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Safety Classification and Learning (SCL) Model

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Executive Summary

The rate of recordable injuries in the electric power sector has declined steadily over the past decade; however, the rate of serious injuries and fatalities (SIFs) has plateaued. Unfortunately, studying SIFs is a paradox. On one hand, SIFs are incredibly important and deserve significant resources for investigation. On the other, learning from these events and detecting causal patterns are challenging because SIFs are relatively rare. To vastly increase the number of learning opportunities and to better characterize safety performance, organizations are beginning to investigate incidents with the potential to cause serious injuries or fatalities (PSIF). PSIFs also offer an opportunity for shared learning, which is necessary to advance toward SIF elimination. Unfortunately, existing methods of identifying and tracking PSIFs are unscientific, heavily biased, and yield inconsistent understanding of whether an incident is a PSIF or not.

An EEI working group of 20 safety leaders and a technical advisor was assembled to create a method for consistently classifying safety incidents and observations that enables shared learning. The EEI safety classification and learning (SCL) model leverages the latest scientific knowledge and the best features of existing methods. The model was tested and refined by the team using 40 actual safety cases.

The resulting tool defines safety incidents and observations based upon the answers to the following yes or no questions:

1. Was high energy present?
2. Did a high-energy incident occur?
3. Was a serious injury sustained?
4. Was a direct control present?

The associated report provides detailed guidance to answer these four questions objectively and consistently. The SCL model is graphically depicted in Figure 3 on page 8.

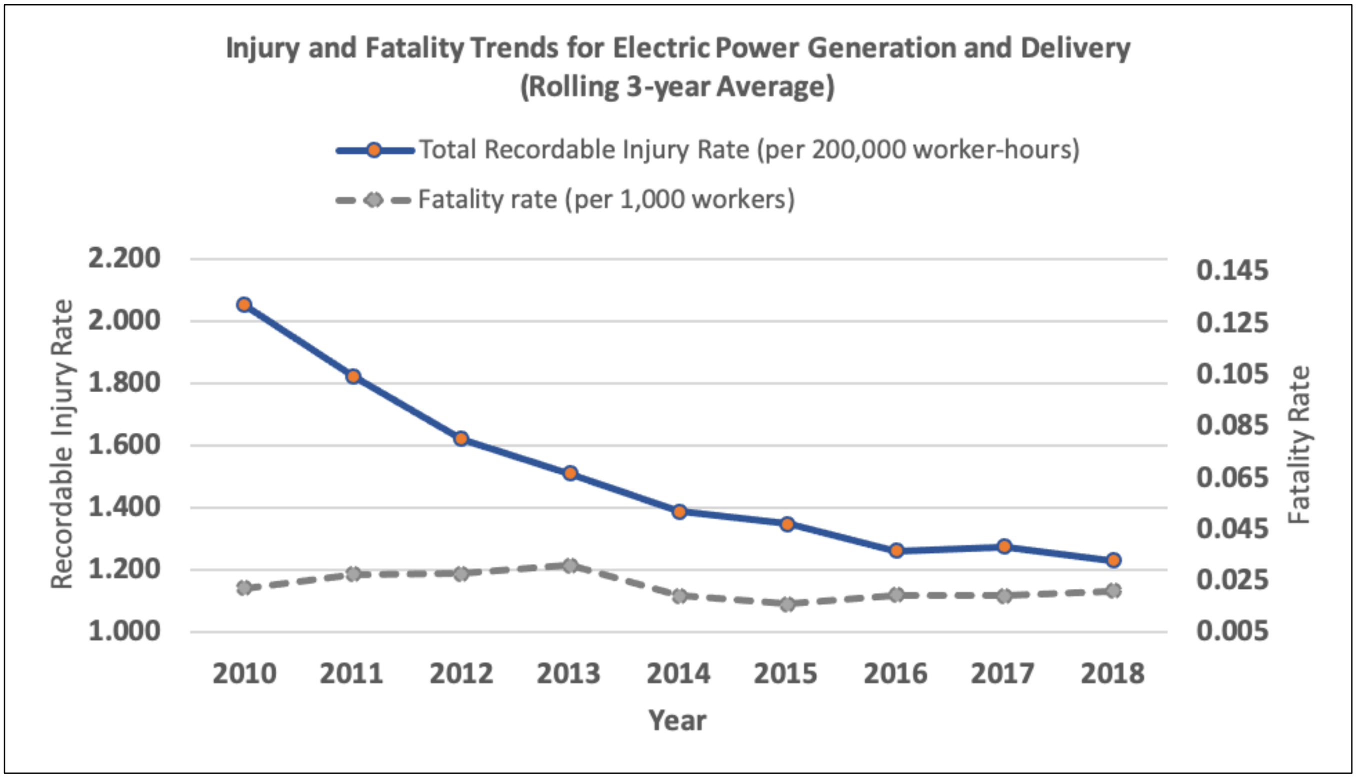
Using this model, consistency in incident classification among the EEI workgroup increased from a baseline of 65 percent to 95 percent. This SCL model enables a common understanding of safety learning opportunities underpinned by a set of definitions for each of the seven incident and observation types in the model. This common language serves as the foundation for shared learning.

Tracking and learning from PSIF could redirect attention from lower-severity incidents to conditions that have the potential to be life-threatening or life-altering, which would be an important step toward the elimination of SIFs. In the future, the SCL model and the associated definitions could be used to form new, more impactful safety metrics that complement traditional indicators like total recordable injury rates (TRIR). This would allow organizations to monitor progress toward the most important goal: saving lives.

Motivation

Serious injuries and fatalities (SIFs) continue to plague nearly every industrial sector. Although recordable injuries in the electric power generation and delivery sector have declined steadily over the last decade, SIF rates have plateaued (see Figure 1). Contrary to past theory, there is mounting evidence that the causes of SIFs are different from low-severity injuries and that reducing the rate of low-severity injuries may not lead to a corresponding reduction in SIFs. Thus, SIFs must be studied differently from lower-severity incidents.

Figure 1 – Power generation and delivery injury and fatality trends



SIF elimination must be set as a priority. Although this goal is theoretically possible, it will require intense collaboration across the industry. From a data availability perspective, SIFs are rare and extreme events that, taken in small sample sizes, do not necessarily represent any meaningful pattern or trend. Therefore, individual organizations simply do not have enough data to fuel learning that is needed to eliminate SIFs. Fortunately, the industry is beginning to tap potential serious injuries and fatalities (PSIF) as a data source, and the sharing of SIF and PSIF data is accelerating.

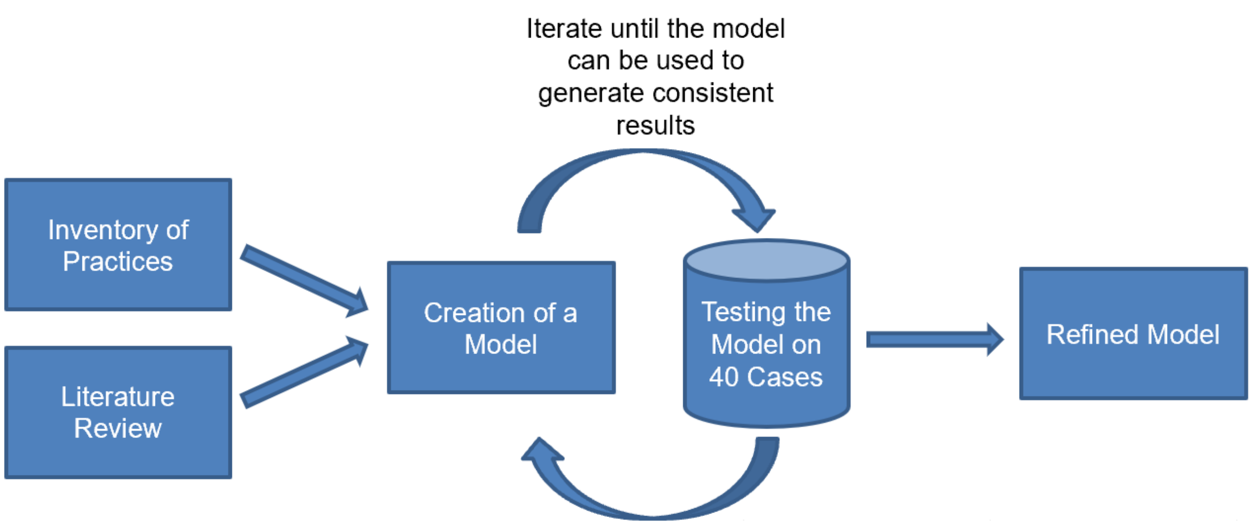
The underpinning of shared learning is a set of common definitions and the ability to classify observations consistently and reliably in accordance with those definitions. This is true for any scientific field because a common understanding of a topic influences how we communicate and what we perceive as relevant. For SIF elimination, a common language around SIF learning is needed because existing methods are incomplete and lead to inconsistent terminology and biased classifications.

To facilitate shared learning, this project aimed to create a safety classification and learning model that enables practitioners to identify, prioritize, and communicate safety learning opportunities with high consistency and reliability.

Model-Building and Validation Process

The EEI Safety Classification and Learning (SCL) Model was created by a team of 20 safety leaders and a technical advisor. As shown in Figure 2, the team first completed an inventory of existing methods of identifying and classifying incidents with SIF potential. Using these tools, theories, and judgment, a baseline assessment exercise was completed for 14 test cases. This exercise revealed the strengths and limitations of existing approaches. The objective features of the existing methods then were combined into a new model that subsequently was tested by the team for a total of 40 actual cases. The goal of the testing and calibration process was to refine the model so that it ultimately produced logical and reliable results. Ultimately, the team reached 95 percent agreement in safety classifications despite starting with only 65 percent agreement in the test cases. Finally, once the model was completed, the team created operational definitions of SIF, PSIF, and other incident and observation types and made recommendations for organizational learning, data collection, and tracking.

Figure 2 – Model creation and testing process



Inventory of Existing Approaches for Assessing SIF Potential

One of the most challenging tasks observed in the test cases was determining if an incident or observation had SIF potential because existing methods involve a great deal of subjectivity. In the literature review, several tools for SIF classification were identified (Campbell, 2018; Martin & Strikoff, 2012; Martin & Black, 2015). Although these tools generally take the form of decision trees, they can be reduced to a list of conditions associated with SIF potential, like the following:

1. Confined Space
2. Lock-out tag-out (LOTO)
3. Work at height
4. Fall greater than 48 inches
5. Falling into deep water
6. Suspended load
7. Hot work
8. Arc flash
9. Fire
10. Explosion
11. Hazardous materials
12. Vehicle collision
13. Struck-by or caught between a vehicle or powered equipment
14. Contact with moving components of stationary machinery
15. Barricades or guarding has been defeated or bypassed
16. Contact with moving components of powered equipment
17. Pinched, caught between, struck by, or in the line of fire of a moving object with sufficient energy to cause SIF harm
18. Violent attacks by a person or animal species capable of inflicting SIF harm
19. Electrical contact of sufficient voltage/amperage to cause SIF harm
20. Uncontrolled energy sources like electrical, mechanical, hydraulic, pneumatic, chemical, thermal, high pressure, or potential energy
21. Any other SIF exposure situation not described
22. Other

Interestingly, most team members had created organization-specific adaptations of this list and some had converted the elements into a set of icons representing categories like falls, confined space, and mechanical equipment. When participating in the background consistency assessment, team members used these existing methods or adaptations.

Background Consistency Assessment

Initial testing was performed with four fabricated test cases via a survey sent to 113 practitioners (see Table 1). The respondents were asked to answer two simple questions for each case: *Is this case a potential serious injury or fatality (yes or no)? What is your confidence in your response (measured on a 1-5 scale where 1 is extremely low and 5 is extremely high)?* Even though existing tools were used when evaluating the test cases, the respondents averaged only 65 percent agreement. Also, despite this high variability, confidence in individual decision making was high (average of 4.6/5).

Table 1 – Case examples

	Is this a PSIF event? (% yes)	Confidence (1-5 scale)
Worker is at 70 feet of height with an 8 lb tool. There is no protection below, but work is under way below the elevated work space. There is no lanyard on the tool and the tool has not been dropped.	68%	4.5/5.0
Worker is at 70 feet of height with an 8 lb tool. There is no protection below, but work is under way below the elevated work space. The worker drops the tool and it falls to the ground, but no one was injured.	93%	4.89/5.0
Worker is at 70 feet of height with an 8 lb tool. There is no protection below, but work is under way below the elevated work space. The tool is dropped but is caught by a tool lanyard.	62%	4.5/5.0
Worker is at 70 feet of height with an 8 lb tool. The tool is dropped but is caught by a tool lanyard and there is a physical barrier in place to keep workers from entering the zone below the elevated work space.	35%	4.4/5.0

In addition to the assessment of the four fabricated cases by a broad audience, the team performed a deep assessment and discussion of 10 real cases. The level of agreement was similar to the four test cases, at approximately 60 percent (where 50 percent represents complete disagreement). One example of a controversial case is presented below because it best illustrates the conundrum that the team faced. The case has been simplified to remove any identifying information.

Interpretation of a Controversial Case

Controversial Case: A worker is at 20 feet of height and falls and was caught by his fall arrest system, which was designed and used properly. The worker was not injured.

The most controversial case that the team discussed is shown to the right. When presented, the team was asked to determine if this event should be recorded as PSIF. Interestingly, the team was completely split, with exactly 50% indicating that the event should be PSIF and the other 50% believing that the event should not be classified as PSIF. The major disagreement was related to the presence of the functioning lanyard. Half of the team believed that the lanyard was a sufficient control because it was used properly, worked as designed, and eliminated SIF exposure. The others believed that the engagement of a fall arrest system categorically represented a PSIF. One point of agreement was that the case did not represent success and that there must be a subset of cases that are not SIF, PSIF, or success. Another point of agreement was that analysts should not ask the question: *does this incident have SIF* *potential?* The answer to this question is inevitably 'yes' if the analyst is creative enough (e.g., a fall to the same level *could* be fatal if the worker struck his or her head just the right way). Rather, the analyst should ask: *Is the most likely outcome of this event a serious injury or fatality?*

Identified Limitations in Existing Methods of Safety Classification

Although the existing list-based methods of safety classification were an important step forward, the team realized the following limitations that caused very high variation in the test cases:

1. Subjectivity in the assessment of whether the condition had a sufficient danger to cause SIF harm (e.g., items 19 and 20);
2. Generalized conditions that do not always have SIF potential (e.g., in item 1, a scratch to an arm does not have SIF potential just because it occurs in a confined space);
3. An 'other' category that can be applied broadly at the discretion of the analyst; and
4. No explicit consideration of the presence or absence of physical controls.

When it comes to consistent classification, the main issue is that existing methods do not help to identify when an incident or observation **does not** have SIF potential. Thus, with the right inclination, the team found that any incident or condition could be classified as having SIF potential. In other words, if an analyst feels that a case has SIF potential, there is no guidance that suggests otherwise. Therefore, it is not surprising that many analysts tend to find these methods satisfying because they inevitably confirm preconceived judgment. It wasn't until the team tested the consistency of classifications that this fatal flaw emerged.

Guiding Principles

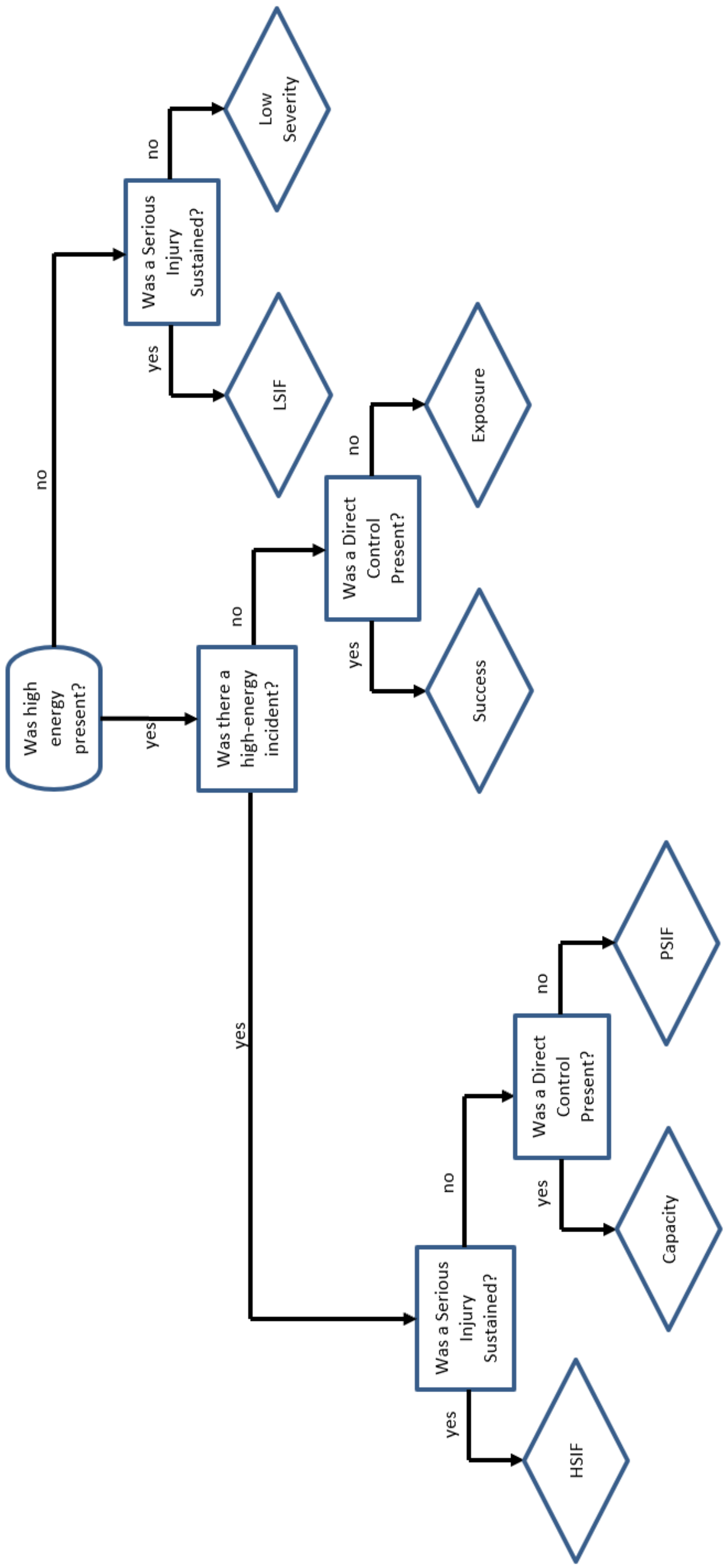
Following the literature review and test cases, the team established some principles that guided the creation of the SCL model. First, the team set the goal of creating a safety classification method that enables consistent and reliable classification of any safety observation or incident (i.e., all analysts should be able to use the model to arrive at the same conclusion). To this end, the team agreed that the model must:

- Be derived from scientific knowledge and objective observation;
- Yield consistent classification results regardless of employer, experience, or background;
- Include an assessment of controls;
- Establish when an event or observation is and is not a PSIF;
- Distinguish success from failure;
- Result in clear and crisp operational definitions of SIF, PSIF, and other event or observation types.

Model Creation and Refinement

Based upon these guiding principles, a new flowchart and decision methodology was created by the technical advisor. This draft model then was tested and refined over an iterative process. During the testing procedure, every definition was worded carefully to remove any ambiguity. After 40 test cases, the model yielded approximately 95 percent agreement within the team when the definitions and instructions are carefully followed. Importantly, the goal of creating this SCL model was not to validate intuition or any one organization's existing approach or philosophy; rather, the model was designed to promote consistent and objective classification. The final SCL model is shown in Figure 3 on the next page.

Figure 3 – EEI Safety Classification and Learning (SCL) Model



Guide to Using the SCL Model

This ***shared*** model is based on four seemingly simple questions:

1. Was high-energy present?
2. Was a there a high-energy incident?
3. Was a serious injury sustained?
4. Was a direct control present?

Although seemingly simple to answer, the answers to these questions can be complex and hotly debated without clear and compelling guidance. This section of the report provides detailed guidance for answering these four questions.

Question 1: Was high-energy present?

The energy assessment method is built upon evidence that serious injuries are the result of some undesirable contact with energy. This applies across energy forms like gravity, motion, mechanical, electrical, pressure, sound, radiation, biological, chemical, and temperature (Figure 4). Existing peer-reviewed literature took this a step further, showing that the magnitude of physical energy predicts the most likely severity of an injury or condition (Hallowell, 2017). Specifically, incidents with more than 500 foot-pounds (ft-lb) of energy are more likely to be a SIF than not. Therefore, the term ‘high-energy’ refers to a condition where the physical energy exceeds 500 ft-lb, which corresponds to a condition where the most likely outcome of an incident is a SIF. See Appendix 4 for the energy-severity distributions.

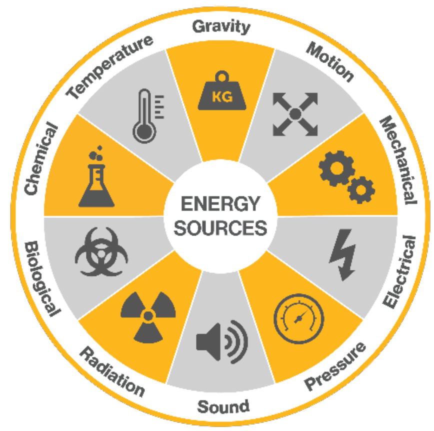
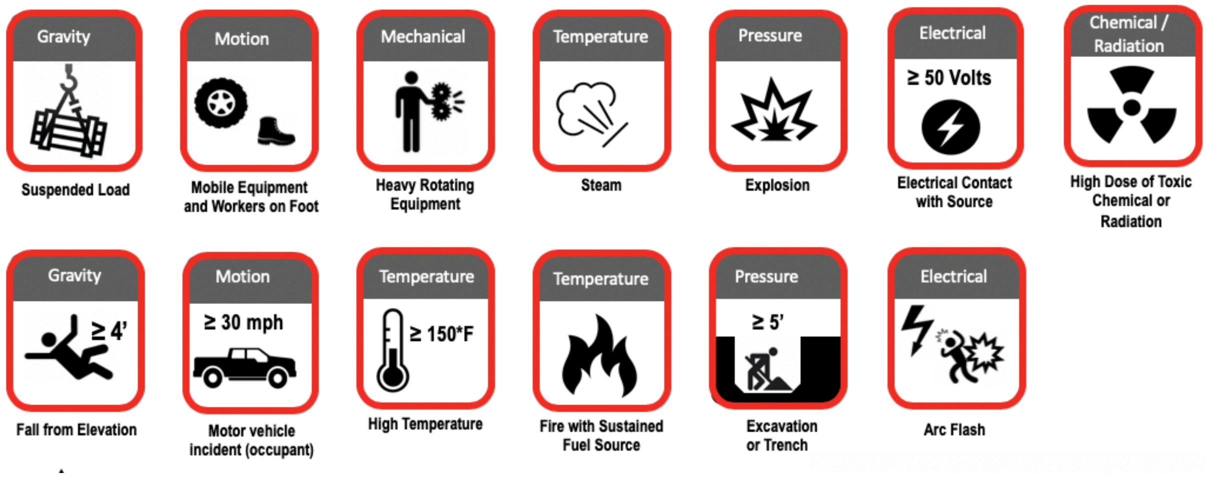


Figure 4 – Energy Sources

Because energy assessment can be challenging, two sets of resources were developed. The first is a set of icons that build upon the previous methods of SIF assessment. Each icon shown in Figure 5 on the next page corresponds to a hazardous condition where the energy magnitude almost always far exceeds the 500-ft-lb threshold. These icons are explained in further detail in Appendix 2.

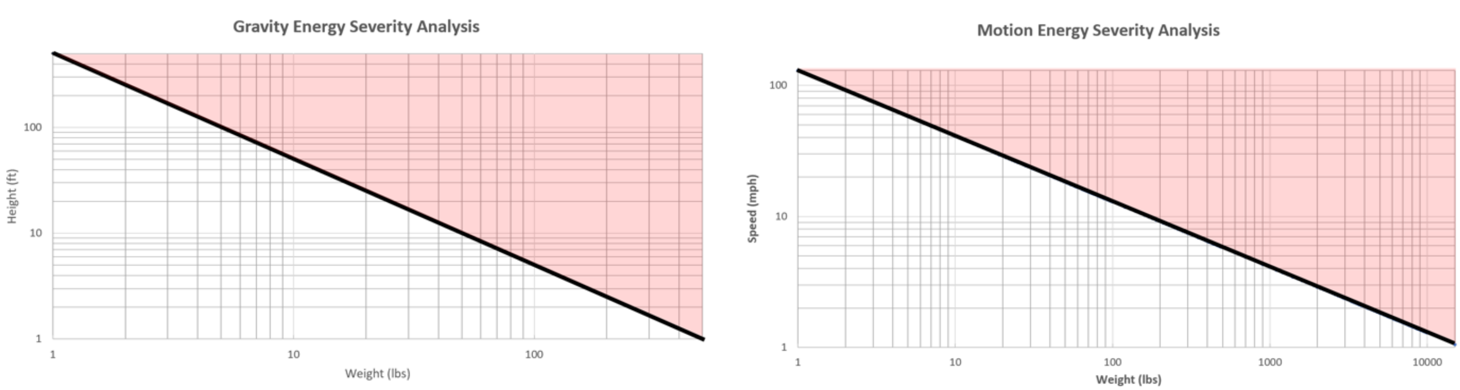
Figure 5 – High-energy icons

(see Appendix 2 for detailed descriptions)



Although useful and simple, the icons in Figure 5 are not all-inclusive. There are situations when objects like tools, materials, or equipment have enough energy to exceed the 500-ft-lb threshold but are not included as an icon. For these circumstances, two energy assessment graphs are provided, one for potential energy (gravity) and one for kinetic energy (motion). These graphs are shown in Figure 6 and in detail in Appendix 3. To use the graph for gravity, one simply must estimate the weight of the object in pounds and the height of the object in feet. If the point where the lines intersect is in the red zone, the condition exceeds 500 ft-lb and is most likely to result in SIF; otherwise, the condition is most likely to be lower severity. The same approach can be used for motion energy, except the weight and the speed of the object must be estimated. These graphics apply for any potential or kinetic energy that is not represented by the icons.

Figure 6 – Learning incident prioritization

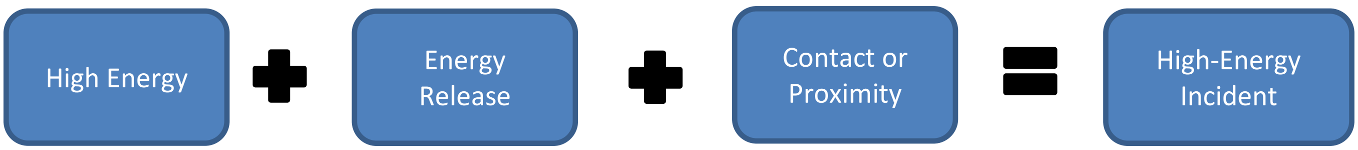


Important Note About Multiple High-Energy Sources: The user should apply the model independently for *every* high-energy source observed. Multiple-energy situations are common, and the model must be applied separately for each high-energy source. The ultimate classification should be the most serious classification.

Question 2: Was there a high-energy incident?

Given that at least one high-energy hazard exists, the next question is whether or not there was an 'incident' related to that energy source. The team first assumed that deciding whether an incident had occurred would be obvious. However, as cases were analyzed, it became apparent that this is more nuanced than anticipated. The team settled on the definition as an ***instance where the high-energy source was released and where the worker came in contact with or proximity to the high-energy source.*** This definition is depicted in Figure 7.

Figure 7 – Components of High-Energy Incident Definition.



To ensure consistent application of this definition, the team defined energy release as an *instance where the energy source changes state while exposed to the work environment*. Examples of energy release could be a tool that is dropped and transitions from potential to kinetic energy, or a person who loses control of his or her balance and stumbles. The energy release is always related to an instance where the energy is no longer contained or in the worker's control. Finally, either the worker(s) must have contact with the energy or be in proximity to the energy. Contact is defined as an *instance when the high energy is transmitted to the human body* and proximity is defined as a *hazardous circumstance where the boundary of the high-energy exposure is within 6 feet of the worker who has unrestricted egress or any distance to the high-energy source when there is a confined space or there is a situation with restricted egress where a worker cannot escape the energy source*. These definitions should be interpreted exactly as worded to ensure consistent classification.

Question 3: Was a serious injury sustained?

Creating a definition of serious injury and fatality (SIF) was outside the scope of this work. The team deferred to the existing EEI SIF criteria and the basic definition that the event was life-threatening or life-altering. The team believes that the work conducted here may be of use when revising the EEI SIF criteria in the future.

Question 4: Was a direct control present?

A core principle in this SCL model is that the primary differentiator between success and failure is the presence or absence of direct controls. The team carefully defined a direct control as one that is specifically targeted to the high-energy source; effectively mitigates exposure to the high-energy source when installed, verified, and used properly (i.e., a SIF reasonable should not occur if these conditions are present); and is effective even if there is unintentional human error during the work (unrelated to the installation of the control). Examples of direct controls include LOTO, machine guarding, hard physical barriers, fall protection, and cover-up. Examples that are not direct controls include training, warning signs, rules, and experience because they are susceptible to unintentional human error. Further, most standard non-specialized personal protective equipment like hard hats, gloves, and boots are not direct controls because they are not specifically targeted to a high-energy source.

Direct controls either can be absolute or mitigating. Absolute controls completely eliminate high-energy exposure when installed, verified, and used properly and include techniques like de-energization, LOTO, or a machine guarding. Mitigating controls reduce energy exposure to below the 500-ft-lb threshold, but do not eliminate all exposure to the energy, like a thermal insulation barrier that reduces heat exposure from a pipe, fall protection that limits free-fall, or airbags and seat belts that reduce impact during a motor vehicle accident. Assessing whether a control mitigates the high-energy source may involve some assumptions, which should be documented and communicated clearly as part of any investigation.

Multiple-Energy Cases

During the review of the 40 real-world cases, approximately one-third involved multiple sources of high energy. As previously indicated, the model is intended to be used independently for each high-energy source. That is, for each high-energy source, one would evaluate whether an incident occurred related to that energy source, whether a SIF incident occurred, and whether direct controls were present. Thus, a single incident or observation may yield multiple classifications. The most serious of these classifications should be used.

Summarizing Incident Classifications

The SCL model can yield one of seven possible outcomes. These include HSIF, LSIF, PSIF, Capacity, Exposure, Low-Severity, and Success. A definition and interpretation of each of these classifications is provided in this section. The definitions are completely consistent with the model, distinguished from each other by the presence or absence of high-energy, a high-energy incident, and direct controls. Table 2 provides a crosswalk of the seven classifications and four decision points for quick interpretation and possible use in programming in a safety management system. Appendix 5 provides test cases with two cases per SCL classification. Also, Table 3 provides a single case that is adjusted to illustrate the subtle but important differences in the classifications. Finally, Appendix 5 provides 10 test cases with guidance on how the classifications were made.

High-Energy Serious Injury or Fatality (HSIF):
Incident with a release of high energy in the absence of a direct control where a serious injury is sustained. These events are primary learning opportunities because a worker, their family, co-workers, and the organization are all deeply affected. The organization must take such events seriously and seek to learn to prevent future failures. These incidents generally relate to the absence of engineering controls that are designed to protect against high-energy hazards. Typically, significant learning can occur because causal factors and vulnerabilities of the controls can be assessed. HSIF are not optimal learning events because they are rare; when lives are lost or disablements occur, it may be impossible to acquire all necessary information.

Low-Energy Serious Injury or Fatality (LSIF):
Incident with a release of low energy in the absence of a direct control where a serious injury is sustained. Typically, LSIF incidents are related to health and physiology. Unlike HSIF that mainly relate to engineering controls, LSIF cases are typically best addressed by an industrial hygienist or a medical professional. Thus, the competencies needed to learn and the means of preventing future incidents may require consultation outside of the safety profession.

Potential Serious Injury or Fatality (PSIF):
Incident with a release of high energy in the absence of a direct control where a serious injury is not sustained. PSIF incidents have the same circumstances and characteristics as HSIF events with the exception of the outcome. In other words, the workers within proximity to the event were only lucky. These events can be cases where no injury occurred, or a low-severity injury was sustained that could have been much worse. These events are excellent learning opportunities because there was no serious outcome and because all parties involved in the incident can be included in the learning team.

Capacity:
Incident with a release of high energy in the presence of a direct control where a serious injury is not sustained. Capacity incidents have the same characteristics as PSIF except for the presence of a direct control. Unlike PSIF, the organization can be described as better prepared for these incidents because of the presence of a direct control. Because of the release of high-energy, capacity incidents are not categorically positive or negative. Rather, they represent excellent learning opportunities because the organization can investigate what triggered the energy release and why workers contacted or were in proximity to the high-energy source. Most importantly, capacity cases provide organizations with the opportunity to verify the resilience of their controls without negative outcomes.

Exposure:
***Condition where high energy is present in the absence of a direct control*.** Unlike incidents, an exposure is an observable condition. Exposure conditions are the same as PSIF and HSIF except that an incident has yet to occur. Thus, learning can occur before any negative incident occurs. Observations also can be made regularly, resulting in a higher volume of learning opportunities. Currently, these cases are often referred to as good catches, stop work, or at-risk observations.

Success:
Condition where high energy is present but is not released because of a direct control. Interestingly, prior to the creation of the SCL model, there was no known universal definition of safety success. The definition presented here distinguishes success from all other observations by the presence of direct controls. Realistically, workers often must be in environments with high-energy sources. Thus, the ideal condition is one where the workers are protected against the energy by targeted, properly installed, and verified controls that effectively eliminate or mitigate high-energy exposure even if the workers were to make an error. Because success is an observation, these cases can be identified and studied in high volume. Furthermore, if organizations wish to become predictive, they must collect success observations and seek to understand how they are different from PSIF or HSIF. Creating predictive models is only possible when both success and failure cases are studied together because predictive analytics are designed to distinguish outcomes mathematically based on observable conditions. Studying HSIF, PSIF, and LSIF alone would not reveal relevant predictors.

Low-Severity:
These low-priority incidents are de-prioritized in the model because they did not result in or have the potential to result in a SIF.

Table 2 – Crosswalk of SCL Model Classifications and Decision Points

Classification	Was high Energy Present?	Did a high-energy incident occur?	Was a direct control present?	Was a serious injury sustained?
HSIF	Yes	Yes	No	Yes
PSIF	Yes	Yes	No	No
LSIF	No	No	N/A	Yes
Capacity	Yes	Yes	Yes	No
Success	Yes	No	Yes	No
Exposure	Yes	No	No	No
Low-Severity	No	No	NA	No

Table 3 – Single Example Illustrating Salient Classification Types

Case Example	Was high energy present?	Did a high-energy incident occur?	Was a direct control present?	Was a serious injury sustained?	Classification
A transmission lineworker was observed working on a tower structure at 100 feet of height with his/her personal fall arrest system anchored properly. Work was completed without incident.	Yes	No	Yes	No	Success
A transmission lineworker was observed working on a tower structure at 100 feet of height but his/her personal fall arrest system was not anchored properly. Work was stopped before an incident occurred.	Yes	No	No	No	Exposure
A transmission lineworker was working on a tower structure at 100 feet of height but his/her personal fall arrest system was not anchored properly. Worker lost his/her balance, fell to the ground, and was fatally injured.	Yes	Yes	No	Yes	HSIF
A transmission lineworker was working on a tower structure at 100 feet of height but his/her personal fall arrest system was not anchored properly. Worker lost his/her balance due to a gust of wind and caught himself/herself within 1 foot of the edge.	Yes	Yes	No	No	PSIF
A transmission lineworker was working on a tower structure at 100 feet of height. The lineworker lost his/her balance due to a gust of wind, fell, and was caught by his/her personal fall arrest system, which was used as designed and worked properly. He/She was retrieved in two minutes and sustained no injuries.	Yes	Yes	Yes	No	Capacity

Using the EEI SCL Model for Learning

The team unanimously agreed that the primary purpose of this model is to help direct learning. Based on this philosophy, the team prioritized the learning potential for each of the injury classifications in the SCL model (see Figure 8). Note that there is no hierarchy within the tiers, but there is a hierarchy among the tiers.

Tier 1 includes all cases with SIF outcomes and SIF potential. These cases deserve the highest priority when investing limited resources for learning and typically should involve full root cause assessments. The team recommends that the industry invest the same level of time and energy into PSIF incidents as HSIF and LSIF. Since the only differentiator is outcome, these incident types have the same learning potential. Including detailed PSIF investigations in an organization's learning portfolio finally could enable data mining and pattern detection for SIF.

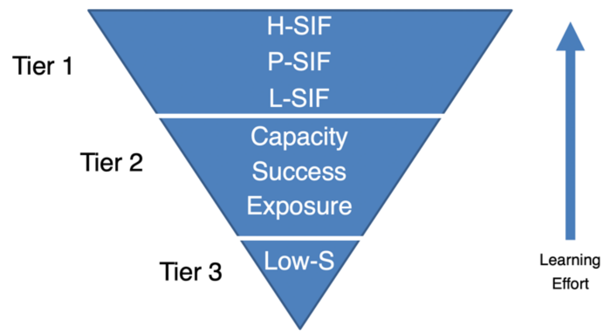


Figure 8 – Learning Prioritization

(note that there is no hierarchy within tiers)

Tier 2 cases include capacity, success, and exposure. Interestingly, success and capacity both have positive attributes and involve the presence of direct controls. Learning from these cases generally would involve asking *why were the direct controls present?* As such, a controls assessment would be the starting point for a root cause analysis of situations that did not yield negative outcomes. Success in particular is a requisite component of organizational learning because these events are required for predictive analytics and diagnostics that may enable SIF prediction. Finally, exposure is included in Tier 2 because these observations have the same characteristics as HSIF and PSIF without the incident.

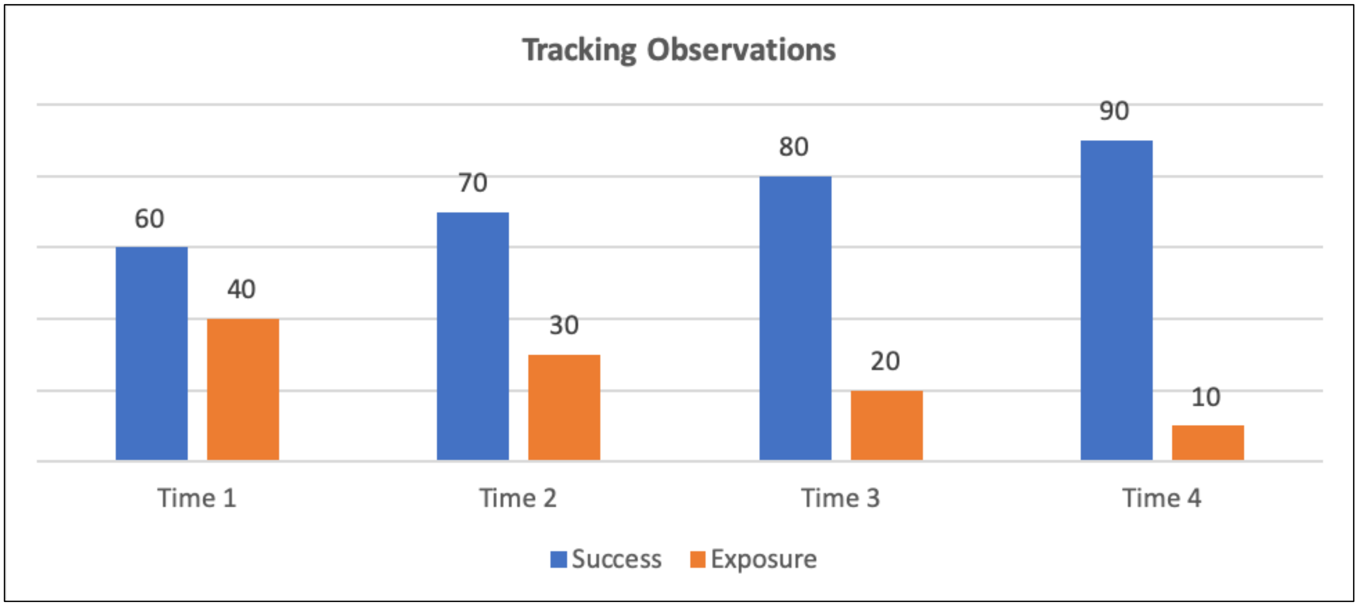
Finally, Tier 3 cases are low-energy learning opportunities with comparatively less importance. These low-energy situations generally do not have the potential to cause a SIF incident. It may be worth tracking the causes of these incidents to understand if there is an important trend that is affecting a large proportion of workers and could consume significant resources.

Using the EEI SCL Model for Tracking

Organizational leadership often focuses its assessment of safety leadership on lagging measures of safety like total recordable injury rate (TRIR), SIF rates, and others. Therefore, it can be difficult to resist the temptation to create a PSIF metric. The team's primary concern with a PSIF metric was that organizations have not matured yet to report such incidents consistently. While reporting is inconsistent, the question for an organization becomes *Do we want to see more PSIF incidents or fewer incidents?* On one hand, many PSIF incidents could reflect serious concerns because of missing or improperly used direct controls. On the other hand, a high number of PSIF incidents could be indicative of an open reporting culture. Alternatively, a low number of PSIF incidents could mean that the organization either has consistent use of direct controls or that the workforce is not yet open about sharing PSIF incidents. Given this paradox, the team unanimously agreed that the focus of this SCL model should be used first as a tool to direct learning before it is used as a performance metric. Only once the EEI community is confident that PSIF reporting and learning is consistent and transparent should a PSIF metric be considered.

As organizations begin to use this new model, there are a few tracking opportunities that are available that do not involve measuring or benchmarking against one absolute PSIF metric. For example, organizations can track the proportion of high-energy safety observations that are marked success. Since most organizations perform safety observations, they could be classified by noting whether direct controls were present (success) or absent (exposure). As organizations evolve in the use of this model, a measure of improvement could be the progress toward the ideal: all high-energy safety observations include the presence of a direct control. A simple fabricated example is provided in Figure 9, showing an organization that is moving on a trajectory of improvement. The benefit of measuring, tracking, and studying trends in observations is that they can be collected at any frequency that resources allow and the organization does not need to wait for an incident to learn.

Figure 9 – Observation Tracking Example



Recommendations

The team recommends that EEI member companies and contractors begin to share PSIF incidents to initiate shared learning. If PSIF incidents are collected and shared in large volumes, patterns and trends may emerge. This may be especially true if these reports include detailed information about the controls that were present or absent. The team recommends launching SIF precursor assessments for PSIF and SIF incidents and sharing these data so that the data about controls could be complemented with human factors data related to the status of the workforce in terms of distraction, normalization, hazard recognition, and others.

Once the EEI community has matured to the point where PSIF incidents are collected consistently and shared among organizations, a PSIF metric could be considered as a complement to TRIR and other lagging indicators. Additionally, composite metrics like SIF Actual (HSIF + LSIF) or SIF Total (HSIF + LSIF + PSIF) could be considered. As long as organizations are using the SCL model consistently and the reporting culture is strong, many valuable composite metrics are possible.

APPENDIX 1 - GLOSSARY

Capacity: Incident with a release of high energy in the presence of a direct control where a serious injury is not sustained.

Direct Control: A barrier that is specifically targeted to the high-energy source; effectively mitigates exposure to the high-energy source when installed, verified, and used properly; and is effective even if there is unintentional human error during work that is unrelated to the installation of the control.

Energy Contact: Instance when high energy is transmitted to the human body.

Energy Proximity: A circumstance where a high-energy source may be within 6 feet of a worker before being contained or any distance when there is restricted egress from the energy source.

Energy Release: An instance where energy source changes state and is exposed to the environment.

Exposure: Condition where high energy is present in the absence of a direct control.

High Energy: An element of work that involves more than 500 ft-lbs of physical energy.

High-Energy Incident: An instance where the high-energy source was released and where the worker came in contact with or proximity to the high-energy source.

High-Energy Serious Injury or Fatality (HSIF): Incident with a release of high energy in the absence of a direct control where a serious injury is sustained.

Low-Energy Serious Injury or Fatality (LSIF): Incident with a release of low energy in the absence of a direct control where a serious injury is sustained.

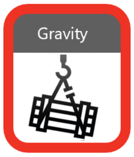
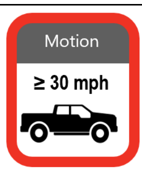
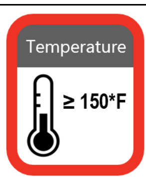
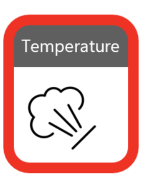
Low Severity: Incident with a release of low energy where no serious injury is sustained.

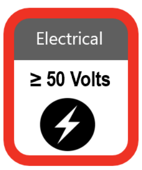
Potential Serious Injury or Fatality (PSIF): Incident with a release of high energy in the absence of a direct control where a serious injury is not sustained.

Serious Injury or Fatality: Life-threatening or life-altering incident.

Success: Condition where high energy is present but is not released because of the presence of a direct control.

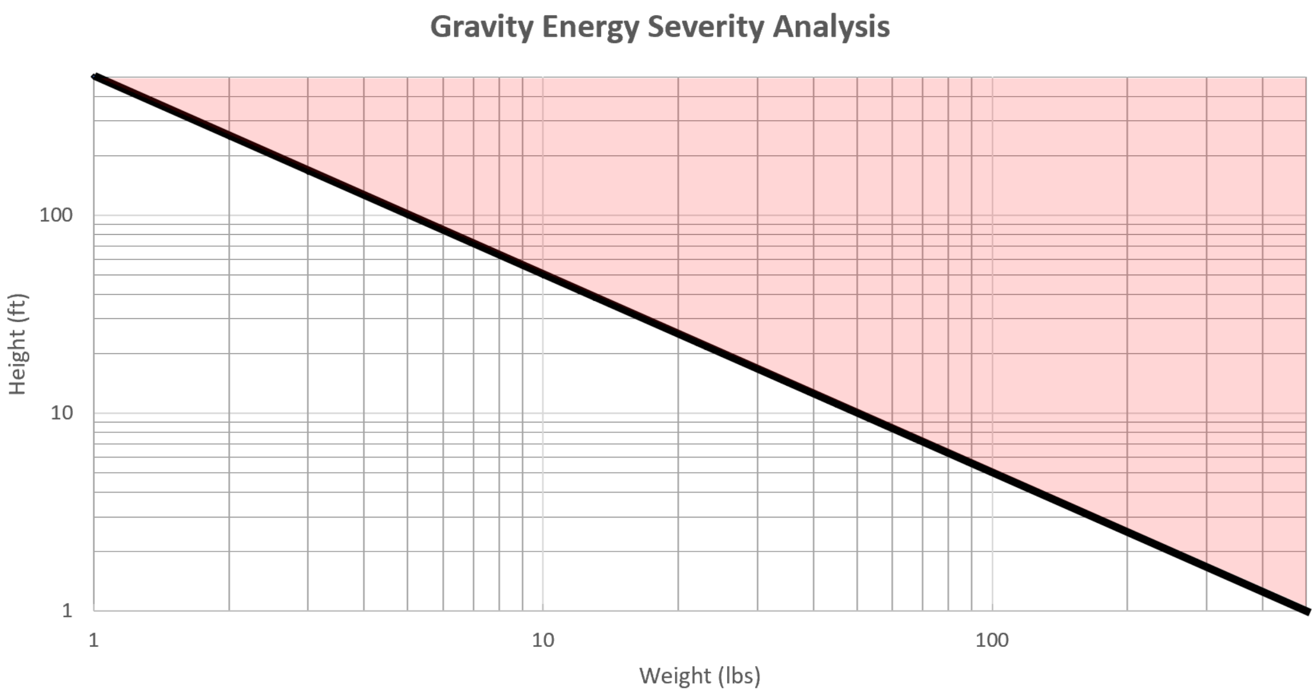
APPENDIX 2 - ICONS FOR ASSESSING SIF POTENTIAL

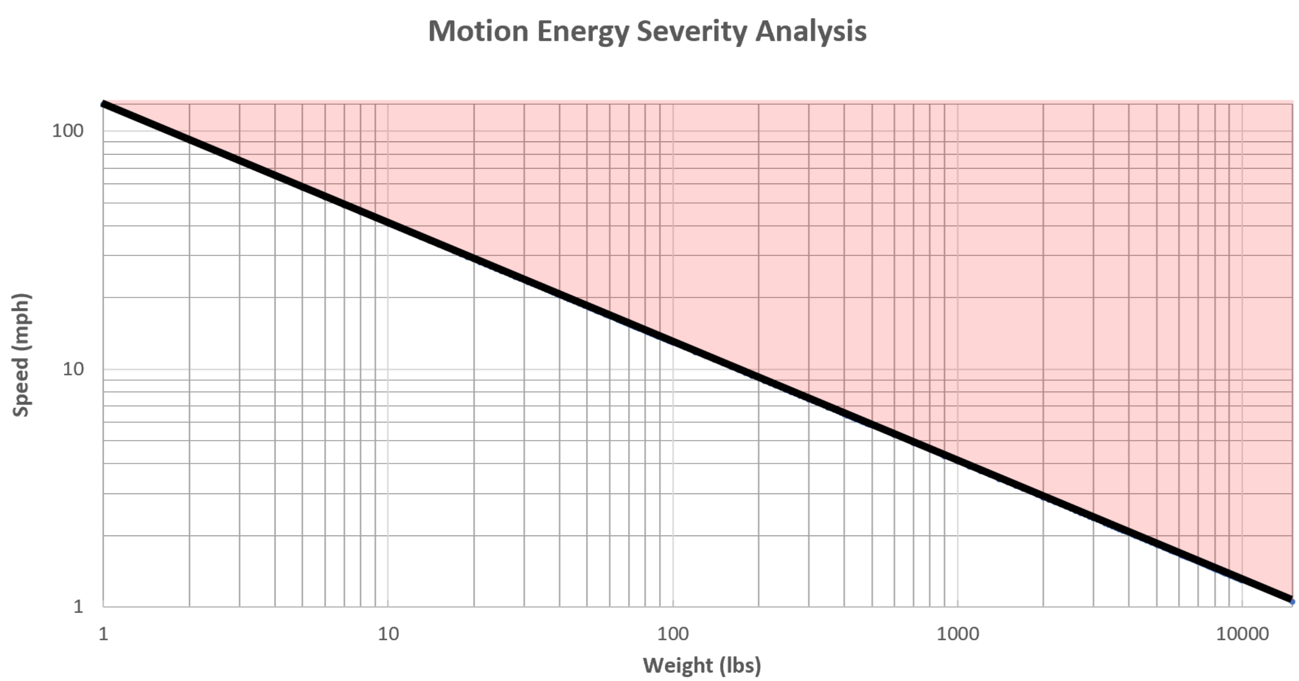
Icon	Description
 Suspended Load	Most suspended loads require specialty equipment to lift more than 500 lbs of load higher than 1 foot off the ground. In such a case, the suspended load would be more than the high-energy threshold.
 Fall from Elevation	Considering the average weight of a human is over 150 lbs, 4 feet of elevation (measured from the ground surface to the bottom of the feet) exceeds the high-energy threshold.
 Mobile Equipment and Workers on Foot	Because of the mass, most mobile equipment exceeds the high-energy threshold when the equipment is moving more than 1 mile per hour. The energy exposure is taken from the point of view of the worker on foot and not the equipment operator.
 Motor vehicle incident (occupant)	Estimates of the motor vehicle speed typically involved in serious or fatal crashes vary greatly from the National Transportation Safety Board, National Highway Transportation Safety Association, and the U.S. Department of Transportation. The team selected a conservative estimate of 30 miles per hour as the high-energy threshold. This energy exposure is taken from the point of view of the vehicle occupants, including the driver.
 Heavy Rotating Equipment	Computing mechanical energy can be complex, as it requires estimates of the moment of inertia and angular velocity for rotating objects and stiffness and displacement for tension or compression. Thus, all heavy rotating equipment beyond powered hand tools typically exceed the high-energy threshold and any rotating equipment or tools exceeding 100 rotations per minute (rpm) should be considered high energy.
 High Temperature	According to the American Burn Association, exposure to any substance greater than or equal to 150 degrees Fahrenheit typically cause third degree burns when contacted for 2 seconds or more.
 Steam	According to the American Burn Association, any circumstance with the release of steam exceeds the high-energy threshold.

 Fire with Sustained Fuel Source	According to the North American Combustion Handbook, a lightly combustible material like paper burns at approximately 700 degrees Fahrenheit, far exceeding the temperature threshold. Fire with a sustained source of fuel exceeds the high-energy threshold.
 Explosion	Most incidents described as an explosion exceed the high-energy threshold.
 Excavation or Trench	An exposure to unsupported soil in a trench or excavation that exceeds 5 feet of height exceeds the high-energy threshold. Typically, for each foot of depth, soil pressure increases by about 40 pounds per square foot. Thus, at 5 feet of depth, the pressure is approximately 200 psf.
 Electrical Contact with Source	Electricity equal to or exceeding 50 volts is sufficient to result in serious injury or death according to the NFPA 70E.
 Arc Flash	Any arc flash exceeds the high-energy threshold because of the voltage exposure, according to the NFPA 70E. Also, permissible distances are covered in OSHA Standard 1910.333 and section 1910.333(c)(3)(ii)(C) in particular.
 High Dose of Toxic Chemical or Radiation	Exposure to toxic chemicals, radiation, or biological agents. An industrial hygienist, chemist, or toxicologist should be involved in the assessment of toxicity and acceptable exposure limits.

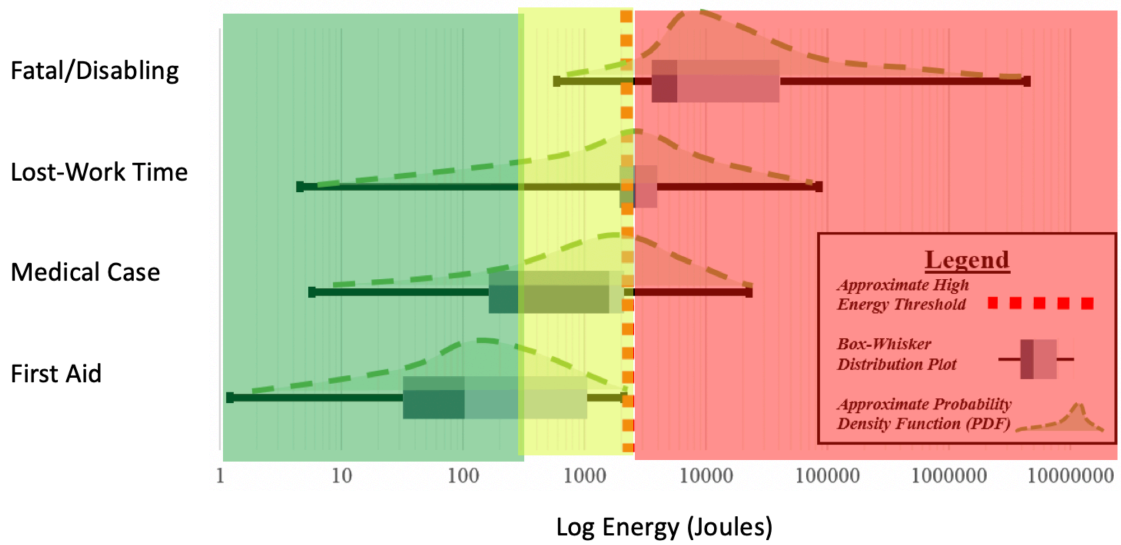
APPENDIX 3 - ENERGY-BASED SEVERITY ASSESSMENT GRAPHS

***Use these graphs if no energy icon applies.





APPENDIX 4 – ENERGY SEVERITY DISTRIBUTION



Note: Green corresponds to energy levels less than 500 Joules, where the most likely injury severity is first-aid; yellow corresponds to energy levels between 500 and 1500 Joules, where the most likely injury severity is medical case or lost work-time; and red corresponds to energy levels above 1500 Joules, where the most likely severity level is a serious injury or fatality (SIF).

APPENDIX 5 – TEST CASES

Case A: An employee was on the top of a de-energized transformer at 25 feet of height with a proper fall arrest system. While working, she tripped on a lifting lug, falling within 2 feet from the unguarded edge. When the employee landed, she sprained her wrist.

Interpretation

1. ***Was high-energy present?*** Yes, the worker was at 25 feet of height, which exceeds 4 feet of height (see icon).
2. ***Was there a high-energy incident?*** Yes, the worker tripped and lost control over the potential energy.
3. ***Was a serious injury sustained?*** No, a sprained wrist is not a SIF.
4. ***Was a direct control present?*** Yes, a proper fall arrest system was used, which is a mitigating control that reduces energy exposure to below 500 ft-lb.

Conclusion: Capacity against high energy, with a low-severity outcome.

Case B: An employee contracted West Nile Virus after being bitten by a mosquito while at work in a boggy area. Because of the exposure, the employee was unconscious and paralyzed for a two-week period.

Interpretation

1. ***Was high-energy present?*** No, a mosquito does not exceed the high-energy threshold.
2. ***Was there a high-energy incident?*** No, high energy was not present.
3. ***Was a serious injury sustained?*** Yes, loss of consciousness and paralysis meet the EEI SIF criteria.
4. ***Was a direct control present?*** N/A

Conclusion: LSIF

Case C: An employee was working alone and placed an extension ladder against the wall. When he reached 10 feet of height, the ladder feet slid out and he fell with the ladder to the floor. The employee was taken to the hospital for a bruise to his right leg and remained off duty for three days.

Interpretation:

1. ***Was high-energy present?*** Yes, the worker was at 10 feet of height, which exceeds the 4 ft threshold (see icon).
2. ***Was there a high-energy incident?*** Yes, the energy was released when the worker fell.
3. ***Was a serious injury sustained?*** No, the injury does not meet the EEI SIF criteria.
4. ***Was a direct control present?*** No, there were no controls that meet the direct control requirements.

Conclusion: PSIF

Case D: A crew was closing a 7-ton door on a coal crusher. As the door was lowered, an observer noticed that the jack was not positioned correctly and could tip. The observer also noted that workers were nearby, within 4 feet of the jack.

Interpretation:

1. ***Was high-energy present?*** Yes, the 7-ton door far exceed the 500 ft-lb threshold for gravity (see gravity energy chart).
2. ***Was there a high-energy incident?*** No, the observer intervened before the energy was released.
3. ***Was serious injury sustained?*** No.
4. ***Was a direct control present?*** No, the jack was not installed and used properly.

Conclusion: Exposure

Case E: Workers were hoisting beams and steel onto a scaffold. A certified mechanic operated an air hoist to lift the beam. As the lift was performed, the rigging was caught under an adjacent beam. Under the increasing tension, the cable snapped and struck a second employee in the leg, fully fracturing his femur. An investigation indicated that the rigging was not properly inspected before the lift.

Interpretation:

1. ***Was high-energy present?*** Yes, hoisting the steel beams meet the suspended load criteria (see icon) and far exceed the 500 ft-lb threshold for gravity (see gravity energy chart).
2. ***Was there a high-energy incident?*** Yes, the energy changed state when the lift was in progress.
3. ***Was serious injury sustained?*** Yes, a fractured femur meets the EEI SIF criteria.
4. ***Was a direct control present?*** No, the rigging was not properly inspected.

Conclusion: HSIF

Case F: A dozer was operating on a pet coke pile and slid down the embankment onto the cab after encountering a void in the pile. The operator was wearing his seat belt, and the roll cage kept the cab from crushing. No workers or machinery were nearby, and no injuries were sustained.

Interpretation:

1. ***Was high-energy present?*** Yes, a dozer meets the ‘mobile equipment’ high-energy icon.
2. ***Was there a high-energy incident?*** Yes, the energy was released when the dozer rolled, and the worker was in proximity to the energy.
3. ***Was a serious injury sustained?*** No.
4. ***Was a direct control present?*** Yes, the worker’s seat belt was used and the roll cage worked properly, reducing energy exposure to below the 500 ft-lb threshold.

Conclusion: Capacity

<u>Case G</u>: A master electrician was called to work on a new 480-volt service line in a commercial building. When working on the meter cabinet, the master electrician had to position himself awkwardly between the cabinet and the standpipe. He was not wearing an arc-rated face shield, balaclava, or proper gloves. During the work, an arc flash occurred, causing third-degree burns to his face.
<u>Interpretation</u>: 1. ***Was high-energy present?*** Yes, 480 volts exceeds the 50-volt icon and meets the arc flash icon. 2. ***Was there a high-energy incident?*** Yes, the energy was released during the arc flash and the worker was in proximity to the energy source. 3. ***Was a serious injury sustained?*** Yes, 3rd degree burns meet the EEI SIF criteria. 4. ***Was a direct control present?*** No, the worker was not wearing energy-specific PPE and no physical guards were present. **<u>Conclusion</u>**: HSIF

<u>Case H</u>: An employee was descending a staircase and when stepping down from the last step she rolled her ankle on an extension cord on the floor. She suffered a torn ligament and a broken ankle that resulted in persistent pain for more than a year.
<u>Interpretation</u>: 1. ***Was high-energy present?*** No, being on the last step of a staircase does not exceed the height thresholds or the 500 ft-lbs of gravity energy or the 4-ft high energy icon. 2. ***Was there a high-energy incident?*** No, high energy was not present. 3. ***Was a serious injury sustained?*** Yes, a torn ligament and broken ankle meet the EEI SIF criteria. 4. ***Was a direct control present?*** N/A **<u>Conclusion</u>**: LSIF

<u>Case I</u>: A crew was working near a sedimentation pond on a rainy day. The boom of the trac-hoe was within 3 feet of a live 12kV line running across the road. No contact was made because a worker intervened and communicated with the operator.
<u>Interpretation</u>: 1. ***Was high-energy present?*** Yes, the 12kV line far exceeds the 50V energy threshold. 2. ***Was there a high-energy incident?*** No, the worker intervened before the energy changed state or was transferred. 3. ***Was a serious injury sustained?*** No. 4. ***Was a direct control present?*** No, there were no controls present to prevent contact between the track hoe and the 12kV line. **<u>Conclusion</u>**: Exposure

<u>Case J</u>: A crew was working in a busy street to repair a cable fault. During the work, the journeyman took a step back from the truck outside of the protected work zone into oncoming traffic. A driver slammed on his brakes and stopped within on foot of the journeyman. No injuries were sustained.

<u>Interpretation</u>:

1. ***Was high-energy present?*** Yes, traveling vehicles adjacent to workers on foot far exceeds the 500 ft-lb threshold in the motion energy chart.
2. ***Was there a high-energy incident?*** Yes, the energy source was within 6 ft of the worker before it was controlled.
3. ***Was a serious injury sustained?*** No, an incident did not occur.
4. ***Was a direct control present?*** No, the worker was outside the protected work zone.

<u>Conclusion</u>: PSIF

APPENDIX 6 – REFERENCES

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