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Performance Analysis: Control of Hazardous Energy

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Performance Analysis:
Control of Hazardous Energy

Occurrences and Associated Noncompliances Discovered

January 2008–August 2010

September 2010

by

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Contractor Assurance Office

Disclaimer

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1.0 Summary

LLNL experienced 26 occurrences related to the control of hazardous energy from January 1, 2008 through August 2010. These occurrences were 17% of the total number of reported occurrences during this 32-month period. The Performance Analysis and Reporting Section of the Contractor Assurance Office (CAO) routinely analyzes reported occurrences and issues looking for patterns that may indicate changes in LLNL's performance and early indications of performance trends. It became apparent through these analyses that LLNL might have experienced a change in the control of hazardous energy and that these occurrences should be analyzed in more detail to determine if the perceived change in performance was real, whether that change is significant and if the causes of the occurrences are similar. This report documents the results of this more detailed analysis.

The DOE process is to analyze individual occurrences for apparent cause, conduct a performance analysis to identify recurring occurrences, then analyze each recurring occurrence for the root causes. This method ensures that valuable analytical resources are applied to the most pressing needs.

The causes of events have changed over the 2.75 years analyzed in this report. It appears that there has been improvement in the analysis of hazards prior to work authorization and in the work control documentation. More attention, however, may need to be given to improving the accuracy of information being communicated and empowering workers to question situations.

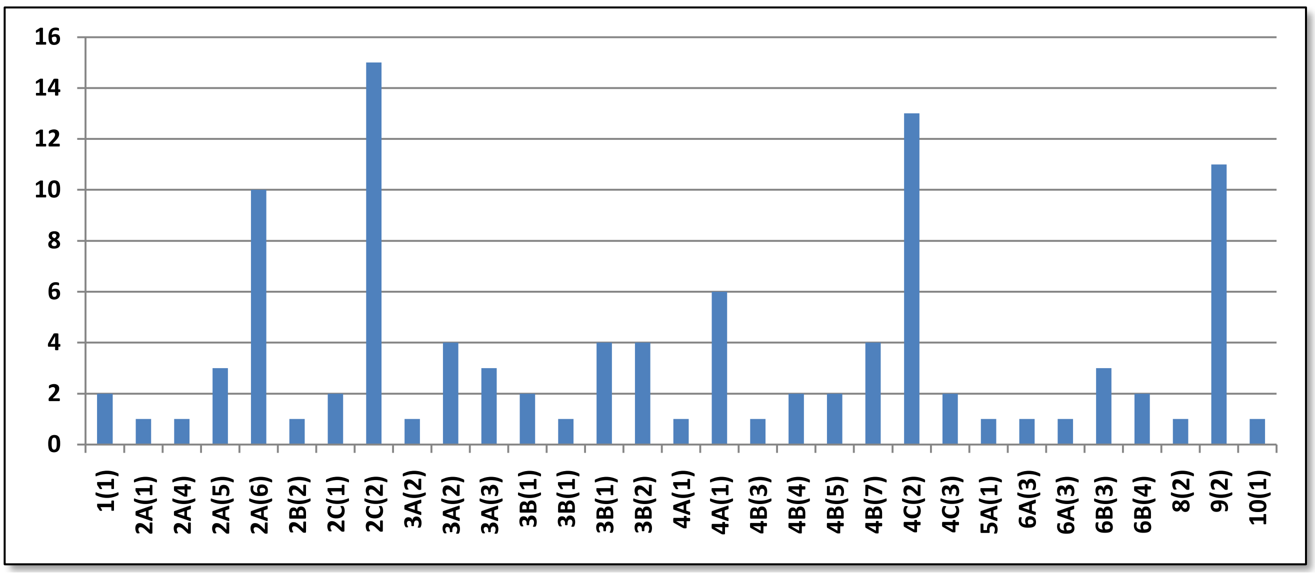
The report concludes that LLNL does not have repetitive noncompliances related to implementing the actual steps of Lockout/tagout (LO/TO). It does, however, have recurring occurrences where hazardous energy is inadequately controlled, due to failures in the execution of work planning and control.

The Department of Energy (DOE) requires contractors, such as LLNL, to report and conduct root cause analysis of recurring occurrences.

2.0 Introduction

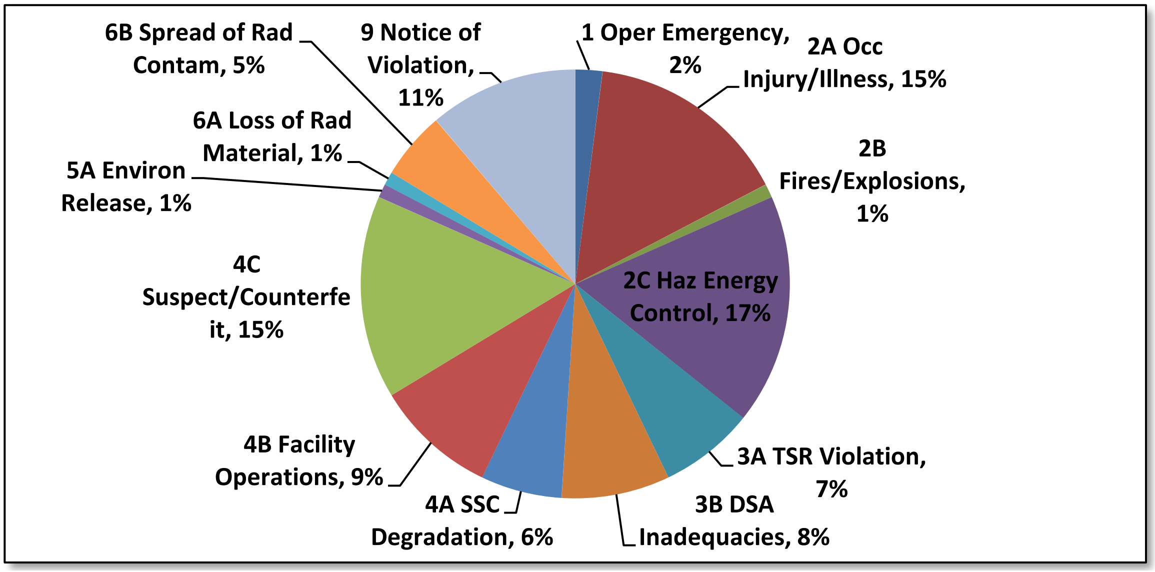
This analysis is a supplement to the routine quarterly analysis of LLNL occurrences conducted by the Performance Analysis and Reporting Section. In the quarterly analyses, occurrences in aggregate are evaluated to identify areas that may possibly require additional management attention and to identify potential recurring conditions or systemic/programmatic noncompliances. During the routine analysis, it was identified that the most frequent occurrence at LLNL was from the inadequate control of hazardous energy, if one excludes the occurrences reported under reporting group 10, management concerns and near misses. The number of occurrences per reporting group is shown in Figure 1.

Figure 1 Frequency of Occurrences during January 2008–August 2010



The number of occurrences related to the inadequate control of hazardous energy amounts to 17% of LLNL's occurrences, as shown in Figure 2.

Figure 2 Proportions of Occurrences by Reporting Criteria



As shown in Figures 1 and 2, the 2C(2) group is the most common group for the occurrences reported by LLNL, followed by occupational injuries and illness 2A, and suspect/counterfeit items 4C. Management concerns 10(2) and Near misses 10(3) are excluded from the figure because occurrences in these categories include events of all types that are similar to the reporting categories shown on the chart, but do not meet the threshold for reporting in these categories. About a third of LLNL's occurrences are reported in the management concerns 10(2) and near misses 10(3) reporting groups.

In addition, after an event in February 2010 and a perceived increase in the number of Lock-out/Tag-out (LO/TO) events, PARS started a special focused analysis of LLNL occurrences and associated noncompliances related to the implementation of LO/TO. As the analysis progressed, it became apparent that the perceived concern with LO/TO was really a concern related to the control of hazardous energy.

Hazardous energy can be any source of electrical, mechanical, hydraulic, pneumatic, chemical, thermal or other energy that, if uncontrolled, has the potential to cause injury up to and including death, to the worker. LLNL describes the process and the requirements to control hazardous energy in *ES&H Manual*, Document 12.6, LLNL Lockout/Tagout Program. One of the most common methods employed to control hazardous energy is through LOTO. The purpose of the LLNL LOTO program is to prevent unintended release of hazardous energy associated with servicing and maintenance activities. LOTO is defined in Document 12.6 as, "the applying of a lock and associated identifying tag to an energy-isolating device in accordance with an established procedure to ensure that the device and equipment being controlled cannot be operated until the lock and associated tag are removed."

The Performance Analysis and Reporting Section conducted this analysis to determine if the occurrences related to inadequate control of hazardous energy are significant and if there are common causes that should be addressed. This report documents the result of the analysis of these occurrences.

3.0 Analysis of Significance

LLNL's most frequent occurrence is related to the inadequate control of hazardous energy. Since January 1, 2008, LLNL has experienced 155 events reportable to DOE in the ORPS. 26 (17%) of these events were where hazardous energy was not adequately controlled and workers were allowed to interact with the hazardous energy, or where management was concerned that workers could have been exposed to hazardous energy (these events did not result in adverse consequences, but could have if the circumstances of the event were different, i.e. higher voltages, currents, etc).

Occurrences can be reported under multiple reporting criteria and, in this time period, the 26 hazardous energy control events were reported under three reporting criteria: Group 2C "Hazardous Energy Control;" 10(2) "Management Concern;" and, 10(3) "Near Miss." Of the 155 occurrences in this period, 51 (33%) were categorized in reporting criteria group 10(2), "Management Concern," and of these 51 occurrences, seven (5%) were related to hazardous energy control. Also, 11 occurrences (7%) were reported under criteria 10(3), "Near Miss" – and of these 11 occurrences, 2 (1%) were related to hazardous energy control. Two occurrences are reported under the 2C and 10(3) criteria. In these two occurrences, there was a "near miss" to a personal injury that prompted the addition of the criteria code.

The 26 occurrences related to ineffective control of hazardous energy are listed in Table 1.

Table 1: List of 26 Hazardous Energy Control-Related Events

Report Number	Categorization Date	Subject / Title	Reporting Category	Signif. Category	Principal Directorate
NA--LSO-LLNL-LLNL-2008-0001	1/8/2008	Building 174 Electrical Shocks	10(2)	3	S&T
NA--LSO-LLNL-LLNL-2008-0004	1/30/2008	Electrical Shock at Building 151 During Main Electrical Service Equipment Replacement Project	2C(2)	3	O&B
NA--LSO-LLNL-LLNL-2008-0010	3/13/2008	Failure to Follow Established Work Procedures Results in Potentially Hazardous Building 241 Air Leak	2C(2)	3	GS
NA--LSO-LLNL-LLNL-2008-0011	4/9/2008	Electrical Wiring Contacted During Seismic Securing of Office Furniture in Building 111	2C(2)	3	O&B
NA--LSO-LLNL-LLNL-2008-0012	4/9/2008	Subcontractor Employee Failed to Follow Hazardous Energy Control Process During Building 365 Bio-Safety Cabinet Repair	2C(2)	3	GS
NA--LSO-LLNL-LLNL-2008-0015	5/8/2008	Building 194 Employee Exposure to Diffuse Laser Light	10(2)	3	S&T
NA--LSO-LLNL-LLNL-2008-0017	5/28/2008	Failure To Perform Proper Lockout / Tagout At Trailer 4377	2C(2)	3	O&B
NA--LSO-LLNL-LLNL-2008-0019	6/17/2008	Building 170 CO2 Gas Vent From Cylinder	10(2)	4	O&B
NA--LSO-LLNL-LLNL-2008-0032	8/13/2008	Building 140 Electrical Shock Incident	2C(1)	2	O&B

Report Number	Categorization Date	Subject / Title	Reporting Category	Signif. Category	Principal Directorate
NA--LSO-LLNL-LLNL-2008-0034	8/20/2008	Degradation of the Building 332 Safety Significant Fire Detection and Alarm System	2C(2) 4A(1)	3	WCI
NA--LSO-LLNL-LLNL-2008-0048	10/14/2008	Natural Gas Valve Found in On Position in Vacant Building 241	2C(2)	3	O&B
NA--LSO-LLNL-LLNL-2008-0061	12/8/2008	Mechanical Interlock Failure on Door to Main Electrical Transformer in Building 191	2C(2)	3	O&B
NA--LSO-LLNL-LLNL-2008-0067	12/19/2008	Building 174 Laser Operations Procedural Weakness	10(3)	3	S&T
NA--LSO-LLNL-LLNL-2009-0006	1/29/2009	Unauthorized Work On Lighting Switch In Building 453 Office	2C(2)	3	S&T
NA--LSO-LLNL-LLNL-2009-0009	2/9/2009	Copper Conductor Left In Electrical Cabinet Causes Short in Building 117	10(2)	3	S&T
NA--LSO-LLNL-LLNL-2009-0013	2/26/2009	110-Volt Power Line Severed During Concrete Cutting Activity in Building 481	10(2)	4	NIF
NA--LSO-LLNL-LLNL-2009-0015	3/13/2009	Arcing Tabletop Laser in Building 179	10(2)	4	S&T
NA--LSO-LLNL-LLNL-2009-0019	4/24/2009	Near Miss Involving Non-authorized Energized Work in Building 691	2C(2) 10(3)	3	S&T
NA--LSO-LLNL-LLNL-2009-0027	6/23/2009	Non-Energized Electrical Cable Cut Without Proper Energy Isolation	10(3)	3	NIF
NA--LSO-LLNL-LLNL-2009-0034	10/22/2009	Worker Receives Electric Shock When Finger Enters Into Broken Light Switch Casing in Building 235 Kitchen	2C(1)	2	O&B
NA--LSO-LLNL-LLNL-2010-0006	2/19/2010	Energized Electrical Conductor Cut Without Energy Isolation in Building 391	2C(2)	3	NIF
NA--LSO-LLNL-LLNL-2010-0016	3/31/2010	Unexpected Discharge of Flammable Gas While Drilling Into Gas Cylinder With a Hand Drill	2C(2) 10(3)	3	O&B
NA--LSO-LLNL-LLNL-2010-0028	7/19/2010	Discovery of Energized Electrical Source During Equipment Installation At Building 391	2C(2)	3	O&B
NA--LSO-LLNL-LLNL-2010-0036	8/9/2010	Building 190 Tube Furnace Minor Electrical Shock	10(2)	4	PLS
NA--LSO-LLNL-LLNL-2010-0037	8/12/2010	Unexpected Discovery Of A Pressurized Hydraulic Oil Line During Fire Sprinkler Upgrade In Building 311	2C(2)	3	O&B
NA--LSO-LLNL-LLNL-2010-0038	8/16/2010	Dynamic Transmission Electron Microscope Improper Shielding Removal in Building 235	2C(2)	3	PLS

The question that follows these observations is, “Are these observations significant?” If they are significant, then an analysis of any common causes or relationships is appropriate.

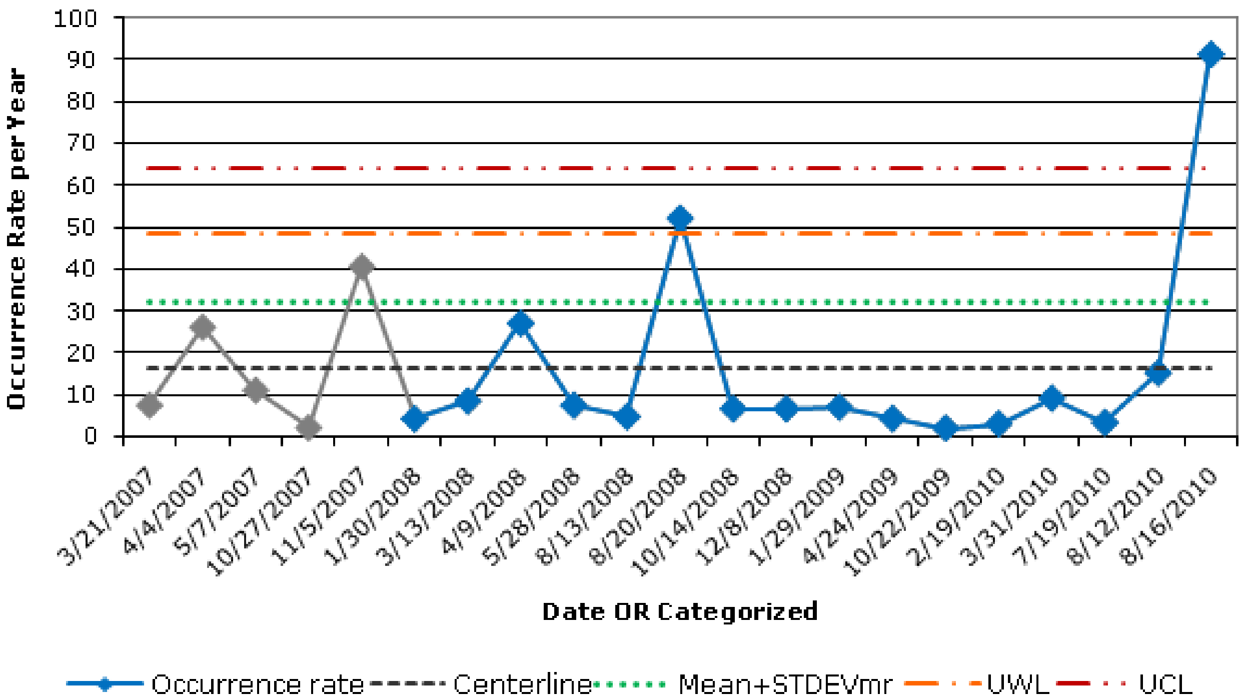
Control charts were used to determine the level of significance of these occurrences. The goal was to understand if there had been a change in the number or frequency of these occurrences and if this change was unique and significant. Control charts were developed that included all occurrences in each of these criteria.

The data in the control charts covered the time period of January 2007 to August 2010. This period is greater than the time period analyzed (January 2008-August 2010) to ensure a large enough sample size and more confidence in the outcome of the statistical test. Appendix A provides a description of the methods for analysis using control charts.

2C -"Hazardous Energy Control"

Seventeen (65% percent) of the 26 occurrences were reported under criterion 2C – "Hazardous Energy Control" reporting criteria. All occurrences categorized as a 2C -"Hazardous Energy Control" since 2007 were graphed, as shown in Figures 3. The data from 2007 is shown in grey. It was included in the calculation of the control limits but is not part of the time period analyzed in this report.

Figure 3. Occurrence Rate per Year Control Chart – Failure of Hazardous Energy Control Occurrences (ORPS Reporting Criteria 2C)



Looking at all occurrences since January 2008 reported under the 2C -"Hazardous Energy Control" reporting criterion, it is apparent that there was a recent increase in the rate per year in August 2010. The rate per year of 2C occurrences is the equivalent of 91 per year or one every four days. This point is above the upper control limit (UCL), which is an action limit, suggesting that this process is out of control and the variability in the process is non-random. Also, the days between these occurrences has been decreasing since the event in July 2010, which contributes to the point above the UCL on Figure 4. The point above the upper control limit indicates that these occurrences should be analyzed for common cause.

10(2) "Management Concern"

Seven (27% percent) of the 26 occurrences were reported under criterion 10(2) – "Management Concern." The number of occurrences in the 10(2) reporting criterion per month since January 2007 are graphed in Figure 4. In Figure 4, the data from 2007 is shown in grey. The 2007 data was included in the calculation of the control limits but is not part of the time period analyzed in this report. Figure 4 includes all occurrences reported under this reporting criterion since January 2007. Since there is some flexibility in identifying occurrences reported under this category, this chart helps to determine if the increase in occurrences is related to an increase in management concern versus an increase in events with actual consequences.

Figure 4. Individual Occurrence Control Chart – Management Concern Occurrences (ORPS Reporting Criteria 10(2))

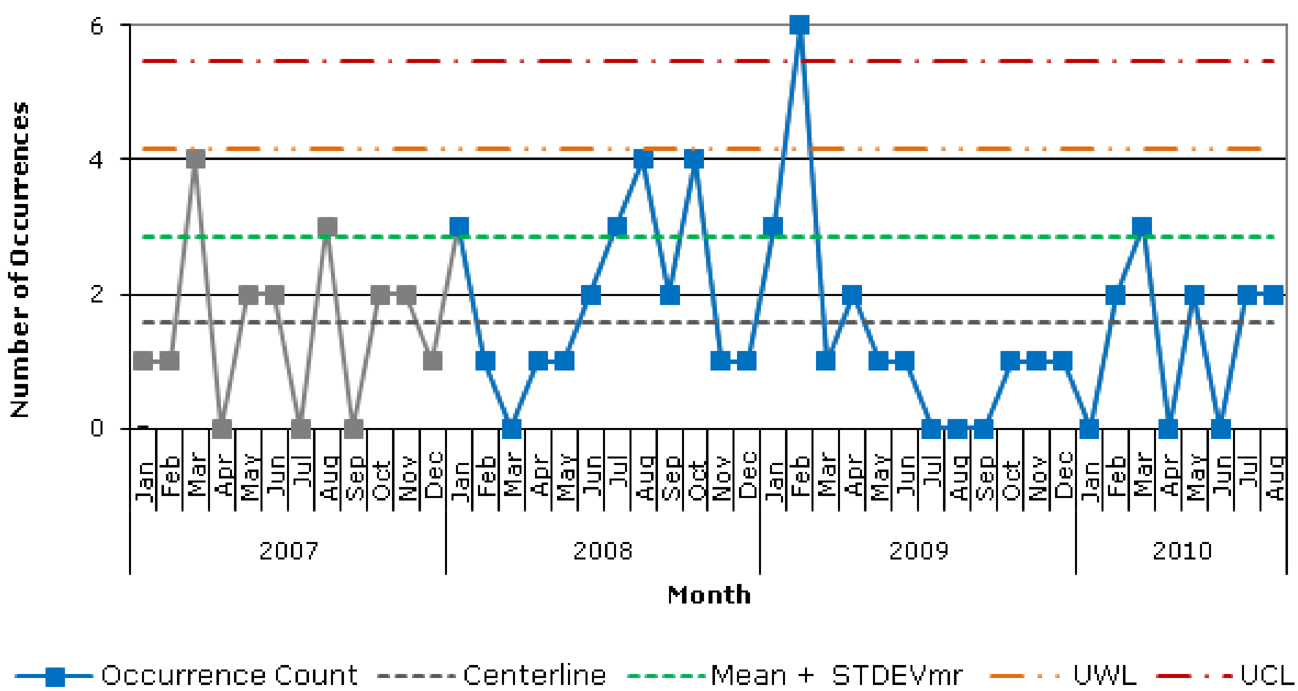


Figure 4 shows that, since January 2008, LLNL experienced one month (February 2009) when the number of 10(2) occurrences was above the upper control limit, which is an action limit. If the number is above an action limit then the variability in the process is non-random and considered out of control. The number of occurrences since February 2009 has not caused a point to meet an action limit, suggesting that since February 2009, this process is in control and the variability in the number of occurrences is random.

Figure 4 also indicates that there has been no increasing trend in the number of occurrences reported as management concerns.

10(3) "Near Miss"

Four (15% percent) of the 26 occurrences were reported under the reporting criterion 10(3) – "Near Miss" reporting criterion. Two of these were also reported under the 2C criterion related to controlling hazardous energy. Figure 5 graphs the rate of all occurrences reported under this reporting criterion. In Figure 5, the data from 2007 is shown in grey. This data was included in the calculation of the control limits but is not part of the time period analyzed in this report.

Figure 5. Occurrence Rate per Year Control Chart – Near Miss Occurrences (ORPS Reporting Criteria 10(3))

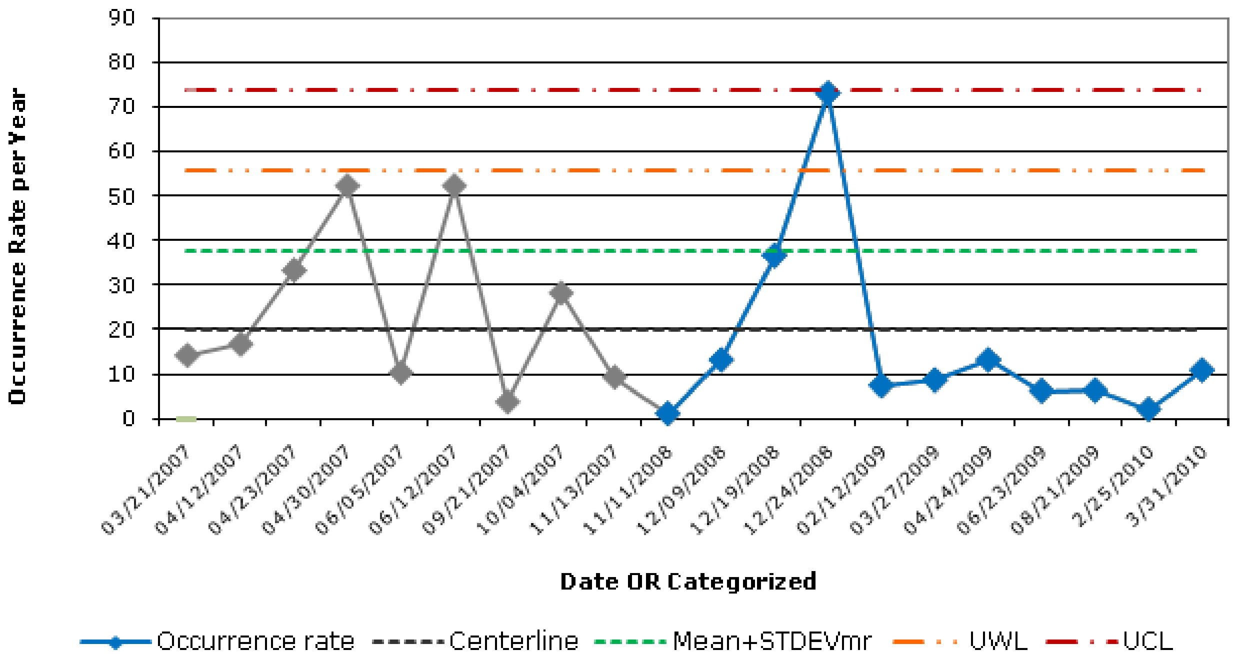


Figure 5 shows that since January 2008 there has been only one significant increase in the rate of occurrences categorized as 10(3) - "Near Miss." This increase was in November and December 2008, causing one point just below the upper control limit, a common test (i.e. above the upper warning limit). This suggests that as of December 24, 2008, the rate of 10(3) occurrences per year was 73 or one every five days. Since this data is considered rare, a rate of one every five days is out of the ordinary. Of the four 10(3) occurrences since November 2008 that moved the occurrence rate close to the upper control limit, only one was related to the control of hazardous energy. In March 2010, there was also a slight increase in the rate for the most recent occurrences categorized as a 10(3). As of March 2010, the rate of 10(3) occurrences per year was 11 or about one a month. The rate of occurrences since December

2008 has not caused a point to meet an action limit, suggesting that since December 2008, this process is in control and the variability in the process is random.

None of the charts indicate a sustained increasing trend in the number of events. Only one of the three control charts, above, show a recent exceedance of the action limit suggesting that processes are out of control. This chart is the one analyzing the occurrences categorized under the 2C reporting criterion related to controlling hazardous energy.

Given that there has been a recent increase in occurrences related to the control of hazardous energy exceeding an action limit and that these occurrences constitute one fifth of all LLNL's occurrences, The analysis was taken to the next step: relationship analysis.

4.0 Relationship Analysis

The 26 events were analyzed for similarities. They were binned by causal codes, ISM function, and narrative comparison. The 26 occurrences were analyzed using relationship or common cause analysis to determine if there are common issues that may need to be addressed.

Most of the occurrences were analyzed for apparent cause. Apparent cause analysis tends to identify active errors and the corrective actions tend to be localized. In relationship or common cause analysis the underlying causes are articulated based on the causal analysis reports. If recurring occurrences or repetitive deficiencies are identified; however, a root cause analysis may need to be conducted to identify latent conditions or latent organizational weaknesses that, if corrected, could prevent recurrence and more confidently assure the control of hazardous energy. Management may desire to develop and implement corrective actions to prevent recurrence. DOE requires recurring occurrences to be reported to the DOE ORPS and repetitive noncompliances to be reported to the DOE NTS.

4.1 Analysis of Causal Codes

LLNL assigns a code for each cause identified during the causal analysis of each occurrence. Cause codes are selected from the DOE Causal Analysis Tree (CAT), described in DOE Guide 231.1-2. The cause codes are applied to the results of both root cause and apparent cause analyses. These codes are useful in analyzing the causes of multiple occurrences in different organizations and locations; however, at times, even when occurrences share like reporting criteria or causal code, it is possible that the events are so dissimilar as to preclude concluding a recurring occurrence. For this reason, relationship analysis is employed to analyze like occurrences. Cause codes were used to initially group the occurrences. This process did not immediately identify commonalities.

4.3 Analysis of causes by ISM Function

It is recognized that the regulations and LLNL's processes for controlling hazardous energy include multiple barriers to avoid adverse events. Each of these barriers provides a level of protection from the hazards. Most barriers are integrated into the facilities, equipment and processes. Some barriers, especially those implemented while conducting the work, provide verification that the controls previously implemented continue to provide protection. A well operating program to control hazardous energy relies primarily on engineering controls, such as disconnecting and locking or removing hazardous energy sources. Then secondarily, it relies on administrative, such as locks and identification tags, meters to verify the absences of hazardous energy or two-person rules to rescue affected workers. The third level of control is personnel protective equipment, such as gloves and face shields. Each subsequent level of protection provides a less reliable level of protection.

The groupings by ISMS function were intended to help analyze the causes that might be common at the first point of error. It is recognized that additional errors may occur during implementation of subsequent functions, however, the initial error may contribute to the probability of subsequent errors. The 26 occurrences were reviewed to identify the point in the work process when the first error occurred, as shown in Table 2.

Table 2. 26 Occurrences Binned by ISMS Function

Report Number	Categorization Date	Subject / Title	ISM-1 Define Work	ISM-2 Analyze Hazards	ISM-3 Control Hazards	ISM-4 Perform Work	ISM-5 Feedback & Improve
NA--LSO-LLNL-LLNL-2008-0001	1/8/2008	Building 174 Electrical Shocks		ISM 2			
NA--LSO-LLNL-LLNL-2008-0004	1/30/2008	Electrical Shock at Building 151 During Main Electrical Service Equipment Replacement Project	ISM1				
NA--LSO-LLNL-LLNL-2008-0010	3/13/2008	Failure to Follow Established Work Procedures Results in Potentially Hazardous Building 241 Air Leak		ISM 2			
NA--LSO-LLNL-LLNL-2008-0011	4/9/2008	Electrical Wiring Contacted During Seismic Securing of Office Furniture in Building 111		ISM 2			
NA--LSO-LLNL-LLNL-2008-0012	4/9/2008	Subcontractor Employee Failed to Follow Hazardous Energy Control Process During Building 365 Bio-Safety Cabinet Repair		ISM 2			
NA--LSO-LLNL-LLNL-2008-0015	5/8/2008	Building 194 Employee Exposure to Diffuse Laser Light		ISM 2			
NA--LSO-LLNL-LLNL-2008-0017	5/28/2008	Failure To Perform Proper Lockout / Tagout At Trailer 4377				ISM4	
NA--LSO-LLNL-LLNL-2008-0019	6/17/2008	Building 170 CO2 Gas Vent From Cylinder		ISM 2			
NA--LSO-LLNL-LLNL-2008-0032	8/13/2008	Building 140 Electrical Shock Incident			ISM3		
NA--LSO-LLNL-LLNL-2008-0034	8/20/2008	Degradation of the Building 332 Safety Significant Fire Detection and Alarm System	ISM1				
NA--LSO-LLNL-LLNL-2008-0048	10/14/2008	Natural Gas Valve Found in On Position in Vacant Building 241		ISM 2			
NA--LSO-LLNL-LLNL-2008-0061	12/8/2008	Mechanical Interlock Failure on Door to Main Electrical Transformer in Building 191			ISM3		
NA--LSO-LLNL-LLNL-2008-0067	12/19/2008	Building 174 Laser Operations Procedural Weakness				ISM4	

Report Number	Categorization Date	Subject / Title	ISM-1 Define Work	ISM-2 Analyze Hazards	ISM-3 Control Hazards	ISM-4 Perform Work	ISM-5 Feedback & Improve
NA--LSO-LLNL-LLNL-2009-0006	1/29/2009	Unauthorized Work On Lighting Switch In Building 453 Office	ISM1				
NA--LSO-LLNL-LLNL-2009-0009	2/9/2009	Copper Conductor Left In Electrical Cabinet Causes Short in Building 117	ISM1				
NA--LSO-LLNL-LLNL-2009-0013	2/26/2009	110-Volt Power Line Severed During Concrete Cutting Activity in Building 481		ISM 2			
NA--LSO-LLNL-LLNL-2009-0015	3/13/2009	Arcing Tabletop Laser in Building 179			ISM3		
NA--LSO-LLNL-LLNL-2009-0019	4/24/2009	Near Miss Involving Non-authorized Energized Work in Building 691			ISM3		
NA--LSO-LLNL-LLNL-2009-0027	6/23/2009	Non-Energized Electrical Cable Cut Without Proper Energy Isolation		ISM 2			
NA--LSO-LLNL-LLNL-2009-0034	10/22/2009	Worker Receives Electric Shock When Finger Enters Into Broken Light Switch Casing in Building 235 Kitchen			ISM3		
NA--LSO-LLNL-LLNL-2010-0006	2/19/2010	Energized Electrical Conductor Cut Without Energy Isolation in Building 391	ISM1				
NA--LSO-LLNL-LLNL-2010-0016	3/31/2010	Unexpected Discharge of Flammable Gas While Drilling Into Gas Cylinder With a Hand Drill		ISM 2			
NA--LSO-LLNL-LLNL-2010-0028	7/19/2010	Discovery of Energized Electrical Source During Equipment Installation At Building 391	ISM1				
NA--LSO-LLNL-LLNL-2010-0036	8/9/2010	Building 190 Tube Furnace Minor Electrical Shock			ISM3		
NA--LSO-LLNL-LLNL-2010-0037	8/12/2010	Unexpected Discovery Of A Pressurized Hydraulic Oil Line During Fire Sprinkler Upgrade In Building 311		ISM 2			
NA--LSO-LLNL-LLNL-2010-0038	8/16/2010	Dynamic Transmission Electron Microscope Improper Shielding Removal in Building 235	ISM1				
Total			7	11	6	2	

It is recognized that analysts may assign different functions or even multiple functions to each occurrence if they have different areas of expertise, different information or are conducting the binning at a future date. The binning provides a structure within which to gain insight and a mechanism to manage the analysis.

4.3.1 Analysis of Causes of Errors in ISMS Function 1 – Define Work

Seven of the occurrences were binned in ISMS Function 1 – Define the work. The seven occurrences, listed in Table 3, appeared to be related to possible errors in how the work was defined.

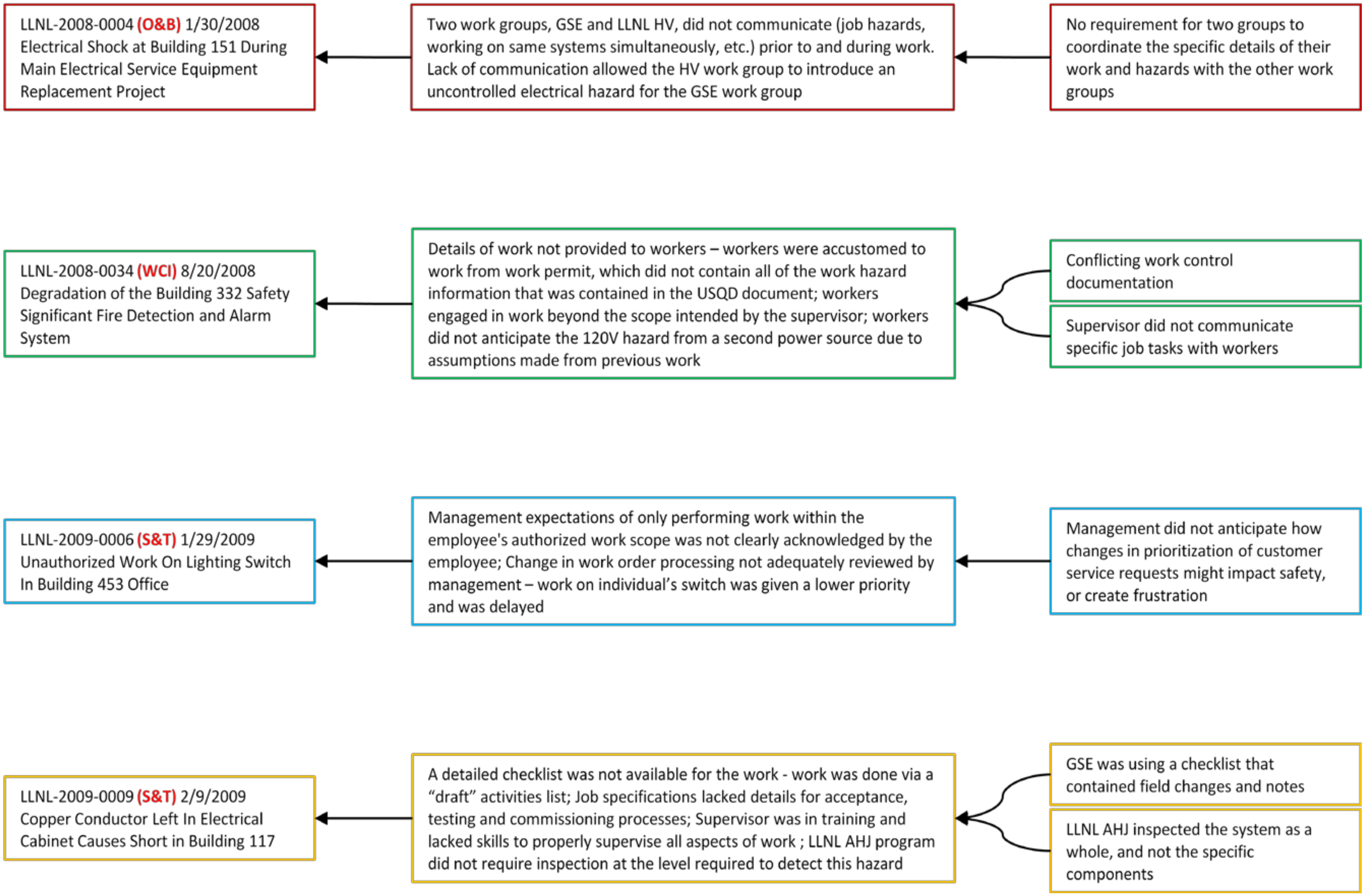
Table 3. List of Occurrences Related to Defining Work

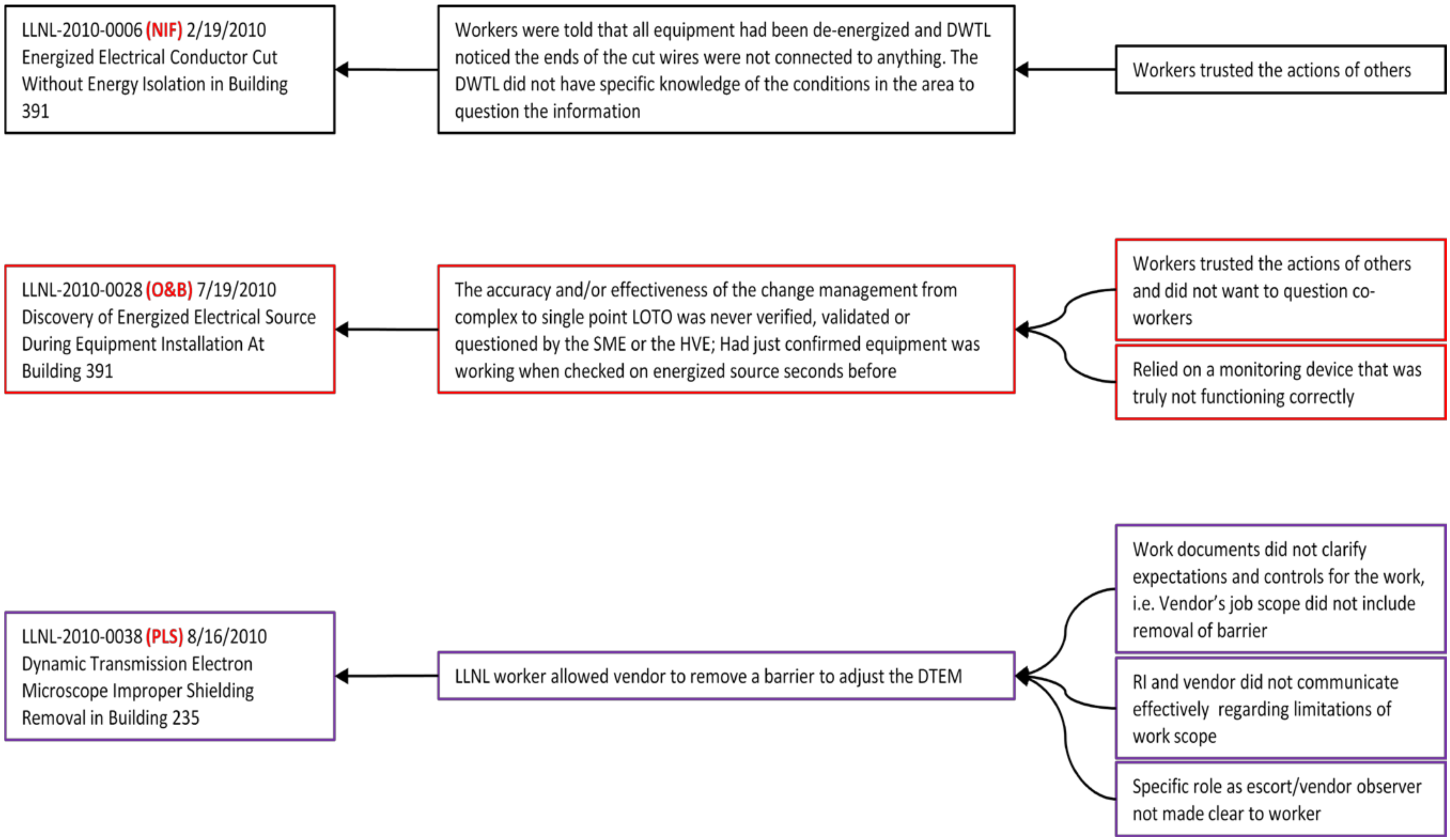
Report Number	Categ. Date	Subject / Title	RC1	SC	ISM-1 Define Work
NA--LSO-LLNL-LLNL-2008-0004	1/30/2008	Electrical Shock at Building 151 During Main Electrical Service Equipment Replacement Project	2C(2)	3	ISM1
NA--LSO-LLNL-LLNL-2008-0034	8/20/2008	Degradation of the Building 332 Safety Significant Fire Detection and Alarm System	2C(2), 4A(1)	3	ISM1
NA--LSO-LLNL-LLNL-2009-0006	1/29/2009	Unauthorized Work On Lighting Switch In Building 453 Office	2C(2)	3	ISM1
NA--LSO-LLNL-LLNL-2009-0009	2/9/2009	Copper Conductor Left In Electrical Cabinet Causes Short in Building 117	10(2c)	3	ISM1
NA--LSO-LLNL-LLNL-2010-0006	2/19/2010	Energized Electrical Conductor Cut Without Energy Isolation in Building 391	2C(2)	3	ISM1
NA--LSO-LLNL-LLNL-2010-0028	7/19/2010	Discovery of Energized Electrical Source During Equipment Installation At Building 391	2C(2)	3	ISM1
NA--LSO-LLNL-LLNL-2010-0038	8/16/2010	Dynamic Transmission Electron Microscope Improper Shielding Removal in Building 235	2C(2)	3	ISM1

A common cause analysis of these occurrences was conducted to see if there were any similarities. Figure 6, ISM Function 1 - Define Work, shows each of the seven occurrences in the boxes on the left of the figure. The causes identified in the individual causal analyses are shown in the boxes to the right of each occurrence. By aligning the causes of similar occurrences, one can evaluate commonalities of the causes.

In Figure 6, as in the following similar figures, the events are described in the far left-hand boxes, the causes are listed in the center boxes, and the underlying causes are described in the boxes on the far right. The causes are related and flow from the right to the left, resulting in the event. Because of variability between directorates in how they conduct and report their causal analyses, we can't state that the middle boxes are always the apparent cause and the right-hand boxes are the root causes.

Figure 6. Common Cause Analysis of Events related to ISM Function 1: Define Work




LLNL-2010-0006 (NIF) 2/19/2010 Energized Electrical Conductor Cut Without Energy Isolation in Building 391
Workers were told that all equipment had been de-energized and DWTL noticed the ends of the cut wires were not connected to anything. The DWTL did not have specific knowledge of the conditions in the area to question the information
Workers trusted the actions of others
LLNL-2010-0028 (O&B) 7/19/2010 Discovery of Energized Electrical Source During Equipment Installation At Building 391
The accuracy and/or effectiveness of the change management from complex to single point LOTO was never verified, validated or questioned by the SME or the HVE; Had just confirmed equipment was working when checked on energized source seconds before
Workers trusted the actions of others and did not want to question co-workers
Relied on a monitoring device that was truly not functioning correctly
LLNL-2010-0038 (PLS) 8/16/2010 Dynamic Transmission Electron Microscope Improper Shielding Removal in Building 235
LLNL worker allowed vendor to remove a barrier to adjust the DTEM
Work documents did not clarify expectations and controls for the work, i.e. Vendor's job scope did not include removal of barrier
RI and vendor did not communicate effectively regarding limitations of work scope
Specific role as escort/vendor observer not made clear to worker

The causes of the specific occurrences were identified by the owning organization and initially appear to be distinct. But, in taking the collective view, there are common themes. For example, work control documents being used to guide the work sometimes conflicted with other documents, policies or guidance; work groups did not coordinate work or communicate to de-conflict work on the same systems; changes in work scope or hazards were not identified and addressed; and checklists that were in a “draft” form were used to define the work.

The cause for some events was the fact that workers were given misinformation and often trusted other workers, or trusted that the work that was done preceding their work was done correctly. This trust is embedded in professional courtesy and culture, but sometimes lends itself to opportunities to overlook hazards or work outside of the designated work scope. Some work processes did not include steps or tools to verify the status of hazardous energy. Three events in this ISM functional area have causes that suggest a reliance or trust on the actions of others. One recent event is of particular note: In the “Discovery of Energized Electrical Source During Equipment Installation At Building 391,” OR # LLNL-2010-0028, a questioning attitude (or verification process) was absent by the work supervisor, which led to irregularities in the work to go unchecked – this worker trusted the actions of the others. This event also had a cause related to using a defective monitoring device critical to the LOTO process – a multi-meter that had a bad probe connection was used to check for the absence of voltage on the equipment, but the LOTO steps were not followed completely, giving a false reading of “no voltage.”

In another event, where a copper conductor was inadvertently left in an electrical cabinet causing a short circuit, a draft checklist that contained field notes and hand-written changes was used in the field. Also, at the completion of work by the subcontractor, the LLNL AHJ inspected this system as a whole, but did not inspect specific components for hazards. Not looking at specific equipment allowed the copper conductor to go unnoticed.

There were communication issues in two events in the area. In one event, “Electrical Shock at Building 151 During Main Electrical Service Equipment Replacement Project,” LLNL OR # LLNL-2008-0004, one work group was working upstairs, and another group working downstairs, on the same buss duct equipment. The group upstairs introduced a current into the windings of a transformer that was connected to the equipment that was being worked on downstairs. The two groups were aware of each other’s presence; but, the groups didn’t coordinate the specific details of their work and hazards with the other work groups.

In a second event, the supervisor did not communicate specific job tasks to workers, which led to the severing of a 120V line in an alarm system.

It appears that there are commonalities in the causes of these events. In all of these occurrences, there was insufficient or erroneous communication between work groups or between manager and worker.

4.3.2 Analysis of Causes of Errors in ISMS Function 2 - Identify and Analyze the Hazard

Eleven occurrences appeared to be related to possible errors in how the hazards were identified and analyzed. A common cause analysis of these occurrences was conducted to see if there were any similarities. Table 4 lists the eleven occurrences.

Table 4 List of occurrences related to identifying and analyzing the hazard.

Report Number	Categ. Date	Subject / Title	RC1	SC	ISM-2 Analyze Hazards
NA--LSO-LLNL-LLNL-2008-0001	1/8/2008	Building 174 Electrical Shocks	10(2c)	3	ISM 2
NA--LSO-LLNL-LLNL-2008-0010	3/13/2008	Failure to Follow Established Work Procedures Results in Potentially Hazardous Building 241 Air Leak	2C(2)	3	ISM 2
NA--LSO-LLNL-LLNL-2008-0011	4/9/2008	Electrical Wiring Contacted During Seismic Securing of Office Furniture in Building 111	2C(2)	3	ISM 2
NA--LSO-LLNL-LLNL-2008-0012	4/9/2008	Subcontractor Employee Failed to Follow Hazardous Energy Control Process During Building 365 Bio-Safety Cabinet Repair	2C(2)	3	ISM 2
NA--LSO-LLNL-LLNL-2008-0015	5/8/2008	Building 194 Employee Exposure to Diffuse Laser Light	10(2c)	3	ISM 2
NA--LSO-LLNL-LLNL-2008-0019	6/17/2008	Building 170 CO2 Gas Vent From Cylinder	10(2d)	4	ISM 2
NA--LSO-LLNL-LLNL-2008-0048	10/14/2008	Natural Gas Valve Found in On Position in Vacant Building 241	2C(2)	3	ISM 2
NA--LSO-LLNL-LLNL-2009-0013	2/26/2009	110-Volt Power Line Severed During Concrete Cutting Activity in Building 481	10(2d)	4	ISM 2
NA--LSO-LLNL-LLNL-2009-0027	6/23/2009	Non-Energized Electrical Cable Cut Without Proper Energy Isolation	10(3c)	3	ISM 2
NA--LSO-LLNL-LLNL-2010-0016	3/31/2010	Unexpected Discharge of Flammable Gas While Drilling Into Gas Cylinder With a Hand Drill	2C(2), 10(3)	3	ISM 2
NA--LSO-LLNL-LLNL-2010-0037	8/12/2010	Unexpected Discovery Of A Pressurized Hydraulic Oil Line During Fire Sprinkler Upgrade In Building 311	2C(2)	3	ISM 2

Figure 7, ISMS Function 2 - Identify and Analyze the Hazard, shows each of the eleven occurrences in the boxes on the left of the figure. The causes identified in the individual causal analyses are shown in the boxes to the right of each occurrence. By aligning the causes of similar occurrences, one can evaluate similarities in the causes.

Figure 7. Common Cause Analysis of Events related to ISM Function 2: Analyze Hazards

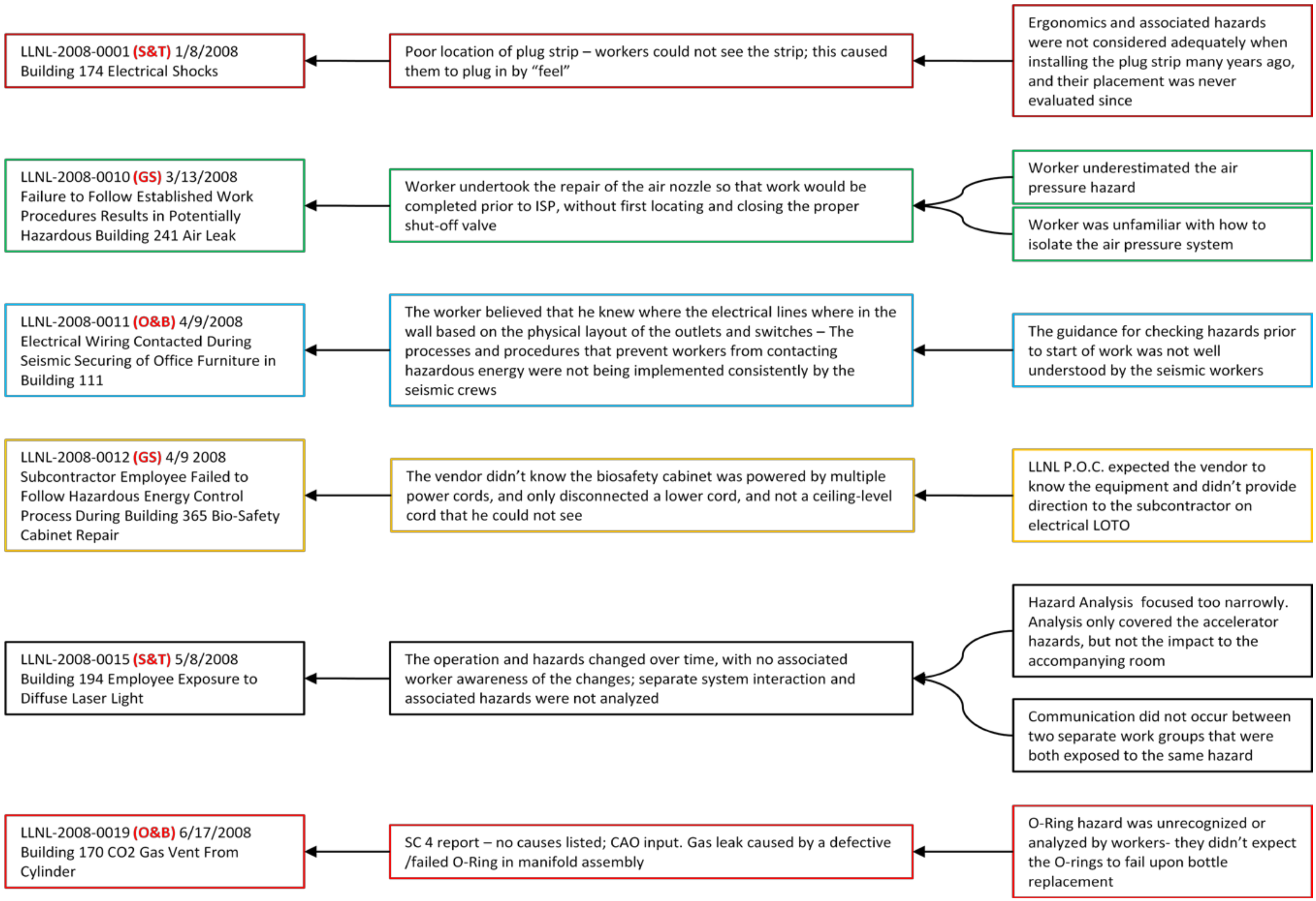


Figure 7 Common Cause Analysis of Events related to ISM Function 2: Analyze Hazards (cont.)

LLNL-2008-0048 **(O&B)** 10/14/2008 Natural Gas Valve Found in On Position in Vacant Building 241	It was hypothesized that someone accessed an unoccupied building for undetermined reasons and left the natural gas valve open in a non-operational fume-hood	Inadequate building access controls
LLNL-2009-0013 **(NIF)** 2/26/2009 110-Volt Power Line Severed During Concrete Cutting Activity in Building 481	SC4 report – no causes listed; CAO input. The workers surveyed and reviewed plans of the work area for electrical conductors and hazards, however, a conduit was severed in an area that was not supposed to contain any conductors	Documentation of hazard locations in the work area was insufficient
LLNL-2009-0027 **(NIF)** 6/23/2009 Non-Energized Electrical Cable Cut Without Proper Energy Isolation	Workers were told that a specific conductor was safe (de-energized) to work on because the RI believed that the conductor could only be energized with voltages below 50V; the line was later determined to be a de-energized 220V line	The hazard of the conductor being 220V was not correctly identified prior to the start of work Workers trusted the actions of others and did not want to question co-workers
LLNL-2010-0016 **(O&B)** 3/31/2010 Unexpected Discharge of Flammable Gas While Drilling Into Gas Cylinder With a Hand Drill	Worker mistakenly thought the cylinder was an empty Freon cylinder. Although the containers are similar, they both were labeled to indicate their contents; worker was required to work directly under the supervision of a journey-level worker; the task was not approved for this worker. Like containers with differing contents stored together.	The worker did not fully understand the hazards associated with his work Supervisor was not present when required
LLNL-2010-0037 **(O&B)** 8/12/2010 Unexpected Discovery Of A Pressurized Hydraulic Oil Line During Fire Sprinkler Upgrade In Building 311	Workers were presented with two similar black-pipe lines, on which one needed work done. The pipes were not labeled as to their purpose or contents. Workers removed a clamp on a pressurized hydraulic line, which they thought was the de-pressured water line on which they were to work.	During the work planning process, not all of the facility's piping was depicted and analyzed Differences in facility's actual/depicted configuration and associated hazards not analyzed after start of work Workers did not recognize the hazard due to using experience and past events as basis for not tracing the line

In one event, a plug strip installation in an older building was the cause of two separate 120V shocks within a one-month period. The plug strip was installed in such a way that the workers could not see the strip - they were required to plug in cords by “feel” only. In these events, the worker’s fingers contacted the plug blades while they were plugging into the strip. The ergonomics of the installation were inadequate when it was installed, and the configuration was not re-evaluated – the hazard went unnoticed until the shocks.

In another event, a worker encountered a problem with a house air source coupling, and decided that he could repair it in order to complete his work before being laid-off the next day. When he removed the bad coupling, the house air system sensed a reduction in air pressure and started to build pressure to compensate. The worker attempted to install a replacement coupling, and when he could not, he thought to shut-off the air at the valve, but was unfamiliar with how to do that and found that the valves were stuck open. The underestimation of the air pressure hazard led to this event.

In another event, a worker seismically securing shelving in a building drilled into the wall without performing a scan of the wall to determine if he would contact live wires. It was determined that the processes and procedures that prevent workers from contacting hazardous energy were not being implemented consistently by the seismic crews - the guidance for checking hazards prior to start of work was not well understood by the seismic workers.

In another event, a vendor started work on a bio-safety cabinet powered by two separate 120V power cords. He disconnected the lower cord from the wall before he started work, but did not see the cord on the upper part of the cabinet, and did not disconnect it. He did not realize that this cabinet was powered by more than one electrical source. The LLNL point of contact expected that the vendor would know the equipment and therefore did not provide direction to the vendor on how to properly isolate the equipment from the multiple power sources.

In yet another event, two workers were doing work in a room adjacent to an accelerator when it was operated. There was a pass-through tunnel between the two rooms that could allow the hazardous energy from one room to travel into the other room where unassociated, but simultaneous work was being conducted. The accelerator operation and hazards had changed over time, with no associated worker awareness of the changes, or consideration of the interactions of the separate systems and their associated hazards – these hazards were not analyzed.

In June of 2009, a non-energized electrical conductor was cut in Building 581. The responsible individual thought that the conductor was not energized with any energy above 50V, and therefore allowed work to progress. The line was later determined to be a 220V line, and the worker could have been exposed to 220V when using cutters to cut the conductor by hand. The hazard of the conductor being 220V was not correctly identified prior to the start of work and the workers trusted the actions of others and did not want to question co-workers.

In March or 2010, a worker drilled into what he believed to be an empty Freon cylinder, which was actually a propane cylinder that was still pressurized to some degree. The containers are similar, but each was marked as to their contents. The worker was not authorized to work without direct supervision, but the supervisor was not present during this work activity. The worker did not fully understand the hazards associated with his work – hazards that could have been communicated to him by others.

In August of 2010, workers were doing upgrades to a fire sprinkler in Building 311. They were presented with two similar black-pipe lines, on which one needed work. The pipes were not labeled as to their purpose or contents. The workers removed a clamp on one of the black pipes, believing it to be the water line associated with their work, but instead, it was a pressurized hydraulic line. This hazard was not identified prior to the start of work.

It appears that there are commonalities in the causes. In nine of these occurrences, the hazards that would have been identified and analyzed during the course of performing the work were underestimated or not recognized by the workers. In the other two occurrences, the hazards were underestimated or not recognized prior to the work being authorized.

4.3.3 Analysis of Causes of Errors in ISMS Function 3 - Develop and Implement Controls

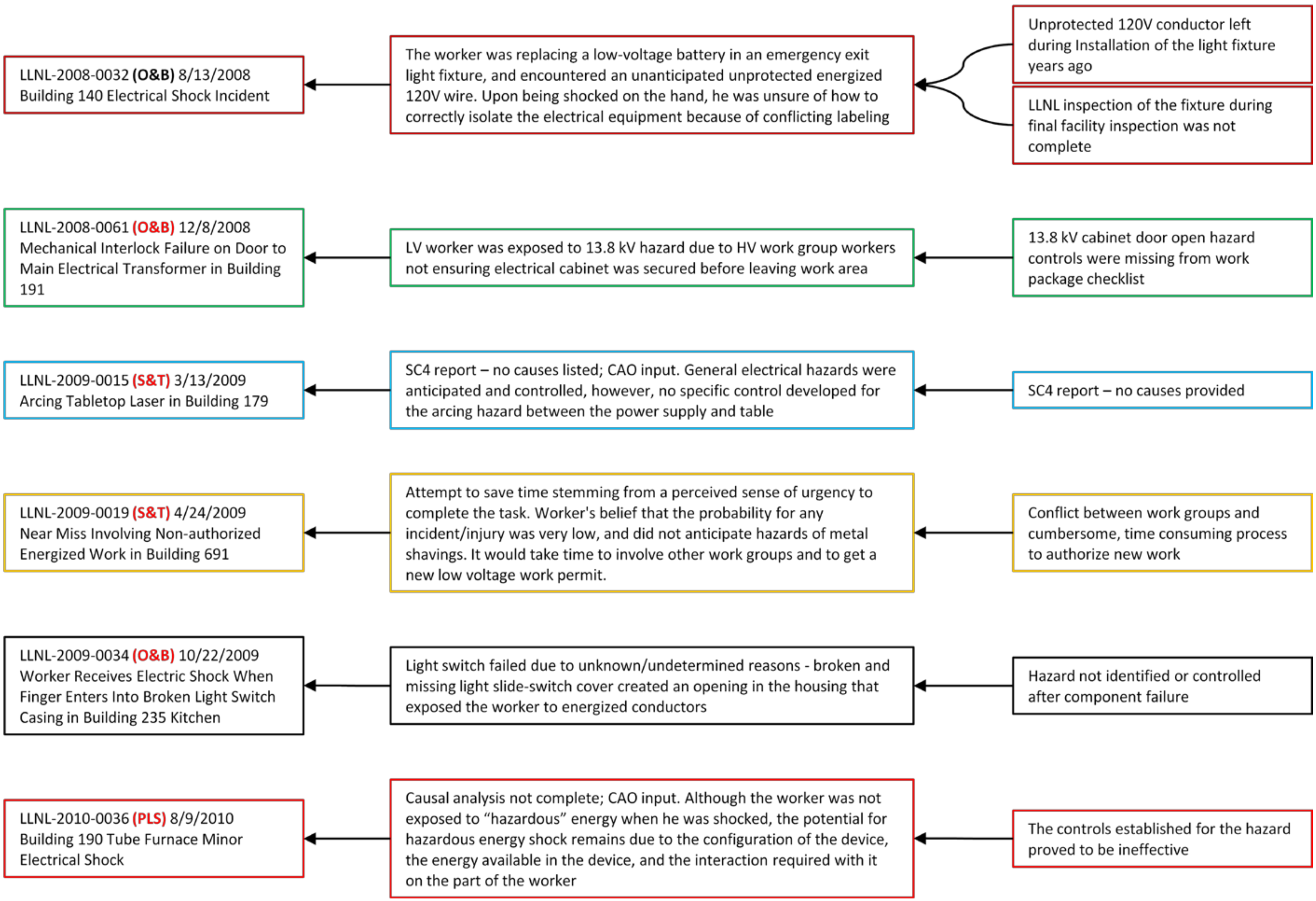
Six occurrences appeared to be related to possible errors in controlling the hazardous energy, as listed in Table 5. A common cause analysis of these occurrences was conducted to see if there were any similarities.

Table 5 List of occurrences related to controlling the hazardous energy.

Report Number	Categ. Date	Subject / Title	RC1	SC	ISM-3 Control Hazards
NA--LSO-LLNL-LLNL-2008-0032	8/13/2008	Building 140 Electrical Shock Incident	2C(1)	2	ISM3
NA--LSO-LLNL-LLNL-2008-0061	12/8/2008	Mechanical Interlock Failure on Door to Main Electrical Transformer in Building 191	2C(2)	3	ISM3
NA--LSO-LLNL-LLNL-2009-0015	3/13/2009	Arcing Tabletop Laser in Building 179	10(2d)	4	ISM3
NA--LSO-LLNL-LLNL-2009-0019	4/24/2009	Near Miss Involving Non-authorized Energized Work in Building 691	2C(2), 10(3)	3	ISM3
NA--LSO-LLNL-LLNL-2009-0034	10/22/2009	Worker Receives Electric Shock When Finger Enters Into Broken Light Switch Casing in Building 235 Kitchen	2C(1)	2	ISM3
NA--LSO-LLNL-LLNL-2010-0036	8/9/2010	Building 190 Tube Furnace Minor Electrical Shock	10(2d)	4	ISM3

Figure 8, ISMS Function 3 - Develop and Implement Controls, shows each of the six occurrences in the boxes on the left of the figure. The causes identified in the individual causal analyses are shown in the boxes to the right of each occurrence. By aligning the causes of similar occurrences, one can evaluate similarities in the causes.

Figure 8. Common Cause Analysis of Events related to ISM Function 3: Develop and Implement controls



In these six events, the hazards associated with the work were not effectively controlled due to several factors: legacy hazards that were left by equipment installers and then accepted by LLNL during final inspection of work; incomplete check of work after completion leaving uncontrolled hazard for follow-on workers; conflict between work groups; a cumbersome, time consuming process to authorize new work; hazards not identified or controlled after component failure; and the controls established for the hazard proving to be ineffective.

In August of 2008, a worker was replacing a battery in an emergency exit light fixture in building 140. Upon opening the fixture access door and reaching inside, the back of his wrist came in contact with an unprotected 120V wire. The 120V unprotected energized wire had been left by the installation crew when the building was completed. This hazard was not discovered, and thus not controlled by LLNL inspection of the fixture during final facility inspection. The worker received a shock, and then capped the wire without performing a LOTO first (because of a conflict between drawings and schedules and a desire to leave the work in a safe condition). He was not injured.

In another event in December 2008, a low-voltage electrical worker was cleaning up a room that contained a 13.8kV electrical cabinet, and inadvertently hit the cabinet door with his broom, causing the door to open, exposing him to the energized components inside. The cabinet had been accessed by high-voltage workers earlier in the day. When the high-voltage crew left at the completion of their work, the crew did not ensure that the door was secured. The causal analysis determined that the proper controls were missing from the work package checklist.

In April 2009, a worker was removing empty metal conduit from a 480V electrical panel by using a metal saw. In doing so, conduit metal shavings were introduced into the panel from above where he was cutting the conduit – this created a serious arc-flash hazard that was not controlled. The causal analysis revealed that conflict between work groups and a cumbersome and time-consuming process to authorize new work were the direct causes of the event.

In another event, in October 2009, a worker attempted to turn on a light in a break room, and in doing so, came in contact with energized conductors that had become exposed on the bottom of the switch. A switch cover was broken and missing on the bottom of the cover, and the worker could not see this. The worker contacted 277V AC power, but was not injured. This hazard was not identified or controlled after the component failure.

In the last event in this area, in August 2010, a worker inserted a metal rod into a tube-furnace, into an access that had plastic beads to help guide and control the rods as they are inserted. The worker did not disconnect the plug from the wall prior to doing this, and was shocked by what was determined to be non-hazardous energy. However, there exists the possibility for contact with hazardous energy when doing this work. Although the causal analysis for the event is on-going, it appears as though the controls implemented for this hazard were not effective.

It appears that there are commonalities in causes. In three of these occurrences, hazards were left uncontrolled by one worker and later discovered by another worker. In two of them, the hazards were known and analyzed but the implemented controls were ineffective. In two of the occurrences, the time consuming process to authorize changes contributed to the work continuing in an uncontrolled manner.

4.3.4 Analysis of Causes of Errors in ISMS Function 4 - Perform Work

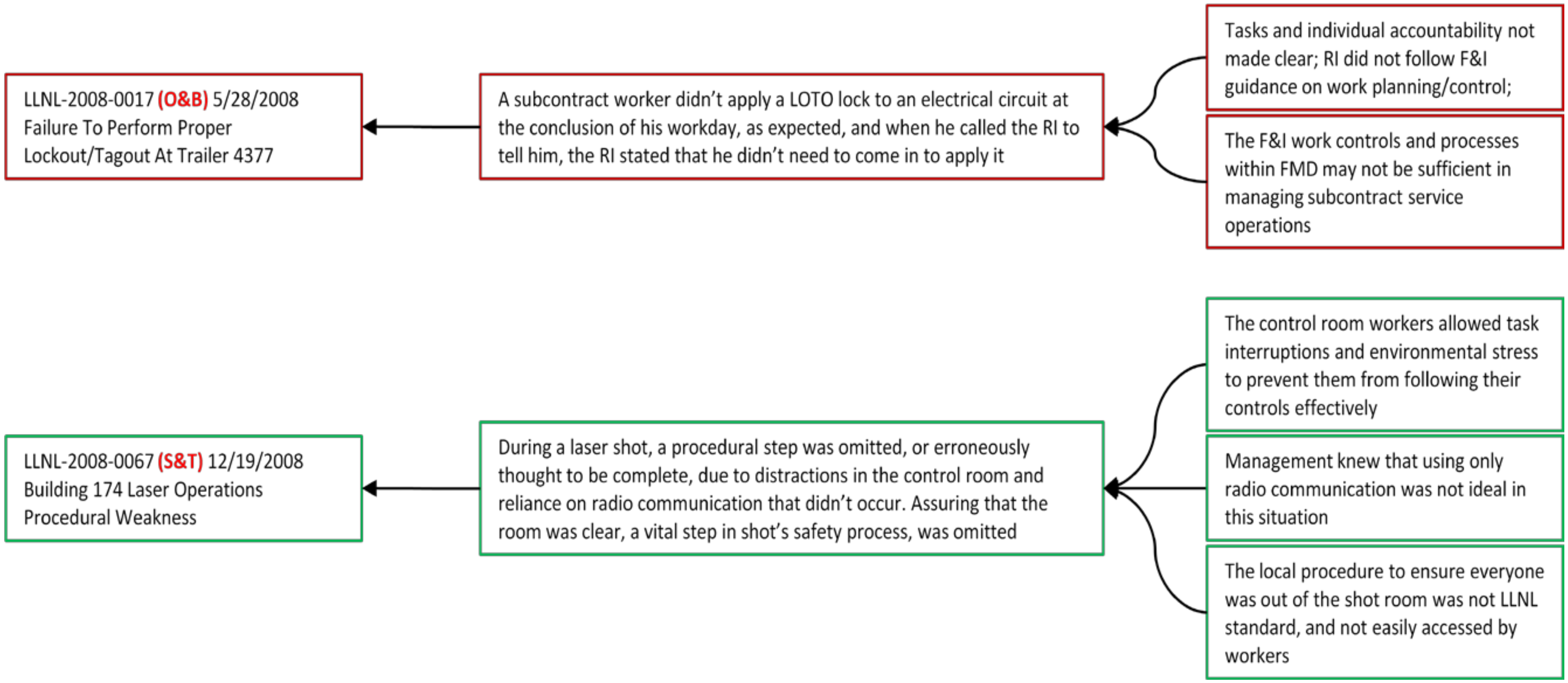
Two occurrences appeared to be related to possible errors in performing work. A common cause analysis of these occurrences was conducted to see if there were any similarities.

Table 6 List of occurrences related to ISM-4 Perform Work.

Report Number	Categ. Date	Subject / Title	RC1	SC	ISM-4 Perform Work
NA--LSO-LLNL-LLNL-2008-0017	5/28/2008	Failure To Perform Proper Lockout / Tagout At Trailer 4377	2C(2)	3	ISM4
NA--LSO-LLNL-LLNL-2008-0067	12/19/2008	Building 174 Laser Operations Procedural Weakness	10(3c)	3	ISM4

Figure 9, ISMS Function 4 - Perform Work, shows the two occurrences in the boxes on the left of the figure. The causes identified in the individual causal analyses are shown in the boxes to the right of each occurrence. By aligning the causes of similar occurrences, one can evaluate similarities in the causes.

Figure 9. Common Cause Analysis of Events related to ISM Function 4: Perform Work



The causes indicate that work was not performed in accordance with work control procedures or guidance, due to the following factors: work task and individual accountability were not made clear to the worker; RI did not follow the directorate work planning guidance; directorate-level controls were not sufficient in managing subcontract work; workers allowed task interruptions and environmental stressors to prevent them from following control; an existing control that was still being used was known to be less than optimum; and local procedures that are meant to ensure the safety of the workers were embedded in a longer alignment procedure and were not easily accessed by the workers.

In the first event, in May 2008, a subcontract worker did not apply a LOTO lock to an electrical disconnect that controls an AC unit that he was working on. He left for the day, and upon remembering that he did not place the LOTO lock on the device, called the RI to tell him. The RI did not require that he return to place the lock, nor did he require another method of protecting the circuit, in accordance with the directorate's expectations. The causal analysis determined that the tasks and the individual accountability were not made clear to the worker, and the RI did not follow the directorate's guidance on work planning and control. The analysis also identified that the directorate may not have a sufficient process for managing subcontract service operations.

In the second event, in December 2008, during a laser shot in Building 174, two workers were inside the shot room when the shot was conducted. A control room worker believed that the room was clear, thinking that he heard the "all clear" over the radio. Distractions in the control room were cited as contributors to this situation. The control room workers were relying on radio communication with the workers in the shot room as the only source to ensure the room was clear and ready for the shot. The causal analysis determined that the control room workers allowed task interruptions and environmental stress to prevent them from following their controls effectively. Management knew that using only radio communication was not ideal in this situation, but allowed it to continue. In addition, the shot sequence procedure that ensures everyone is out of the shot room was embedded in the longer alignment procedure and was not easily accessed by workers

It appears that there are commonalities in causes. In each case, workers were following local directions that were not consistent or easily accessible.

Summary:
The 26 occurrences related to the control of hazardous energy reported between January 1, 2008 and August 2010 were binned into the ISM functions to determine where the first error occurred, in defining the work, analyzing the hazard, controlling the hazard or performing the work. The majority of the first errors occurred before the work was performed and during the planning and preparation phases (92% of occurrences).

Inadequate hazard analysis was the common cause for 42% of occurrences analyzed. In nine of these occurrences, the hazards that would have been analyzed during the course of performing the work were underestimated or not recognized by the workers. In the other two occurrences, the hazards were underestimated or not recognized prior to the work being authorized. Specific issues are that hazards were not identified; existing hazards were not re-evaluated periodically; workers underestimated or didn't fully understand the hazards; erroneous expectations that workers are aware of all the hazards; hazard identification in work control documentation was insufficient; required supervision to guide workers and brief hazards was missing; and lack of hazard communication between workers.

Work defined improperly was the common cause for 27% of occurrences. In all of these occurrences, there was insufficient, inadequate or erroneous communication between work groups or between managers and workers. The occurrences were due to work control documents being used to guide the work sometimes conflicting with other documents, policies or guidance; no requirement for separate work groups to coordinate work or communicate to de-conflict work on the same systems; changes in work scope or hazards were not represented in the documents that the workers were using; and using checklists that were in a "draft" form. Additionally, the cause for some events was the fact that workers often trust other workers, or trust that the work that was done preceding their work was done correctly. This trust is embedded in professional courtesy and culture, but sometimes lends itself to opportunities to overlook hazards or work outside of the designated work scope.

The hazard not being controlled properly was the common cause for 23% of occurrences. In three of these occurrences, hazards were left uncontrolled by one worker and later discovered by another worker. In two of them, the hazards were known and analyzed but the implemented controls were ineffective. In two of the occurrences, the time consuming process to authorize changes, contributed to the work continuing in an uncontrolled manner. The occurrences were due to legacy hazards left by equipment installers and then accepted by LLNL during final inspection of work; incomplete check of work after completion leaves uncontrolled hazard for follow-on workers; conflict between work groups and cumbersome, time consuming process to authorize new work; hazards not identified or controlled after component failure; and the controls established for the hazard proved to be ineffective.

Work being incorrectly performed was the common cause for 8% of occurrences. In each case, workers were following local directions that were not clear or standardized. Additional causes were work task and individual accountability not made clear to the worker; RI not following the local work planning guidance; directorate-level controls were not sufficient in managing subcontract work; workers allowed task interruptions and environmental stressors to prevent them from following control; an existing control that was still being used was known to be less than optimum; and local procedures that are meant to ensure the safety of the workers was not up to LLNL standards, and was not easily accessible by the workers

5.0 Analysis of LOTO in the Control of Hazardous Energy

Can employees authorized to perform LOTO successfully implement LLNL's LOTO program to control hazardous energy? If not, there may be a programmatic noncompliance with LLNL's LOTO program that warrants additional management attention and reporting to the DOE Office of Enforcement. This program is described in *ES&H Manual*, Document 12.6, LLNL Lockout/Tagout Program.

The list of 26 occurrences was reviewed to determine those with an associated noncompliance related to the implementation of the LOTO process (i.e. steps), and common cause analysis was performed to determine if the underlying cause is related to the LOTO program, e.g. the process is too cumbersome or difficult to follow.

Document 12.6 LLNL Lockout/Tagout Program, outlines six general LOTO steps.

1. The first step of LOTO, "*prepare and notify,"* includes notification to affected workers that service/maintenance is to be performed and equipment is to be shut down, locked out and tagged out and the LOTO-authorized worker ensures that this is done. During this step the LOTO-authorized worker identifies the type and magnitude of energy the equipment uses, understands the hazards of the energy involved, and knows the method for controlling the energy sources.
2. The second step of LOTO, "*shut down the equipment,"* includes shutting down the equipment if it is operating using normal shutdown procedures.
3. The third step of LOTO, "*isolate the energy,"* includes isolating the energy by positioning the energy-isolating device to positively isolate the equipment from the energy source.
4. The fourth step of LOTO, "*apply the LOTO devices,"* includes locking out the energy-isolating device with an approved LLNL LOTO lock and attachment of the LLNL LOTO tag.
5. The fifth step of LOTO, "*control stored energy,"* includes rendering safe all sources of stored energy and preventing the reaccumulation of stored energy.
6. The sixth and final step of LOTO, "*verify and test,"* includes treating all equipment as energized until positively proven otherwise, ensuring equipment is disconnected from all energy sources, returning all operating controls to the neutral position once verified that it is isolated, using test instruments to verify deenergization and verifying that these instruments are operational both before and after use. Depending on the voltage and/or stored energy, this last step may require more analysis and controls.

The PARS Occurrence Reporting Officer and the Regulatory Compliance Assurance Analyst led a team of experts to review the 26 occurrences and determine which ones were related to the implementation of the LOTO steps. This team included five experienced individuals with relevant safety expertise and operating experience. These subject matter experts were recommended by the Worker Safety and Health Functional Area Manager and the Facilities and Infrastructure Assurance Manager:

- Bill Andrews, explosive safety subject matter expert
- Gregg Holtmeier, pressure safety subject matter expert
- Paul Swyers, high and low voltage electrical safety expert

- Bill Ulm, electrical safety subject matter expert
- Michael Williams, machine guarding subject matter expert

Some occurrences were eliminated from the set if the person performing work was not authorized to perform LOTO and didn't know to apply the LOTO process, or if a mistake was made prior to getting to LOTO applicability. An as-found condition, or a noncompliance with a prescribed procedure other than Document 12.6 would be examples of occurrences that were eliminated. During the team meeting and follow-on discussions, the team identified four occurrences, 15% of the original list where the main issue that led to the occurrence was related to an error in implementing one of the LOTO steps. These four events/noncompliances, listed in Table 7 are from three different principal directorates.

Table 7. Four Occurrences related to implementing the six steps of LOTO

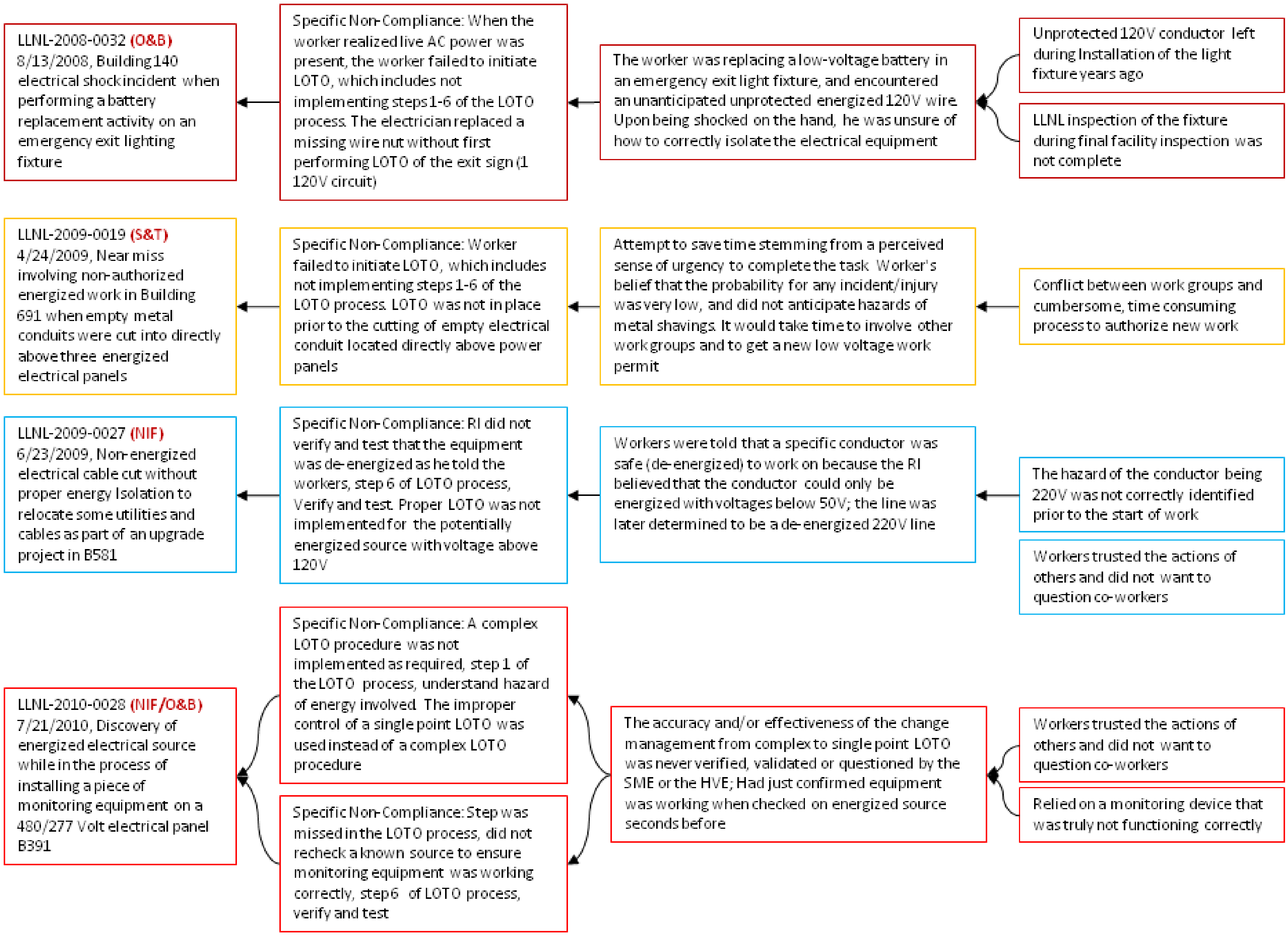
Report Number	Date Categorized	Subject / Title	LOTO Step Not Performed
NA--LSO-LLNL-LLNL-2008-0032	08/13/2008	Building 140 Electrical Shock Incident	Steps 1-6, LOTO not initiated
NA--LSO-LLNL-LLNL-2009-0019	04/23/2009	Near Miss Involving Non-authorized Energized Work in Building 691	Steps 1-6, LOTO not initiated
NA--LSO-LLNL-LLNL-2009-0027	06/22/2009	Non-Energized Electrical Cable Cut Without Proper Energy Isolation	Step 6, verify and test
NA--LSO-LLNL-LLNL-2010-0028	7/19/2010	Discovery of Energized Electrical Source During Equipment Installation at B391	Steps 1 and 6, prepare and notify and verify and test

This subset of occurrences and their causes was analyzed further to determine if the reason for the lack of implementation of the LOTO steps was related to the program outlined in Document 12.6 LLNL Lockout/Tagout Program.

Figure 10 displays the commonalities between the four events based on the information provided from the apparent causal analyses. There are two cases where occurrences have similar causes. For occurrences 2009-0027 and 2010-0028, the common cause is workers trusted the actions of others and did not question or verify the work of a co-worker, supervisor or expert. For occurrences 2008-0032 and 2009-0019, the hazards were known and analyzed, but the implementation of controls were ineffective.

The specific LOTO related noncompliance(s) with each of the four occurrences are shown in Figure 10.

Figure 10. Common Cause Analysis of the Four Occurrences related to the Implementation of LOTO



The apparent causes of the four occurrences were as follows:

- The hazard was underestimated or not identified,
- Implemented controls were ineffective,
- Time consuming process to authorize changes,
- Hazards had been left uncontrolled and later discovered by another worker,
- Conflict between work groups,
- Workers trusted actions of others and didn't question or verify the directions given,
- Device not functioning correctly.

None of results from the causal analysis for each occurrence identified the Lockout/Tagout program or program description as the cause of the occurrences or individual noncompliances.

Simultaneous with this analysis, the Quality Assurance Office conducted an assessment of LOTO. The objective of this assessment was to determine if the LLNL LOTO program is appropriately implemented to prevent unexpected releases of hazardous energy sources (including, but not limited to, rotational, mechanical, radiation, chemical, hydraulic, or pneumatic energy sources) during servicing, maintenance, and construction activities. The report concluded, "Generally, LLNL met this objective, but there are several areas where improvements can be made."

The assessment was not focused on groups with high-frequency LOTO activities, but on groups or individuals who infrequently performed LOTO or whose LOTO activities involved control of multiple energy sources or energy sources other than electrical energy. One deficiency discussed in the report is relevant to the four occurrences/noncompliances discussed in this section, "The verification of zero energy (test or try step of LOTO) was not consistently executed during the work observed during this assessment. It is recommended that LLNL management provide additional specific emphasis (via procedural reviews, safety meetings, or other communication mechanisms) of the critical importance of executing the validation step of the LOTO procedure - including the need to verify electrical meter function before and after an electrical test for zero energy verification." This deficiency was based on three work observations where two of the three showed weaknesses in the execution of the validation step of the LOTO process.

None of the four occurrences discussed in this section were caused by a weakness in the LLNL LOTO program, but were mainly due to inadequate planning and execution of work. Based on this and the conclusion of the Quality Assurance Office assessment, there is no programmatic noncompliance with the LLNL LOTO program.

6.0 Analysis of Work Control Documentation

LLNL has been converting to task-based Integration Work Sheets (IWS) since May 2009. It is possible that this conversion may address some of the implementation issues. The work control documents for each event were identified and the database was reviewed to determine whether the work was conducted under the old IWS or the new task-based IWS. Table 8 identifies whether the work related to the 26 occurrences was controlled by an IWS, if the IWS had been converted to the new task-based format and the length of the work control documentation.

As would be expected, all of the twenty occurrences in 2008 and 2009 were in the performance of work under the old IWS system and five of the six occurrences in 2010 were under the new IWS system.

A frequent comment in many of the causal analysis reports (but not a frequently identified cause) was the length of the work control documents. The identified causes related to the work control documents were that the specific important instructions were embedded within larger documents and not easily accessible or there were conflicts between the different documents controlling the work.

Many of the work control documents are several pages long and some also have several attachments. The work control documents were reviewed and the number of pages were counted. For the twelve occurrences where the work control document could be identified, the page range is 16–212 pages and the average length is 58.2 pages. This page count did include the attachments, but excluded the employee training requirements section of the IWS, which adds several more pages. There is some question as to the clarity of communicating work directions and work scope limitations when the work control documents are this large. It may be of value to further analyze this frequent observation.

Table 8 Work Control Documents for the 26 occurrences and associated noncompliances

Report Number	Cat Date	Subject / Title	RC	SC	PD	Work done under new Work Control?	IWS No.	Length of Work Control Document, including Attachments	Notes
NA--LSO-LLNL-LLNL-2008-0001	1/8/08	Building 174 Electrical Shocks	10(2c)	3	PLS	No	No IWS	N/A	1, 4
NA--LSO-LLNL-LLNL-2008-0004	1/30/08	Electrical Shock at Building 151 During Main Electrical Service Equipment Replacement Project	2C(2)	3	O&B	No	IWS #10645.03. Found reference to a PTHA	43 pages	2, 3, 5
NA--LSO-LLNL-LLNL-2008-0010	3/13/08	Failure to Follow Established Work Procedures Results in Potentially Hazardous Building 241 Air Leak	2C(2)	3	GS	No	Unable to locate IWS if applicable	Unable to determine	2
NA--LSO-LLNL-LLNL-2008-0011	4/9/08	Electrical Wiring Contacted During Seismic Securing of Office Furniture in Building 111	2C(2)	3	O&B	No	Unable to locate IWS if applicable. Found reference to a ISM Work Permit for Carpenter Shop Field Skill of the Craft Work Activities and F&I DISPATCH Work Order	Unable to determine	1
NA--LSO-LLNL-LLNL-2008-0012	4/9/08	Subcontractor Employee Failed to Follow Hazardous Energy Control Process During Building 365 Bio-Safety Cabinet Repair	2C(2)	3	GS	No	Unable to locate IWS if applicable. Found reference to a PWS	Unable to determine	2
NA--LSO-LLNL-LLNL-2008-0015	5/8/08	Building 194 Employee Exposure to Diffuse Laser Light	10(2c)	3	PLS	No	IWS#12536 and #13935 for work in zero degree cave)	69 pages (12536), 5 pages (13935)	1, 3
NA--LSO-LLNL-LLNL-2008-0017	5/28/08	Failure To Perform Proper Lockout / Tagout At Trailer 4377	2C(2)	3	O&B	No	No IWS. Found reference to a PWS, TIP and Sub safety specification document	16 pages (documents attached to causal analysis)	1, 3
NA--LSO-LLNL-LLNL-2008-0019	6/17/08	Building 170 CO2 Gas Vent From Cylinder	10(2d)	4	O&B	No	No IWS	Unable to determine	1

Report Number	Cat Date	Subject / Title	RC	SC	PD	Work done under new Work Control?	IWS No.	Length of Work Control Document, including Attachments	Notes
NA--LSO-LLNL-LLNL-2008-0032	8/13/08	Building 140 Electrical Shock Incident	2C(1)	2	O&B	No	Unable to locate IWS. Found reference to work order #251687	Unable to determine	2
NA--LSO-LLNL-LLNL-2008-0034	8/20/08	Degradation of the Building 332 Safety Significant Fire Detection and Alarm System	2C(2), 4A(1)	3	WCI	No	No IWS. Found reference to work permit #332-08-077 and USQ # B-332-08-003	20 pages	1, 3
NA--LSO-LLNL-LLNL-2008-0048	10/14/08	Natural Gas Valve Found in On Position in Vacant Building 241	2C(2)	3	O&B	N/A	N/A	N/A	4
NA--LSO-LLNL-LLNL-2008-0061	12/8/08	Mechanical Interlock Failure on Door to Main Electrical Transformer in Building 191	2C(2)	3	O&B	No	Unable to locate IWS	Unable to determine	2
NA--LSO-LLNL-LLNL-2008-0067	12/19/08	Building 174 Laser Operations Procedural Weakness	10(3c)	3	PLS	No	IWS #12639 (either r227 or .01r13)	13 pages (r227), 16 pages (.01r13)	1, 3
NA--LSO-LLNL-LLNL-2009-0006	1/29/09	Unauthorized Work On Lighting Switch In Building 453 Office	2C(2)	3	CO MP	N/A	N/A	N/A	1, 4
NA--LSO-LLNL-LLNL-2009-0009	2/9/09	Copper Conductor Left In Electrical Cabinet Causes Short in Building 117	10(2c)	3	CO MP	Unable to determine	No IWS	N/A	1, 4
NA--LSO-LLNL-LLNL-2009-0013	2/26/09	110-Volt Power Line Severed During Concrete Cutting Activity in Building 481	10(2d)	4	NIF	No	Unable to locate IWS. Used work permit #013108	Unable to determine	1
NA--LSO-LLNL-LLNL-2009-0015	3/13/09	Arcing Tabletop Laser in Building 179	10(2d)	4	PLS	No	IWS #12154.01r41	29 pages	1, 3
NA--LSO-LLNL-LLNL-2009-0019	4/24/09	Near Miss Involving Non-authorized Energized Work in Building 691	2C(2), 10(3)	3	ENG	No	11434.04r18	212 pages	1, 3, 7
NA--LSO-LLNL-LLNL-2009-0027	6/23/09	Non-Energized Electrical Cable Cut Without Proper Energy Isolation	10(3c)	3	NIF	No	IWS #581.11r51 and work permit # 291318	79 pages	1, 3, 6
NA--LSO-LLNL-LLNL-2009-0034	10/22/09	Worker Receives Electric Shock When Finger Enters Into Broken Light Switch Casing in Building 235 Kitchen	2C(1)	2	O&B	N/A	N/A	N/A	4

Report Number	Cat Date	Subject / Title	RC	SC	PD	Work done under new Work Control?	IWS No.	Length of Work Control Document, including Attachments	Notes
NA--LSO-LLNL-LLNL-2010-0006	2/19/10	Energized Electrical Conductor Cut Without Energy Isolation in Building 391	2C(2)	3	NIF	No	IWS #14684r27	61 pages	1, 3
NA--LSO-LLNL-LLNL-2010-0016	3/31/10	Unexpected Discharge of Flammable Gas While Drilling Into Gas Cylinder With a Hand Drill	2C(2), 10(3)	3	O&B	Yes	IWS# 19.07r30	48 pages	1, 3
NA--LSO-LLNL-LLNL-2010-0028	7/19/10	Discovery of Energized Electrical Source During Equipment Installation At Building 391	2C(2)	3	O&B	Yes	Unable to locate IWS. Found reference to NIF SMaRT work permit #155809, F&I permits #102726 and #102727, work order PW00402253 Att. #3 and PTHA	Unable to determine	1
NA--LSO-LLNL-LLNL-2010-0036	8/9/10	Building 190 Tube Furnace Minor Electrical Shock	10(2d)	4	PLS	Yes	IWS #10680.02r8	24 pages	1, 3
NA--LSO-LLNL-LLNL-2010-0037	8/12/10	Unexpected Discovery Of A Pressurized Hydraulic Oil Line During Fire Sprinkler Upgrade In Building 311	2C(2)	3	O&B	Unable to determine	Unable to locate IWS	Unable to determine	2
NA--LSO-LLNL-LLNL-2010-0038	8/16/10	Dynamic Transmission Electron Microscope Improper Shielding Removal in Building 235	2C(2)	3	PLS	Yes	IWS #14415.02r5	79 pages	1, 3

NOTES:

1: Information was confirmed with POC

2: Information was not confirmed with POC

3: Page number was calculated using a custom report in the eIWS which excludes employee training information

4: N/A means not applicable

5: Unsure if this IWS was suppose to be used by both groups

6: All work in B581 is broken down by a work permit so cannot use length of IWS as a an indication of pages that need to be read

7: Attached FSP was 130 pages (Used r22 for page count since r18 was not visible in eIWS)

7.0 Conclusion

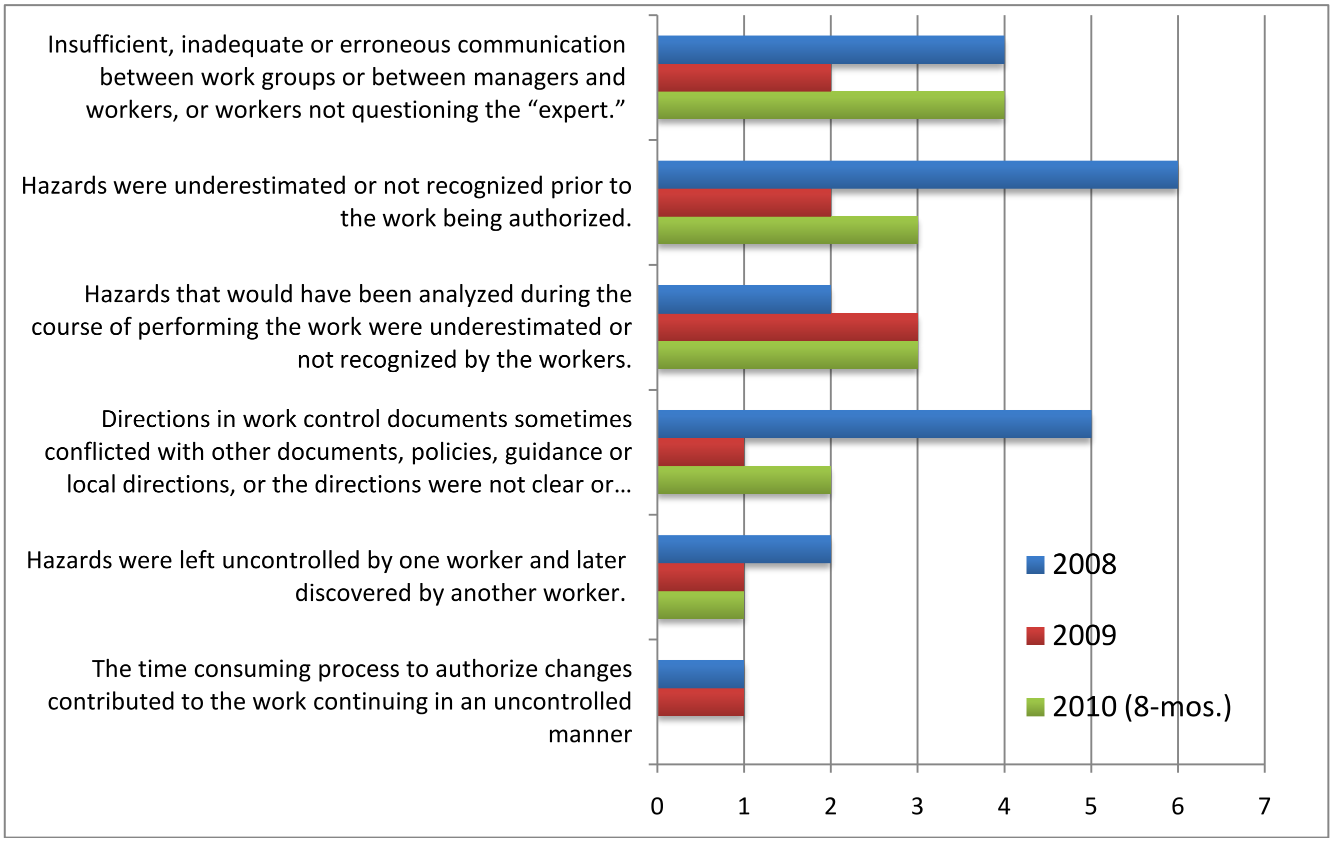
This report documents an analysis of a specific area of concern: control of hazardous energy. The analysis concludes that LLNL has experienced multiple occurrences and noncompliances related to the control of hazardous energy, as a result of the issues listed in Table 9.

Table 9 Primary Causes of Inadequate Control of Hazardous Energy

Cause/ Issue	Number of Occurrences
• Hazards were underestimated or not recognized prior to the work being authorized.	10
• Insufficient, inadequate or erroneous communication between work groups or between managers and workers, or workers not questioning the "expert."	11
• Directions in work control documents sometimes conflicted with other documents, policies, guidance or local directions, or the directions were not clear or readily available	8
• Hazards that would have been analyzed during the course of performing the work were underestimated or not recognized by the workers.	8
• Hazards were left uncontrolled by one worker and later discovered by another worker.	4
• The time consuming process to authorize changes contributed to the work continuing in an uncontrolled manner.	2

The frequency of these causes was graphed to show possible changes over the 2.75 years analyzed in this report, as shown in Figure 11.

Figure 11. Frequency of Causes by Year



The most common causes in 2008 and 2009 (*Directions in work control documents sometimes conflicted with other documents, policies, guidance or local directions, or the directions were not clear or readily available*, and *Hazards were underestimated or not recognized prior to the work being authorized*) were not the most common causes in 2010. In 2010, the most common cause was, *Insufficient, inadequate or erroneous communication between work groups or between managers and workers, or workers not questioning the "expert."* This change may reflect the improvements in the work control processes. In addition, it may identify a potential problem that has not been addressed. If there is a problem related to erroneous information being communicated, then it may be appropriate to understand why the erroneous information was believed to be correct and why it was provided to workers. Most of the occurrences were analyzed, as required, for apparent cause and not root cause, so the answer to this question would be available after a root cause analysis is conducted.

The 26 occurrences were reviewed to determine the level of involvement of *ES&H Manual,* Document 12.6 LLNL Lockout/Tagout Program, in the occurrences or noncompliances. If there were issues with this document describing the LOTO process, then there might be a programmatic/systemic noncompliance. The analysis concludes that LLNL does not have a programmatic/systemic noncompliance with the LOTO program. The issue appears to be related to the planning and execution of work and not with the overall LOTO safety program established by Document 12.6 LLNL Lockout/Tagout Program.

A frequent comment in many of the causal analysis reports (but not a frequently identified cause) was the length of the work control documents. Many of the work control documents are several pages long and some also have several attachments. The average length of the documents controlling the work related to the occurrences is 58.2 pages.

The Department of Energy (DOE) Manual 231.1-2, *Occurrence Reporting and Processing of Operations Information* requires a performance analysis of occurrence-based data to identify common elements that may present recurring problems. The DOE Office of Enforcement communicates their expectations for worker safety and health in the *Enforcement Process Overview*, "DOE expects programmatic (i.e. systemic) or repetitive noncompliances to be reported." Recurring conditions and systemic noncompliances are expected to be identified by the contractor and reported to DOE through the ORPS and the Noncompliance Tracking System (NTS). Consideration should be made for reporting the results related to the control of hazardous energy based on the reporting thresholds defined by DOE.

This analysis concludes that LLNL does not have repetitive noncompliances related to implementing the actual steps of Lockout/tagout (LO/TO). It does, however, have recurring occurrences where hazardous energy is inadequately controlled, due to failures in the execution of work planning and control. It is suggested that a knowledgeable team be convened to analyze the root causes of the issues presented in this report and develop corrective actions that address the root causes and will prevent recurrence.

8.0 Definitions

Apparent cause	The most probable cause of a condition or event based upon readily available information.
Active Error	An error that changes equipment, system, or facility state, triggering immediate, undesired consequences
Latent Condition	Undetected circumstances or situations such as equipment flaws; a willingness to sacrifice safety margin for immediate production goals; and various process, program, and procedure deficiencies that remain hidden until revealed by periodic testing, self-assessment processes, operating experience, or an event.
LOTO	Lockout and Tagout. Specifically, the applying of a lock and associated identifying tag to an energy-isolating device in accordance with an established procedure to ensure that the device and equipment being controlled cannot be operated until the lock and associated tag are removed.
Recurring occurrence	Recurring occurrence is when events or conditions that have a common cause are identified over time and the corrective actions previously implemented have failed or where ineffective.
Repetitive noncompliance	*A repetitive problem is generally two or more different events that involve substantially similar conditions, locations, equipment, or individuals. Repetitive problems tend to be narrower in scope than programmatic problems.*
Systemic noncompliance	*A programmatic (i.e. systemic) problem generally involves some weakness in administrative or management controls, or their implementation, to such a degree that a broader management or process control problem exists.*

9.0 References

Burgin, C., Ulm, B., *Assessment of the LLNL Lock-out, Tag-out Program*, Assessment Number 29497, August 31, 2010

ES&H Manual, Document 12.6, LLNL Lockout/Tagout Program

Appendix A Methods for Analysis Using Control Charts

Control charts were used to analyze the events with reporting criteria that made up the 26 events from this analysis. Three reporting criteria are analyzed below, 2C -“Hazardous Energy Control,” 10(2) -“Management Concern,” and 10(3) -“Near Miss.”

Two types of control charts are used to analyze reportable events: Occurrence *Count* Control Charts and Occurrence *Rate* Control Charts.

<u>Occurrence *Count* Control Charts</u>
These control charts are used to identify trends and identify processes that may be outside of the expected range of performance.

The occurrence count control charts consist of five key elements:

1. The count of occurrences within a given month by reporting criteria group
2. Centerline: the average number of occurrences over the time period (mean)
3. Moving range standard deviation: one times the average moving range divided by a constant value of 1.128 above the mean
4. Upper warning limit (UWL): two times the average moving range divided by a constant with a value of 1.128 above the centerline
5. Upper Control-limit (UCL): three times the average moving range divided by a constant value of 1.128 above the centerline

<u>Occurrence *Rate* Control Charts</u>
In this analysis report, a new methodology for control charting is being introduced for events – the “Individual-X/MR” method, described in *The Introduction to Statistical Quality Control* (Montgomery, 1997). This control charting technique utilizes counts of rare events, and converts the count to an event *rate*. This is of benefit in occurrence reporting because most LLNL events do not occur frequently enough for the occurrence count control charts to accurately depict trends. This type of control chart will be used in the future to chart infrequent events.

The occurrence rate control charts consist of four key elements:

1. The event rate per year for a given categorization date, by reporting criteria group
2. Centerline: the average rate per year
3. Moving range standard deviation: one times the average moving range divided by a constant value of 1.128 above the mean

4. Upper warning limit (UWL): two times the average moving range divided by a constant value of 1.128 above the centerline
5. Upper Control-limit (UCL): three times the average moving range divided by a constant value of 1.128 above the centerline

The UCL is a common calculation for control charts. In an ideal world, the majority of one's data would lie within the range defined by the UCL and a lower control limit. For these control charts, it is three times the average moving range divided by a constant with a value of 1.128 above the centerline. However, since occurrences are tracked on a positive scale the lower control limit does not apply (e.g. negative occurrences do not exist).

The moving range is defined as $|x_i - x_{i-1}|$, where x is the number of occurrences for a specific quarter. It can also be defined as the absolute difference between two successive data points, in this case quarterly occurrence counts. The constant discussed above (1.128), referred to as d_2 in the *Introduction to Statistical Quality Control* is defined as the mean of the distribution of the relative range and is used in calculating the estimate of the standard deviation, which is defined as the average moving range divided by this constant (d_2). The value of d_2 ranges anywhere from 1.128 to 3.931 depending on how many observations are included in each sample. Since each data point in the control charts used in this analysis are based on individual counts and not a sample average, the moving range, instead of the range is used. Since the moving range is calculated using two successive data points, our value of n=2. Therefore the value of d_2 for n=2 is defined as 1.128 in Table VI (Montgomery, 1997).

A control chart can be considered a way of performing a statistical test – a test to determine if the process is in a state of control. Theoretically, if a process is 'in-control,' then none of the data points will fall outside of the UCL. With these charts we are looking for *special causes of variation*. This type of variation can be found by using four common tests called action limits as listed in as listed in "Introduction to Statistical Quality Control:"

1) One data point falling above the UCL or below the LCL
2) Two consecutive points above the UWL or below the LWL
3) Four out of five points in a row are more than one standard deviation from the mean in the same direction
4) Eight consecutive points plot on one side of the centerline

Theoretically, if a process is 'in-control' then none of the data points will fall outside of the UCL. The other three action limits are other rules for detecting nonrandom patterns on a control chart. If data reaches or exceeds an action limit, a more detailed examination of the specific events will occur.

In addition, occurrence reporting criteria groups were analyzed to see if any of the below common tests are met:

1) One data point above the UWL
2) Single increase in data points for the quarter in question,
3) Recent increasing trend for more than one quarter
4) An unusual or nonrandom pattern in the data

These are used to identify events that may be of interest and will be further analyzed.

Some of the common tests described above are more conservative than the typical set of decision rules for detecting nonrandom patterns on control charts listed in “Introduction to Statistical Quality Control.” These non-typical common tests are meant to detect events that should be analyzed using control charts in future quarterly analyses to watch for potential nonrandom patterns.