



# OPERATING EXPERIENCE SUMMARY



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## Arc Flash Accident at Los Alamos National Laboratories Technical Area 53

# 1

On May 3, 2015, at Los Alamos National Laboratory (LANL) Technical Area 53 (TA-53), during Preventive Maintenance (PM) on an electrical substation, a wireman (W1) entered a cubicle on the energized portion of the switchgear to clean it with a commercial spray cleaner and suffered severe injuries from the resulting arc flash and blast. The cleaning solution created a path to ground between the 13.8-kV bus and the grounded cubicle wall, and the force of the arc flash/blast ejected W1 from the cubicle. In addition to suffering significant burns, W1 lacerated his head when he fell backward and struck nearby test equipment. He was airlifted to the regional burn center in critical condition. The National Nuclear Security Administration (NNSA) Secretarial Officer for Safety appointed a joint Department of Energy (DOE) and LANL Accident Investigation Team (Team) to analyze the event and determine causes and Judgments of Need (JON). (ORPS Report NA--LASO-LANL-PHYSTECH-2015-0003; Final Report issued October 20, 2015.)

### Background: The Site and Its Management

The NNSA is a semiautonomous organization within DOE, focusing on the mission of operating the U.S. nuclear weapons enterprise. LANL supports this mission through weapons-system maintenance, non-nuclear testing, advanced computer modeling, and development and applied science and engineering. The NNSA Los Alamos Field Office interfaces with the LANL management team and its operations contractor, Los Alamos National Security, LLC.

### Work Location and Activity

The accident took place at the Los Alamos Neutron Science Center (LANSCE), where a linear accelerator generates sub-atomic particles for a variety of science and nuclear applications. LANSCE operates on regular annual cycles of continuous (24/7) beam operation for several months at a time. That cycle is followed by planned, long-term outages that can last several months. During those outages, workers perform maintenance and testing of the specialized equipment needed for operations, while maintaining ancillary equipment operational to avoid interruption of beam operations. The arc accident occurred at Substation TA-53-0070, pictured in Figure 1-1. The substation consists of 28 closely adjoined cubicles that contain distribution breakers, tie breakers, and power-system metering instrumentation; these cubicles can be electrically segmented by opening tie breakers and isolating them into separate buses.



Figure 1-1. The 13.8-kV substation TA-53-0070

During the May 2 and May 3, 2015, weekend, workers on overtime were simultaneously executing two separate work orders: a 5-year switchgear PM task and a 2-year air circuit breaker PM task. The work was being performed by a mixed crew of workers, consisting of wiremen and linemen with various levels of substation and switchgear experience. At least one lineman was available to support the wiremen by performing zero-voltage checks and attaching grounds.

On May 2, buses A, B, and C were de-energized so PM could begin on all three. By the end of the shift, breaker maintenance and cleaning had been completed for Bus B and Bus C, so they were both re-energized to restore electrical service to some facilities. Bus A was still de-energized, and personnel attached a clearance tag indicating a demarcation between the energized and de-energized cubicles.

Because all the workers had worked a 40-hour week and the substation was some distance from most workers' homes, arrangements had been made for the team to stay at a nearby hotel, so they would not have the added burden of a long commute. On Sunday, May 3, the crew of 10 that had worked the previous day returned. Work began at 0700 with a pre-job briefing, which included a reading of the work scope, as well as a detailed briefing on the associated hazards, mandatory mitigation methods, and personal safety requirements.

The briefing took place directly in front of cubicle 18. The foreman reminded them that Bus B and Bus C were now energized and that all work on this day would be performed ONLY on Bus A (cubicles 19 through 28), which was not energized. The clearance tag was verified to be in place on the cubicle 18 tie breaker, indicating that entry was allowed into Bus A cubicles. During the pre-job briefing, W1 inquired about the status of the personal safety ground, and W1 and a lineman installed and verified this ground. All 10 workers then acknowledged their understanding of the scope and requirements, and work began.

At approximately 1100 hours, W1 walked past the clearance tag affixed to cubicle 18 and opened the door to cubicle 17, which was part of the energized Bus B segment. He was wearing personal protective equipment (PPE) consisting of nitrile gloves and an arc-rated (AR) long-sleeved shirt, non-AR coveralls, and a baseball cap. He positioned a 4-foot fiberglass ladder along the inside of cubicle 17 and removed the internal, steel protective

cover panels to expose the bus bars and switchgear, apparently to allow cleaning of the internal components and assemblies. Because Bus B and Bus C had been energized at the end of the shift on the previous day, unbolting and removing the protective covers exposed the energized bus bars. W1 sprayed a commercial liquid cleaner into the air gap between the energized switchgear bus and the grounded enclosure, resulting in the explosion.

The explosion impacted W1 directly. Investigators assume that, while inside the confined space, W1 placed his hands, forearms, and chest close to the energized components to clean them. The commercially available spray cleaner is intended for use only on non-energized surfaces because it has no established dielectric characteristics – that is, no insulating properties to prevent the conducting of electrical current. W1 received no burns from direct skin-to-electrical component contact; all burns were caused by exposure to the extreme thermal energy of the arc flash. Figure 1-2 shows the energy released from a typical arc flash event, and Figure 1-3 shows W1's burned clothing (recovered after the event). The subsequent pressure wave forced W1 backward and downward onto the floor, where his head struck a piece of micro-ohm testing equipment, resulting in a laceration.

Immediately following the arc flash, other members of the team came to W1's aid, patting out the flames on his clothing, calling for everyone to evacuate the switchgear, and summoning emergency



**Figure 1-2. Energy released after a typical arc-flash event**



**Figure 1-3. Clothing recovered after the arc flash event**

response. Nine individuals were transported by emergency vehicles to the Los Alamos Medical Center (LAMC). Medical Center staff evaluated W1 and determined he had suffered burns to his hands, face, neck, and torso, as well as a minor laceration to the back of his head, but they found no evidence of damage to his hearing or vision. They determined he was in critical condition and he was transported by CareFlight to the regional burn center. He has since been released. One wireman was admitted to LAMC for observation and treatment related to inhalation exposure and released 2 days later; all of the other workers were treated and released the same day.

In its investigation, the Accident Investigation Team determined that personnel reacted effectively and appropriately to evacuate workers and give first aid to

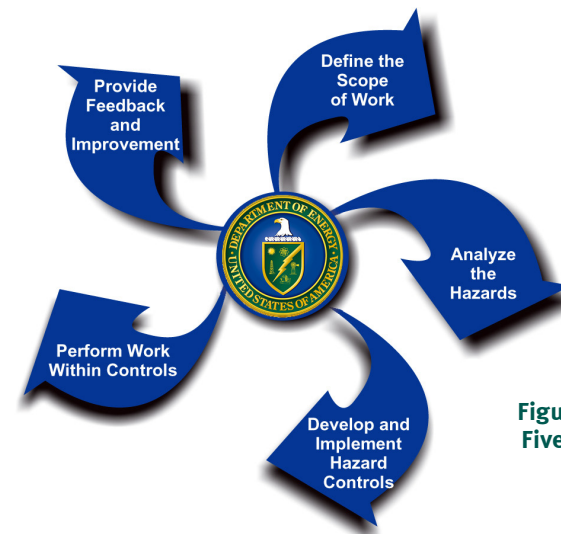
W1. Their ability to react quickly may have prevented additional injuries. Proper notifications were made, and emergency responses by fire department, medical teams, and hospitals were commendable. The accident scene was preserved adequately so that the Team could obtain pertinent facts. However, no drug or alcohol testing was performed on any members of the work crew as required by LANL procedures.

### Investigation Team's Analysis of Primary Issues

The Team analyzed multiple issues, including the three discussed below: past experience and use of lessons learned; Integrated Safety Management (ISM)/work planning and control; and human performance.

### Past Experience and Use of Lessons Learned

The Team analyzed LANL's past experience associated with electrical safety and related Integrated Work Management (IWM) implementation. This included analyzing information from multiple sources, including LANL assessments, lessons learned, occurrence reports, and enforcement actions. Analysis of the key precursor data showed precursors grouped in eight categories and a strong correlation with the causal factors observed in the investigation of this event. Those categories include engaging Subject Matter Experts in work scope and planning; improving work package consistency and formality; defining and communicating roles and responsibilities; analyzing hazards and implementing controls; communicating work conditions (pre-job briefing); changing work conditions; working outside the Integrated Work Document (IWD) or failing to implement controls; and assessing work practices (feedback). Figure 1-4 depicts the ISM Five Core Functions.



**Figure 1-4. The ISM Five Core Functions**



LANL had identified the precursors and established corresponding corrective actions, improvement plans, and integrated activities. Some actions have demonstrated management and worker commitment, but others have not yet been completed, and those that were completed were not sustained or effective at the task level, as shown by this historical analysis.

## ISM/Work Planning and Control

The five ISM Core Functions as they pertain to this event are discussed briefly below.

**Define the scope of work.** The over-arching document for LANL work planning is P300, *Integrated Work Management*, supported by P950, *Conduct of Maintenance*, and AP-Work-002, *Work Planning*, which documents and provides a detailed planning process. LANL's Computerized Maintenance Management System and IWM process were used to plan the LANSCE switchgear outage PM. The Responsible Line Manager determined that the work at TA-53-0070 was a moderate hazard activity. Original planning was to de-energize the switchgear over the entire weekend, but that status was changed on April 28, with no additional hazard analysis. Because the two PM activities are performed only every 2 and 5 years, the model work orders used by the crew were created – and used successfully – years before the May 2 and 3, 2015, work. The planners reviewed the work orders as part of the work package development process. However, they were written at the broad, activity level, not the task level. As a result, hazards were not sufficiently identified, analyzed, or mitigated.

**Analyze the hazards.** The IWD analysis did not evaluate the hazards and associated effects of the following: concurrently performing two PMs, which contributed to workplace clutter and a crowded environment; initiating a changed work configuration where all buses were de-energized on Saturday, but

only partially de-energized on Sunday; the possibility of human error by accidentally entering and performing work on an energized cubicle. Failure to perform the analysis resulted in a missed opportunity to include and analyze task-level controls.

**Develop and implement controls.** The following controls are common to both work packages.

- Require minimum Mode 0 Class 1.5 PPE of hard hat, safety glasses, Nomex/arc-rated long-sleeved shirt, and leather gloves.
- Ensure zero-voltage step has been performed, and use a second person to verify.

In contrast, W1 was allowed to work wearing a ball cap instead of hard hat, nitrile gloves instead of leather gloves, and an AR-rated shirt with the sleeves rolled up. The zero-voltage check was not performed, and there was no physical barrier installed to decrease the likelihood of human error that led to W1's injury.

**Perform work within controls.** The LANL Electrical Safety Program has requirements for pre-job briefing content that include following procedures/two-person rule or safety watch; special precautions; wearing required PPE; and asking questions such as “Can we make a mistake at this point?” and “What is the worst thing that can go wrong?” The pre-job for this work did not anticipate the possibility of a worker opening and performing work in an energized cubicle.

**Provide feedback and improvement.** LANL procedures require feedback (self-assessment) to help improve the work planning process. The Team's analysis identified previous electrical events and determined that this accident could have been prevented if LANL's corporate feedback and improvement process had driven corrective actions from previous events.



## Human Performance

Within DOE, most serious events do not happen during high-hazard or complex operations because workers are paying attention, many people are involved, things move slowly, and everyone is mindful. Most serious events occur during so-called routine or low-to-moderate hazard work. Workers may have their minds elsewhere, may be overly tired, may simply want to “get the job done,” or may have a sense of complacency.

This crew was assembled to work a projected 28 hours of overtime the weekend of May 2 and 3, after working a 40-hour week. Each member clearly understood the objectives, but the work package had been created at the activity, not the task, level. When the work conditions – status of buses being energized or de-energized – changed from Saturday to Sunday, the work package did not include the detailed hazard controls necessary to prevent W1 from entering cubicle 17. Potential hazards were also introduced by working two PMs concurrently in a small, cluttered work space and by assigning a mixed work crew. Four crew members normally did other work and did not work with the switchgear team, and one crew member was doing this sort of work for the first time. It should be noted, however, that W1 was familiar with the switchgear work.

In order to track breaker cleaning, an informal, potentially confusing system was being used; it was neither formalized nor proceduralized. Blue tape signified that cubicle cleaning was complete; red tape signified that breaker testing was complete, but no verification was required in either case. Cubicle 17 – where the accident occurred – should have been marked with blue tape only, since it contains no breaker and had been cleaned on Saturday. However, photographic evidence revealed that cubicle 17 did not have tape of any color on it.

In post-event interviews, some workers pointed out that this was the first time they had worked on two concurrent PMs (cleaning cubicles and breaker testing). Past practice had been to complete cleaning with the switchgear fully isolated. In addition, there were no physical barriers to prevent work in cubicle 17. Workers (wiremen and linemen) had to rely on a clearance tag, a process familiar to linemen but not to wiremen.

The crew worked 14 hours Saturday, May 2. LANL provided hotel accommodations for the crew to afford the maximum down time by avoiding travel. Later worker interviews revealed that all workers felt well rested and optimistic Sunday morning; the progress made the previous day made them believe Sunday’s work would be completed early.

## **Causes and Judgments of Need (JONS)**

Based on the results of its investigation, the Team determined that the accident was preventable.

### Causes

The Team identified the *direct cause* as W1 entering the energized cubical and spraying cleaning fluid into the air gap between the bus bars and the grounded enclosure, where the spray created a path to ground and resulted in an arc flash.

The Team identified the overall *root cause* as less-than-adequate management of control implementation, which the Team considered a combination of two specific root causes:

- Failure to require and implement zero-voltage checks; and
- Lack of established physical barriers.

The Team summarized all 34 causal factors into the five contributing causes (similar to the ISM Five Core Functions) discussed on the following page.



- Scope of work at task level was not adequately defined. IWDs did not include tracking processes to validate work planned and work completed. Mixed equipment status was not addressed with process steps to prevent entry into energized equipment. In addition, both training and procedure require *zero-energy verification*, but that step is not consistently performed, and was not performed when cubicle 17 was opened on Sunday.
- Weaknesses in Hazard Analysis (HA) resulted in some hazards not being analyzed. The HA for this work was conducted at the higher *activity* level and did not require controls at the lower, more specific *task* level. Hazards introduced by working two activities in parallel and the differing operational status of the switchgear were not considered. As a result, there was no effective barrier to separate the energized and de-energized buses.
- Controls were not effectively implemented to ensure safety on the job. The crew for this job consisted of linemen, breaker maintenance electricians, and wiremen (electricians familiar with lower-voltage applications). Linemen rely primarily on the clearance process for utility work, whereas electricians and wiremen rely on Lockout/Tagout (LOTO). Although there are common skills and training among these positions, the IWD identified both sets of rules without specifying the final controls and did not account for the limited lines of sight and the mixed equipment configuration.
- Work was not performed within controls envisioned by job planners and management. Work activities were not assigned to specific individuals and were informally tracked; confusion about the zero-voltage check requirements resulted in that control being inconsistently

implemented; visual work boundaries and work completion status did not clearly indicate that the energized cubicle was outside the work scope. The Team's review of the management processes applicable to the electrical maintenance work revealed that procedures and policies were in place. However, this and other recent events at LANL demonstrate that those procedures and policies are often applied at the minimum level possible to execute work – or in some cases, not at all.

- Feedback and lessons learned were not applied. The Team noted that, although electrical events with similar causes have been documented at LANL, there was no evidence that lessons learned from any of them had been applied to the HA for this preventive maintenance work.

### Judgments of Need (JONs)

The Team identified 13 JONs, including the 5 shown below that are most pertinent to this discussion.

- Management needs to strengthen expectations regarding work-scope determination as well as task-level work and hazard analysis.
- LANL needs to establish uniform and stringent implementation of safety requirements when executing work involving mixed work crews.
- LANL needs to effectively implement human performance error-prevention tools in work planning and hazard analysis.
- Management needs to reinforce and clarify expectations and implementation of zero-voltage verification requirements in the course of all electrical work.
- LANL needs to improve its ability to implement and verify corrective actions from previous assessments and events.



The Team strongly recommended that LANL apply critical thought in developing corrective actions in response to the JONs because simply adding procedures, policies, or requirements may not address the issues experienced during this particular event. Instead, the Team recommended that more focus be placed on ways to ensure implementation, clearly understood expectations, and effective verification of implementation as well as a review of current processes to remove inefficiencies and distractions. For a complete list of JONs and detailed discussion, readers should refer to the final investigation report to better understand how the JONs are linked to 34 causal factors.

## Conclusion

After the arc flash event, separate briefings were held for workers (with no managers present); for mid-to-upper managers from Facility Operations, Utilities, Safety, and Maintenance-Site Services; for LANL and Los Alamos Site Office management; and for NNSA and the Office of Enforcement. Then, on June 25, 2015, the LANL Electrical Safety Committee (ESC) and site management held a LANL-wide electrical safety meeting featuring nine presentations, including discussion of recent electrical incidents, site electrical safety performance, human performance, real-time risk assessment, risk assessment for electrical work, the 2015 NFPA 70E, electrical safety program revision, and a view of future activities. The meeting included multiple question and answer sessions. It was broadcast on LANL's *View It* site, and was made available to everyone on the ESC website afterwards.

More information about the event and the Team's Findings and Recommendations is available in the Team's report, *TA-53 Arc-Flash Accident Joint Accident Investigation Team (JAIT) Report*. It can be accessed on the AU Operating Experience Wiki by clicking [here](#).

**KEYWORDS:** Arc flash, injury, cubicle, hazard analysis, human performance, Integrated Work Document, IWD, Integrated Work Management, IWM, preventive maintenance, PM, switchgear, TA-53, zero-voltage check, Los Alamos Neutron Science Center (LANSCE)

**ISM CORE FUNCTIONS:** Define the Scope of Work, Analyze the Hazards, Develop and Implement Hazard Controls, Perform Work within Controls, Provide Feedback and Improvement





The Office of Environment, Health, Safety and Security (AU), Office of Analysis publishes the *Operating Experience Summary* to promote safety throughout the Department of Energy (DOE) Complex by encouraging the exchange of lessons-learned information among DOE facilities.

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