for 5yr PM
Lineman completed outside cleaning on all 3 buses
Discussed de-energizing of the gear
Discussed work inside the switchgear
Clearance process based on OSHA utility requirements 29 CFR 1910.269 not 29 CFR 1910.147 for LOTO
All Buses de-energized
Work was clicking - nothing unusual
PPE used
1st Pre-job brief conducted 0630
Concurrent pre-job brief conducted
Procedure initiated 0758
Bus B & C work nearly complete 1500
Clearance released 1837
Breakers back in and energized 1730

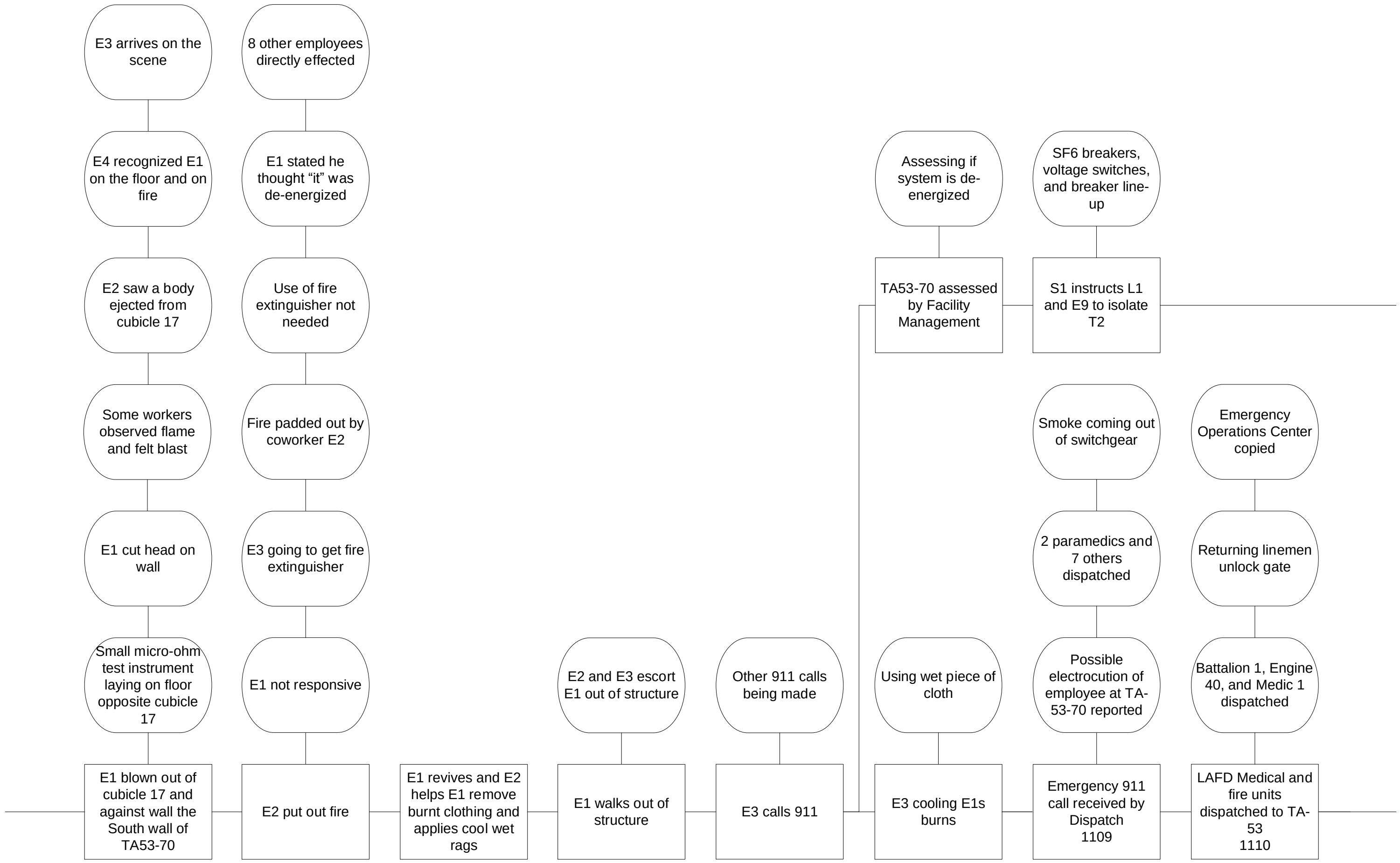
## May 3, 2015
## TA-53 Arc Flash
## Los Alamos National Laboratory

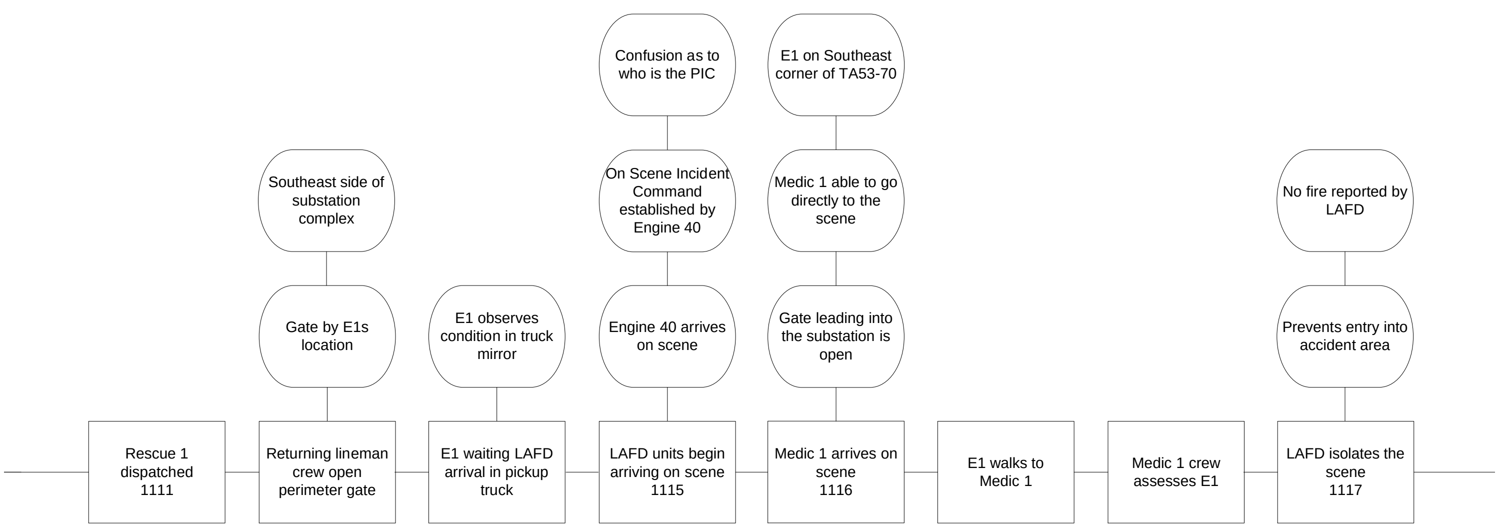


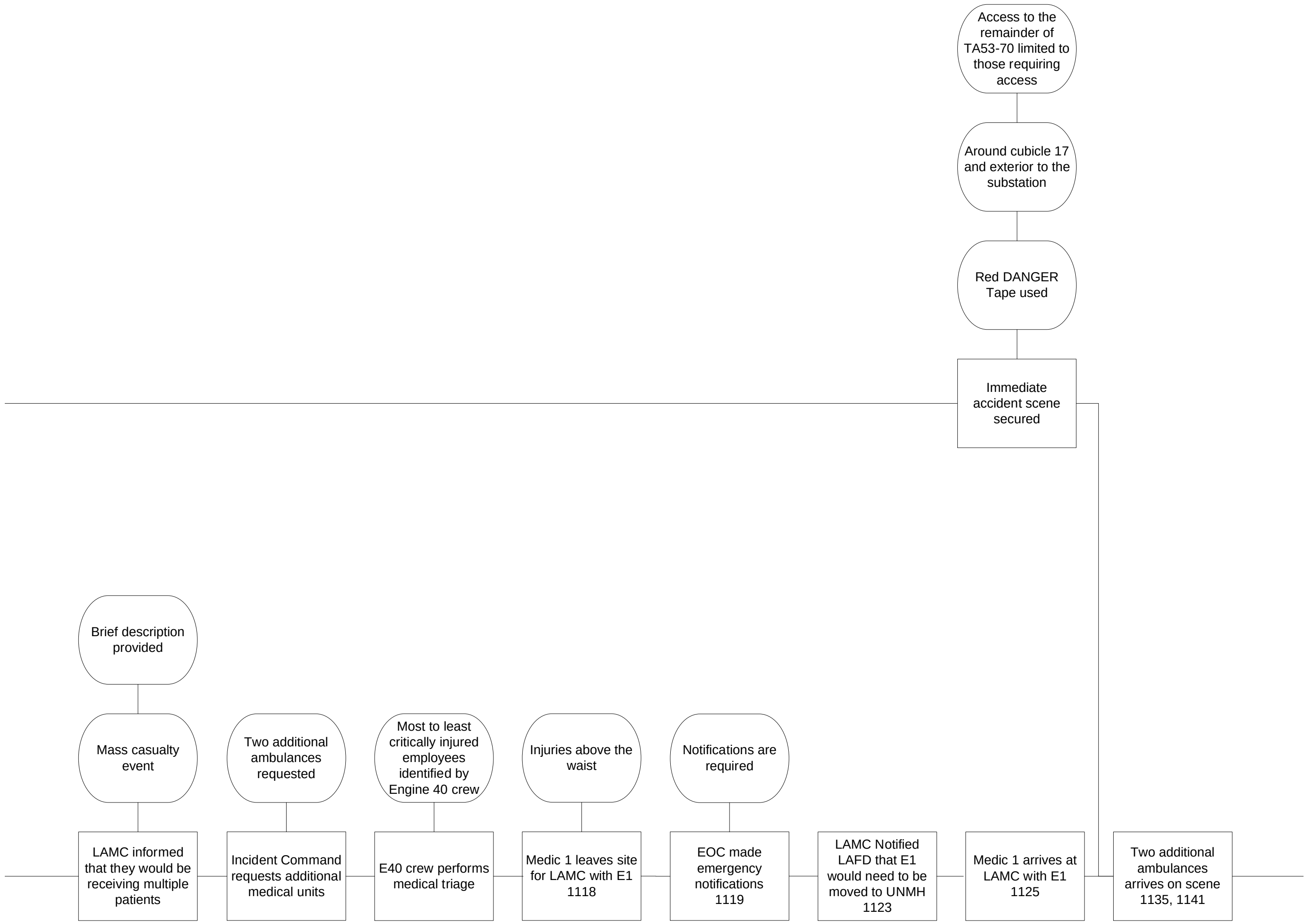

RC-1, 2, 3, 4, & 5
Management of control implementation was less than adequate RC
Root Cause
CC4-3
Use of cleaner needed for the job
C-3
The opportunity was missed to establish and implement effective barriers that would have prevented the accident C-3
CC2-2
Cluttered workspace may have caused some confusion that led E1 to believe cubicle 17 was de-energized C-26
Clearance point established
No confirmation whether S1 and E9 attended the pre-job briefing
White tag is not recognized as readily as the red and blue tape
Cluttered workspace, due to working two jobs concurrently, reduced the ability of work team and supervisor from seeing and preventing E1 from entering cubicle 17 C-25
The scope of the work at the task level was not adequately defined CC-1
Contributing Cause
Two jobs being conducted simultaneously
Tiebreaker established
Only one PIC to oversee two IWDs
White tag used for establishing clearance point in place on cubicle 18
RC-3
Trained employees did not identify lack of required signs, tags, and barriers as required by NFPA 70E C-16
CC4-5
Work area was crowded and congested
Bus B is energized
Confusion as to who is the PIC
Yellow caution tape identified between cubicles 16 and 17 for hipot work only
E1 did not perform Zero Voltage Verification for cubicle 17 C-12
Use of clearance tags is not the typical isolation method used for Wireman C-15
The visual boundary (clearance tag) was ineffective in preventing E1 from working outside the intended work scope C-6
Bus A double grounded
IWD Part 2 does not include partially energized work
Hotel reservations made for Sunday night, if needed
Difference in experience between linemen and electricians
Red tape not applicable for cubicle 17
Processes (zero voltage checks were not consistently implemented or understood at the task level C-13
White tag confirmed on cubicle 18 by personnel involved in the PM
Requested by E1
Wiremen (Electricians) working on two PMs inside substation
Work going well
Difference of opinion as to whether crew members had worked on mixed energized systems
Blue tape could not be identified in photographs taken after the accident
Clearance tag at Breaker 18 defined as a boundary not in accordance with NFPA 70E
Personal protection ground
Exclusion area not established for energized/in operation cubicles
Everyone understood the work
Crew is well rested and ready to finish job
Red and blue tape from May 3 work still present on completed cubicles and breakers
Ground installed on primary side of TR-1
L1 by radio call informed UI-OPS work commencing 0710

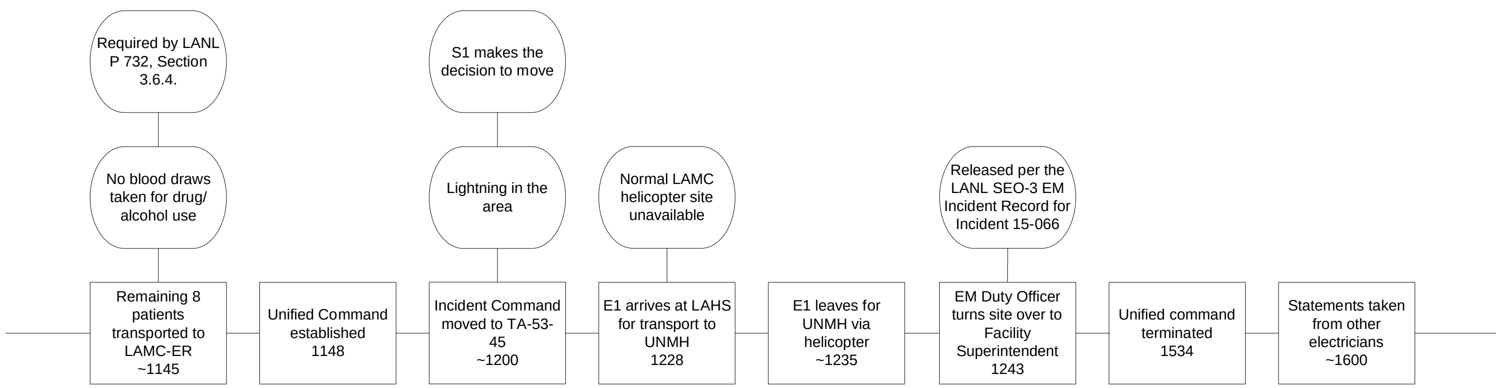

RC-4
Contributing Cause
CC4-1,2, 3, 4 & 5
Work was not performed within controls as envisioned by management and job planners CC-4
Lack of formal work tracking mechanism prevented positive control and backup by supervision for worker actions that would have prevented E1 from entering cubicle 17 C-21
The yellow caution barricade, demarking hi-pot testing boundary, could have created confusion as to the location of the clearance point boundary, and led E1 to believe cubicle 17 was de-energized C-7
Work area was congested with people and equipment contributing to lack of awareness of other workers C-5
C3-2
No one noticed E1 working in Bus B
Similarity of equipment and congested environment contributed to workers not recognizing E1 was working in cubicle 17 C-28
Failure to formally track cubicle progress and completion may have resulted in belief that cubicle 17 had not been cleaned Saturday C-4
E1 working in energized Bus B
CC5-1
Zero-energy verification was not followed as prescribed in training C-14
Reduced worker focus may have contributed to the E1's error C-17
Potential for early completion of task may have shifted focus away from task C-23
C4-1
Cubicles looked similar
No work was planned for Bus B
Question on whether zero-voltage checks are needed
Anticipating early finish
Work area was crowded and congested
S1 and E9 completing paperwork and were not in TA53-70
Humidity and temperature acceptable
Crew is well rested and ready to finish job
Hipot testing on going
Cleaned at least 1 cubicle on Bus A before moving to Cubicle 17
Busy and congested work area
Pick up tools ~0730
Breaker testing activity registered by SCADA Cubicle 2032 0742
Breaker testing activity registered by SCADA Cubicle 2039 0749
E1 cleaning other panels
Breaker testing activity registered by SCADA Cubicle 2038 1037

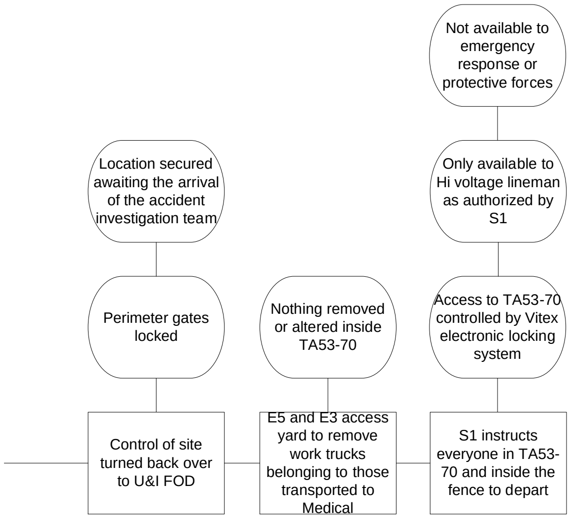

Alerting techniques like signs & tags, barricades and/or attendants were not in place as would have been standard industry practice. E1 entered look alike equipment, cubicle 17
C-10
C3-1 & 2
Controls were not effectively implemented to ensure safety on the job
CC-3
RC-5
Contributing Cause
CC1-2
One Foreman (E3) was monitoring the work through frequent work area passes, but did not notice E1 accessing energized cubicle
C-11
RC-2
Direct Cause
Arc flash engulfing the employee
CC4-5
The absence of blue tape, intended to help identify the cubicle cleaning was complete, possibly contributed to E1 thinking the cubicle still needed cleaning and was de-energized
C-8
E1 wearing class 1.5 PPE but with nitrile gloves for chemicals
The absence of uniquely marked physical barrier allowed E1 to access cubicle 17, by removing the cubicle door and internal panels
C-20
Opportunity was missed to identify and warn E1 to not open energized cabinet
C-19
Stop work authority was not exercised
41.4 Cal/cm2 at 18"
31.2 Cal/cm2 at 24"
No blue tape present
Step 6 requires proper gloves for solvents/ degreasers
Stop work authority was not exercised
E2, E3, and E4 heard noise in the buildup to the arc flash
Cubicle 17 Bus B Phase C to ground
Should have blue tape only
Work order indicates Mode 0 Class 1.5 PPE
No physical barrier or deterrence to prevent cubicles from being opened
No one notices E1 in cubicle 17 leading up to the event
Procedure says to spray cleaning fluid on rag
No one noticed E1 working in Bus B
Cubicle 17 Bus B Phase B - A to ground fault develops
No breaker in cubicle 17
No PPE other than FR Gear required by supervisor
Clearance tag and pre-job brief only barriers
E1 needed to physically remove hardware
Wrench in back pocket of coveralls
E4 and E6 noticed cubicle 17 door open
No work was supposed to be conducted on Bus B
E1 opens outer door to Cubicle 17
~1100
E1 removes two access covers
~1104
E1 begins work inside cubicle 17
E1 sprayed cleaning fluid in air gap between energized 13.8 kV bus and grounded side panel of cubicle 17
Accident
1108


E3 arrives on the scene
E4 recognized E1 on the floor and on fire
E2 saw a body ejected from cubicle 17
Some workers observed flame and felt blast
E1 cut head on wall
Small micro-ohm test instrument laying on floor opposite cubicle 17
E1 blown out of cubicle 17 and against wall the South wall of TA53-70
8 other employees directly effected
E1 stated he thought "it" was de-energized
Use of fire extinguisher not needed
Fire padded out by coworker E2
E3 going to get fire extinguisher
E1 not responsive
E2 put out fire
E1 revives and E2 helps E1 remove burnt clothing and applies cool wet rags
E2 and E3 escort E1 out of structure
E1 walks out of structure
Other 911 calls being made
E3 calls 911
Assessing if system is de-energized
TA53-70 assessed by Facility Management
Using wet piece of cloth
E3 cooling E1s burns
SF6 breakers, voltage switches, and breaker line-up
S1 instructs L1 and E9 to isolate T2
Smoke coming out of switchgear
2 paramedics and 7 others dispatched
Possible electrocution of employee at TA-53-70 reported
Emergency 911 call received by Dispatch 1109
Emergency Operations Center copied
Returning linemen unlock gate
Battalion 1, Engine 40, and Medic 1 dispatched
LAFD Medical and fire units dispatched to TA-53 1110


Confusion as to who is the PIC
E1 on Southeast corner of TA53-70
Southeast side of substation complex
On Scene Incident Command established by Engine 40
Medic 1 able to go directly to the scene
No fire reported by LAFD
Gate by E1s location
E1 observes condition in truck mirror
Engine 40 arrives on scene
Gate leading into the substation is open
Prevents entry into accident area
Rescue 1 dispatched 1111
Returning lineman crew open perimeter gate
E1 waiting LAFD arrival in pickup truck
LAFD units begin arriving on scene 1115
Medic 1 arrives on scene 1116
E1 walks to Medic 1
Medic 1 crew assesses E1
LAFD isolates the scene 1117


Access to the remainder of TA53-70 limited to those requiring access
Around cubicle 17 and exterior to the substation
Red DANGER Tape used
Immediate accident scene secured
Brief description provided
Mass casualty event
Two additional ambulances requested
Most to least critically injured employees identified by Engine 40 crew
Injuries above the waist
Notifications are required
LAMC informed that they would be receiving multiple patients
Incident Command requests additional medical units
E40 crew performs medical triage
Medic 1 leaves site for LAMC with E1 1118
EOC made emergency notifications 1119
LAMC Notified LAFD that E1 would need to be moved to UNMH 1123
Medic 1 arrives at LAMC with E1 1125
Two additional ambulances arrives on scene 1135, 1141


Required by LANL P 732, Section 3.6.4.
No blood draws taken for drug/ alcohol use
Remaining 8 patients transported to LAMC-ER ~1145
Unified Command established 1148
S1 makes the decision to move
Lightning in the area
Incident Command moved to TA-53-45 ~1200
Normal LAMC helicopter site unavailable
E1 arrives at LAHS for transport to UNMH 1228
E1 leaves for UNMH via helicopter ~1235
Released per the LANL SEO-3 EM Incident Record for Incident 15-066
EM Duty Officer turns site over to Facility Superintendent 1243
Unified command terminated 1534
Statements taken from other electricians ~1600


Not available to emergency response or protective forces
Location secured awaiting the arrival of the accident investigation team
Only available to Hi voltage lineman as authorized by S1
Perimeter gates locked
Nothing removed or altered inside TA53-70
Access to TA53-70 controlled by Vitex electronic locking system
Control of site turned back over to U&I FOD
E5 and E3 access yard to remove work trucks belonging to those transported to Medical
S1 instructs everyone in TA53-70 and inside the fence to depart

## APPENDIX H
## PERSONNEL TASK EXPERIENCE SUMMARY

| ID | ROLE | TASK | TASK PERFORMED – EXPERIENCE LEVEL |
|---|---|---|---|
| E1 | Wireman (in switchgear) | 5-Yr / 2-Yr /Switchgear | 5-Yr Package/Yes (Y); 2-Yr Package/Yes (Y); Switchgear Work/Yes (Y) – High-level experience |
| E2 | Wireman (in switchgear) | 5-Yr / 2-Yr /Switchgear | Y/Y/Y – Moderate-level experience |
| E3 | Foreman Wireman (in switchgear) | 5-Yr / 2-Yr /Switchgear | Y/Y/Y – High-level experience |
| E4 | Wireman (in switchgear) | 5-Yr / 2-Yr /Switchgear | N/N/N – No Experience |
| E5 | Lineman (in switchgear) | 5-Yr / 2-Yr /Switchgear | Y/Y/Y – High-level experience |
| E6 | Wireman (in switchgear) | 5-Yr / 2-Yr /Switchgear | Y/Y/Y – High-level experience |
| E7 | Wireman Apprentice (in switchgear) | 5-Yr / 2-Yr /Switchgear | N/N/Y – Minimal-level experience |
| E8 | Wireman (in switchgear) | 5-Yr / 2-Yr /Switchgear | Y/Y/Y – High-level experience |
| E9 | General Foreman Wireman (outside switchgear) | 5-Yr / 2-Yr /Switchgear | Y/Y/Y – High-level experience |
| E10 | Wireman (in switchgear) | 5-Yr / 2-Yr /Switchgear | Y/Y/Y – High-level experience |
| EM 1-3 | Emergency Management Personnel | Emergency Management Duty Officer | Duty Officer – High-level experience |
| S1 | Electrical Superintendent (outside switchgear) | 5-Yr / 2-Yr /Switchgear | Y/Y/Y – High-level experience |
| L1 | Lineman (in and out of switchgear) | 5-Yr / 2-Yr /Switchgear | Y/Y/Y – High-level experience |

| ID | ROLE | TASK | TASK PERFORMED – EXPERIENCE LEVEL |
|---|---|---|---|
| L2 | General Foreman Lineman (ESO) | 5-Yr / 2-Yr /Switchgear | Y/Y/Y – High-level experience |
| O1 | Electric System Operator | 5-Yr / 2-Yr /Switchgear | Y/Y/Y – High-level experience |
| FP1 | Fire Protection | Fire Protection System Support | Fire station notifications and fire panel monitoring, no switchgear work performed. High-level experience. |
| FP2 | Fire Protection | Fire Protection System Support | Fire station notifications and fire-panel monitoring, no switchgear work performed. High-level experience. |
| FP3 | Fire Protection | Fire Protection System Support | Fire station notifications and fire-panel monitoring, no switchgear work performed. High-level experience. |
| G1 | Groundsman – Provide non-electrical support for Linemen.<br>Not electrical worker. | 5-Yr / 2-Yr/Switchgear | N/N/N – Familiar with the tasks, no electrical work performed. Moderate-level experience. |