SAFETY CLAS & LEARNIN

Defining & Class Serious Injurie

By Matthew R. Hallowell and Carren Spencer

IN THE SAFETY PROFESSION, nothing is more important than preventing serious injuries and fatalities (SIFs). Despite widespread efforts, however, SIFs continue to plague every major industry. In 2021 alone, 5,190 fatal injuries occurred in U.S. workplaces (BLS, 2022), resulting in $6 billion of direct costs and immeasurable harm to the well-being of the workforce and their families (NSC, n.d.). Although safety professionals have made great strides in the prevention of recordable injuries, the rate of SIFs has generally plateaued and even increased in recent years (BLS, 2022). For example, as observed in Figure 1 (p. 20), the rate of OSHA-recordable injuries declined in the electric utility sector by approximately 50% over the past decade while the rate of fatal injuries has remained relatively stable. When examining 3.2 trillion worker hours of data across industrial sectors, Hallowell et al. (2021) found a similar statistical disconnect. These trends provide compelling evidence that reductions in lower-severity injuries do not translate to proportional reductions in SIFs, which directly contradicts antiquated theories stemming from the unfortunately ubiquitous Heinrich pyramid (Heinrich, 1931). Therefore, targeted methods are needed for SIF-specific learning and prevention.

KEY TAKEAWAYS

- **Understanding how to prevent serious injuries and fatalities (SIFs) is a priority for the safety profession. Potential SIF (PSIF) events may be used to significantly broaden learning. However, an experiment revealed that current methods of defining PSIF events result in so much inconsistency in classification (noise) that they have limited utility.**
- **To address this core limitation, the safety classification and learning (SCL) model was created by an integrated team of academic and industry professionals. This model is based on the science of energy-based safety, controls analysis and principles of human performance.**
- **A community of practice was created to facilitate implementation and diffusion of the SCL model via calibration, revision, data sharing, sector-level trending and advocacy.**

SIFs are paradoxical for organizational learning. Although SIFs are extraordinarily important, they are exceedingly rare and randomly distributed over time and space (Hallowell et al., 2021). Consequently, safety professionals observe a "whack a mole" approach to learning from SIFs whereby organizations rightfully deploy significant resources to deeply investigate the few cases that occur. The findings are then aggregated using common cause analyses and conclusions are presented as if they characterize underlying patterns. Unfortunately, it is difficult to apply robust statistics to reveal meaningful trends from the few fatalities that occur within individual companies. Although many companies may attempt to leverage the information available, the lack of sufficient data means that no single company has enough SIF data to effectively trend, learn from and eliminate fatalities on its own.

Progress toward eliminating SIFs requires increasing the number of learning opportunities and community-level data sharing that transcends traditional company boundaries. To expand relevant learning opportunities, many organizations have begun to explore potential SIF (PSIF) events. If companies adopt a common method of defining and classifying PSIF events and share data within their respective communities, safety professionals could transition from the fragmented and isolated analysis of a handful of SIF events to an integrated method of learning from thousands of SIF and PSIF events.

In pursuit of this vision, the Edison Electric Institute (EEI), the association that represents all U.S. investor-owned electric companies, formed a team of academic researchers and industry safety professionals to create a robust scientific method of defining and classifying PSIFs and other high-potential learning opportunities, and to initiate and maintain a community of practice where EEI members may collaborate to learn and respond to salient trends.

Background

The goal of this study was to create definitions. Although seemingly banal, common definitions are the

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foundation of learning because a common understanding of a topic influences how people communicate and what is perceived as relevant (Vincent, 2022). Precise definitions afford the ability to classify observations consistently and reliably, which facilitates communication, hypothesis testing, trending and innovation. Without shared definitions, there can be no reliable measurement or trending and, consequently, no scientific advancement.

When a new phenomenon is observed or conceived, its associated definitions tend to mature over time. The process begins with the subjective interpretation of an observer (i.e., "you know it when you see it"). Then, as a phenomenon is observed more broadly, extensional definitions emerge that explain a term by specifying every observed element (i.e., a list-based approach). Finally, once conceptual meaning is assigned to a phenomenon, intensional definitions are created, taking the form of a set of precise rules that can be empirically examined (i.e., a rule-based approach). Intensional definitions are preferable because they enable consistent and robust classification.

A case example is the evolution of the term "planet." The term was first coined by the ancient Greeks to describe a celestial object that appeared to move independently from fixed stars (NASA, n.d.). During the 17th century, an extensional definition formed as a comprehensive list of all observed planets. It wasn't until 2006 that the International Astronomical Union (IAU, 2006) created an intensional definition. Now, a planet is precisely defined as a celestial body that 1) is in orbit around the Sun, 2) is massive enough that it takes a nearly round shape, and 3) has cleared the neighborhood around its orbit. Using this rule-based definition, any newly observed celestial object may be consistently classified, and the findings can be unambiguously shared with the scientific community.

In the case of PSIFs, definitions have recently matured from personal interpretation (i.e., "you know it when you see it") to extensional definitions (i.e., lists of hazardous situations that commonly cause a SIF). These extensional definitions still lead to inconsistent classifications and incoherent communication. Therefore, an intensional definition of PSIF is needed to accelerate learning.

Existing Methods of Assessing PSIFs

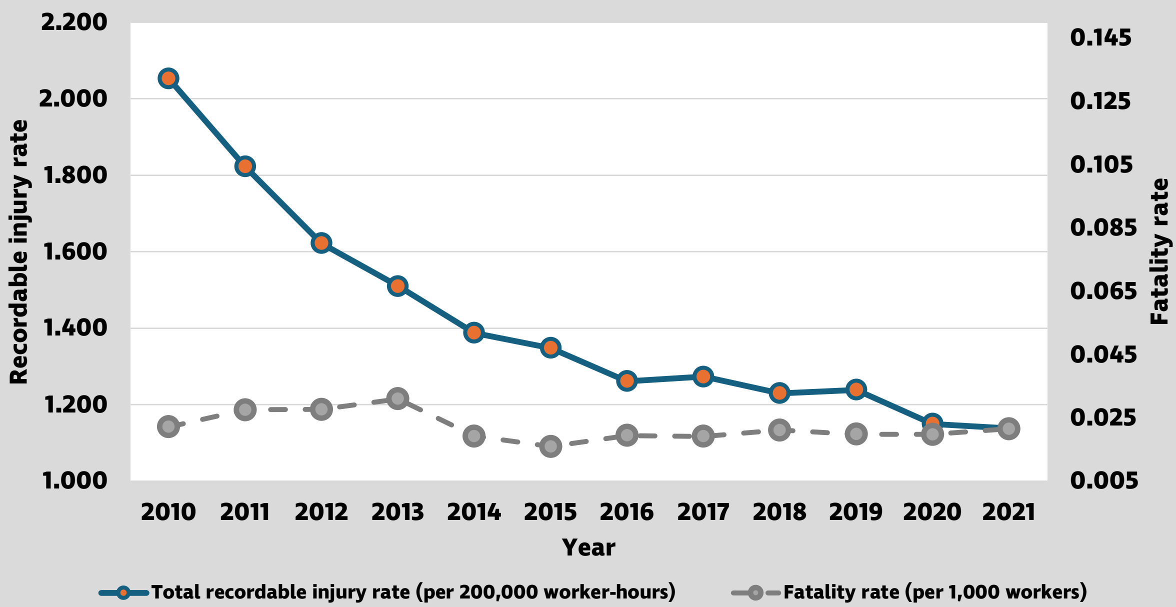
The concept of PSIFs is hardly new. Blog posts and white papers have been published about PSIFs for more than a decade. Although authors of these publications made the case that PSIF events should be studied to expand learning, they did not offer a definition of the term (e.g., Horan, 2017). To find a more precise definition, the authors of this study turned to peer-reviewed literature. Unfortunately, a thorough search of the Web of Science, Scopus and Google Scholar revealed no peer-reviewed studies that provide a definition of PSIF. Instead, the authors' review revealed that most mature methods of assessing PSIFs are extensional (i.e., list-based) definitions in reports published by the Campbell Institute (2018) and DEKRA (2019). These resources present PSIF classification schemes that involve a list of SIF exposures such as:

1) confined space
2) lockout/tagout
3) work at height
4) fall greater than 48 in.
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

FIGURE 1

POWER GENERATION & DELIVERY INJURY & FATALITY TRENDS

Injury and fatality trends for electric power generation and delivery (rolling 3-year average).



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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 or 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

These list-based definitions advance understanding of PSIFs because they provide tangible examples that practitioners can use to begin to calibrate. Unfortunately, some serious limitations remain. They do not help identify when an incident or observation *is not* a PSIF. For example, with a desired conclusion, any incident or condition could be classified as a PSIF by citing items 19, 20 or 21 from the preceding list. In other words, if an analyst believes that a case is a PSIF, there are no rules to suggest otherwise. This increases the potential for overinclusion, which waters down SIF-specific learning.

Honoring the important progress made by others, the authors' goal was to mature a PSIF definition by introducing an intensional (rule-based) definition that gives meaning via the science of energy-based safety, controls analysis and principles of human performance.

Study Protocol

To create and test a new method of PSIF definition and classification, EEI convened a team of 20 professionals, a technical advisor and a program manager. The professional members of the team were senior safety leaders representing electric companies in North America. To execute the study, the team met in person for 1 day each month for 6 months. Figure 2 provides a high-level summary of the model development process.

The process began with an inventory of existing methods of PSIF classification used by the members of the team. Each team member described the methods used by their company. Most team members (80%) made decisions based on the experience and judgment of their internal safety team. Although approximately 20% of the team used the existing reference tools, they all made organization-specific adaptations such as adding, removing or editing categories from the lists. Therefore, no two organizations on the team used the same method to classify PSIF events.

To examine the variability in PSIF assessment, the authors conducted an experiment on 14 recent incident cases submitted by the team members using the methods suggested by Kahneman et al. (2021). In the experiment, the authors asked the team members to independently review each case and draw a conclusion (PSIF or not a PSIF) using their preferred method of classification. Surprisingly, the average level of agreement was only 64%, where 50% represents perfect disagreement (i.e., a 50/50 split). This small experiment exposed the magnitude of the PSIF classification problem and subsequent discussions revealed the root causes of the variability.

After the cases were independently reviewed and classified, the team discussed and debated their conclusions.

These discussions revealed two key philosophical differences. The first related to assessing the worst possible outcome versus the most likely outcome. That is, while some focused on whether the event could have *possibly* caused a SIF, others judged whether the condition was *likely* to cause a SIF. Although seemingly inconsequential, the difference in these perspectives had a significant impact on the results. The team reconciled these perspectives, concluding that we should not be asking the question "does this incident have SIF potential?" because every hazard has the remote possibility of causing a SIF. Instead, we should ask, "Is the *most likely* outcome of this event a SIF?" The second major philosophical difference related to controls. Although some team members focused only on the seriousness of the hazard involved, others considered the presence and adequacy of relevant controls. After the discussions, the team concluded that cases where an adequate control was present were fundamentally different from those with an inadequate level of control. The team agreed that a new model must address, reflect and operationalize these positions.

Model Creation & Refinement

The model was designed based on guiding principles. Specifically, the team agreed that a new model of PSIF classification must:

- align with the team's collective philosophies and principles,
- establish when an event is and is not a PSIF,
- involve objective assessment based on scientific knowledge,
- yield consistent classification results regardless of employer, experience or background,
- include an assessment of controls, and
- result in clear and crisp operational definitions of SIF, PSIF, and other event or observation types.

Based upon these principles, a first draft of the new model was created by the technical advisor. The draft model was then tested by analyzing actual cases and refined over an iterative process. To enhance the robustness of the model, the team members were asked to bring the cases that they found most challenging. During the testing procedure, every decision criterion was carefully revised to remove ambiguity and potential subjectivity. To ensure that the model would be broadly useful, all decisions related to the model structure and definitions were made by consensus. In each iteration of the model, the team members individually reviewed and classified 10 cases. The level of agreement was computed for the round and cases with high levels of disagreement were discussed. After four rounds of review (i.e., 40 test cases), the model yielded greater than 95% agreement. The final model, named the safety classification and learning (SCL) model, is shown in Figure 3 (p. 22).

Using the SCL Model

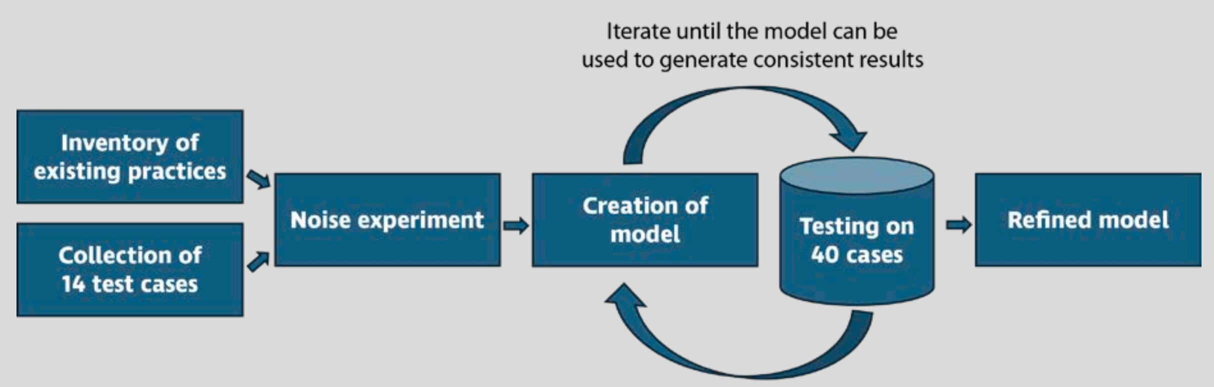
This SCL model is based on four questions. The answers to these questions can be complex and hotly debated without clear and compelling rules. Thus, detailed guidance was created for each question.

Question 1: Was High Energy Present?

The team decided that a hazardous condition is serious when the *most likely* outcome associated with the hazard is a SIF. To assist with objective assessments, the authors leveraged knowledge from energy-based safety. In an experiment based on empirical data, Hallowell et al. (2017) found that the magnitude of physical energy predicts the most likely severity of an incident. Specifically, incidents with energy greater than 500 joules are most likely to cause a medical case or more severe injury, and incidents with energy greater than 1,500 joules are most likely to be fatal. To be conservative and to conform to imperial units used by most of the team members, the high-energy threshold was set as 500 ft-lb (slightly less than 500 joules). Consequently, the term "high-energy" in the SCL model refers to a condition where a SIF is the most likely outcome because the physical energy exceeds 500 ft-lb.

Because energy assessment can be challenging, two resources were developed. First, the authors created an energy calculator application that enables precise

FIGURE 2
MODEL CREATION & TESTING PROCESS



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computations of energy magnitude based on reasonably estimated parameters such as height, weight, speed and voltage. Second, to make energy assessment more feasible in the field, the authors also created a set of icons that correspond to the different hazardous conditions where the energy magnitude almost always exceeds the 500-ft-lb threshold (see Table 1). Although these icons are generally objective, they are not all-inclusive and actual energy computations should be made for the most precise assessments.

Question 2: Was There a High-Energy Incident?

Given that at least one high-energy hazard exists, the next question is whether 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 this definition:

> 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 graphically described in Figure 4 (p. 24).

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 their balance and stumbles. The energy release is always related to an instance where the energy is no longer contained or in the control of the worker. Finally, the worker must either 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. "Proximity" is defined as a hazardous circumstance where the boundary of the high-energy exposure is 1) within 6 ft of the worker; 2) within a confined space; or 3) within a situation where a worker cannot escape the energy source (restricted egress). These definitions should be interpreted exactly as worded to ensure consistent classification.

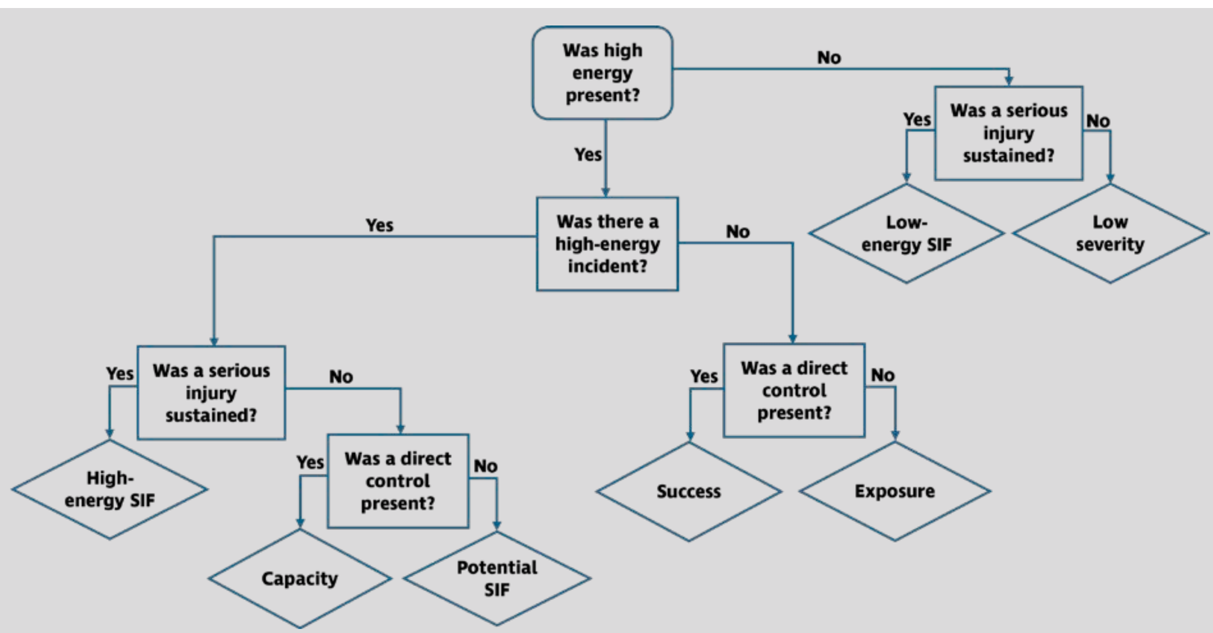
Question 3: Was a Serious Injury Sustained?

When determining whether an injury is serious, the team deferred to the EEI (n.d.) SIF criteria maintained by the EEI Recordkeeping Task Force. EEI maintains a definition of serious injury based on a list of injuries and illnesses that are considered serious. Since there is no single definition of serious injury that transcends all industrial sectors, future research is recommended.

Question 4: Was a Direct Control Present?

A core principle in the SCL model is that the primary differentiator between safety success and failure is the presence or absence of direct controls. The team carefully defined a direct control as one that 1) is specifically targeted to the high-energy source; 2) effectively mitigates exposure to the high-energy source when installed, verified and used properly (i.e., a SIF should not reasonably occur if these conditions are present); and 3) is effective even if there is unintentional human error during the work (unrelated to the installation of the control). The first two criteria relate to energy control theory

FIGURE 3
SAFETY CLASSIFICATION & LEARNING (SCL)



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while the third criterion was included to align with principles of human performance (Conklin, 2019). Since human error is normal and inevitable, controls must be effective even when people make mistakes (Reason, 1990).

Examples of direct controls that typically correspond to this definition include physical lockout/tagout, machine guarding, hard physical barriers, fall protection and rubber 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 nonspecialized PPE such as hard hats, gloves and boots are not direct controls because they are not specifically targeted to a high-energy source. Although many of these safety practices are extremely important, they are not considered sufficient as the only protection against life-threatening hazards. By contrast, some specialized PPE such as rated rubber gloves and sleeves, arc-flash suits or a properly rated respirator do meet the definition of a direct control.

Direct controls can be either absolute or mitigating. Absolute controls eliminate high-energy exposure when installed, verified and used properly, and include techniques such as de-energization, physical lockout/tagout or machine guarding. Mitigating controls reduce energy exposure to below the 500-ft-lb threshold, but do not eliminate all exposure to the energy, such as 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 crash.

Definitions of SCL Model Categories

The SCL model can yield one of seven possible outcomes. A definition and interpretation for each of these classifications are provided here. The definitions are consistent with the four SCL model questions.

•**High-energy SIF: Incident with a release of high energy where a serious injury is sustained.** These are high-priority events because a worker, their family, coworkers and the organization are all deeply affected. The organization must respond seriously to such events and seek to learn to prevent future failures. In almost every high-energy SIF event, a direct control was absent.

•**Low-energy SIF: Incident with a release of low energy where a serious injury is sustained.** Typically, low-energy SIF incidents are related to health and

TABLE 1
COMMON HIGH-ENERGY HAZARDS

Icon	Description
Gravity – Suspended load	Most suspended loads require specialty equipment to lift more than 500 lb of load higher than 1 ft off the ground. In such a case, the suspended load would exceed the high-energy threshold.
Gravity ≥ 4 ft – Fall from elevation	Considering the average weight of a human is more than 150 lb, 4 ft of elevation (measured from the ground surface to the bottom of the feet) exceeds the high-energy threshold.
Motion – Mobile equipment/ traffic with workers on foot	Because of the mass, most mobile equipment including motor vehicles exceeds the high-energy threshold when the equipment or vehicle is in motion at any speed. The energy exposure is taken from the point of view of the worker on foot and not the equipment operator or vehicle driver. (Note: For work zone traffic, an incident occurs only when a vehicle departs from the intended path of travel and is within 6 ft of an exposed employee, or if an employee enters the traffic pattern.)
Motion ≥ 30 mph – Motor vehicle incident (occupant)	Estimations 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 mph as the high-energy threshold. This energy exposure is taken from the point of view of the vehicle occupants, including the driver.
Mechanical – Heavy rotating equipment	Computing mechanical energy can be complex as it requires estimation of 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 should be considered high energy.
Temperature ≥ 150°F – High temperature	According to the American Burn Association (2023), exposure to any substance ≥150 °F typically causes third-degree burns when contacted for 2 seconds or more.
Temperature – Steam	According to the American Burn Association (2023), any circumstance with the release of steam exceeds the high-energy threshold.
Temperature – Fire with sustained fuel source	According to the North American Combustion Handbook (Reed, 1978), a lightly combustible material such as paper burns at approximately 700 °F, far exceeding the temperature threshold. Fire with a sustained source of fuel exceeds the high-energy threshold.
Pressure – Explosion	Most incidents described as an explosion exceed the high-energy threshold.
Pressure ≥ 5 ft – Excavation or trench	An exposure to unsupported soil in a trench or excavation more than 5 ft deep exceeds the high-energy threshold. Typically, for each foot of depth, soil pressure increases by about 40 lb per square foot. Thus, at a depth of 5ft, the pressure is approximately 200 lb per square foot.
Electrical ≥ 50 V – Electrical contact with source	Electricity ≥ 50 V is sufficient to result in serious injury or death according to NFPA 70E (2024). Note that this icon is conservative, as most medical literature indicates that a current of 1 A or greater has the likely potential to cause a SIF.
Electrical – Arc flash	Any arc flash exceeds the high-energy threshold because of the voltage exposure according to NFPA 70E (2024). Also, permissible distances are covered in 29 CFR 1910.333, in particular, section 1910.333(c)(3)(ii)(C).
Chemical/ radiation – High dose of toxic chemical or radiation	Exposure to toxic chemicals or radiation. An industrial hygienist, chemist, toxicologist, or other competent person should be involved in the assessment of toxicity and acceptable exposure limits. The following references should be used to judge acceptable exposure limits: • immediately dangerous to life or health (IDLH) values from NIOSH • exposures which reduce oxygen levels below 16% • corrosive chemical exposures (pH < 2 or > 12.5)

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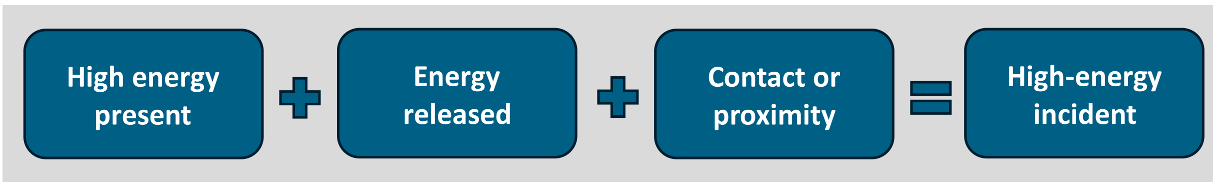
FIGURE 4
COMPONENTS OF HIGH-ENERGY INCIDENT DEFINITION



physiology. Unlike high-energy SIF events that mainly relate to engineering controls, low-energy SIF events 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. Low-energy SIFs are not less important than high-energy SIFs; they are simply different.

•**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 high-energy SIF events except for the SIF outcome. In other words, we were simply lucky that a SIF did not occur. These events are excellent learning opportunities because there was no serious outcome and 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.** Unlike PSIF cases, direct controls are present in capacity cases. Because a high-energy incident occurred in the presence of a direct control, capacity incidents are not inherently positive or negative. Rather, they represent excellent learning opportunities because they provide insight on what triggered the energy release and the opportunity to verify the resilience of their controls without negative consequences.

•**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 PSIFs and high-energy SIFs except that an incident has yet to occur. Thus, learning can occur from exposure events before a negative incident occurs. Observations of conditions can also be made regularly, resulting in a higher volume of learning opportunities.

•**Success: Condition where a high-energy incident does not occur because of the presence of a direct control.** The SCL model creates an operational definition of success as it applies to SIFs. Here, success is distinguished from all other observations by the presence of direct controls. As with exposure cases, success cases are conditions that may be regularly observed. Therefore, they can be studied in high volume.

•**Low severity: These low-priority situations did not result in or are unlikely to result in a SIF.** Although they should not be ignored, they have minimal relevance for SIF prevention.

Example Cases

To assist the reader with interpreting and applying the SCL model, three example cases are provided. More cases are available from EEI (n.d.).

Case 1

An employee was on the top of a de-energized transformer at 25 ft of height with a proper fall arrest system. While working, she tripped on a lifting lug and fell from the unguarded edge. She was caught by the fall arrest system, which functioned as designed. The employee sprained a wrist in the fall, which was treated on site by a medical professional.

Classification decisions:

1) *Was high-energy present?* Yes, the worker was at 25 ft of height, which exceeds 4-ft threshold (see Table 1 icon, p. 23).

2) *Was there a high-energy incident?* Yes, the worker tripped and fell.

3) *Was a serious injury sustained?* No, a sprained wrist is not considered serious per the EEI SIF criteria.

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

Case 2

An employee was working alone and placed an extension ladder against the wall. When he reached 10 ft 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 3 days.

Classification decisions:

1) *Was high-energy present?* Yes, the worker was at 10 ft of height, which exceeds the 4-ft threshold (see Table 1 icon, p. 23).

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 3

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 ft of the jack.

Classification decisions:

1) *Was high-energy present?* Yes, the 7-ton door far exceeds the 500-ft-lb threshold for gravity per energy calculations.

2) *Was there a high-energy incident?* No, the observer intervened before the energy was released.

3) *Was a serious injury sustained?* No.

4) *Was a direct control present?* No, the jack was not installed and used properly.

Conclusion: Exposure

Community of Practice

The author's team was motivated to create the SCL model to 1) improve consistency in the assessment of PSIF and other high-value learning opportunities and 2) create a mechanism by which the EEI community could share and learn from relevant data. The authors perceived the risk that without some form of moderation, companies would begin to customize and adapt the SCL model to align with their individual company philosophies. Such alterations would erode the ability to share and collaborate across organizational boundaries. Thus, EEI created a community of practice (COP) to assist with training, calibration, revision, data sharing and trending.

The SCL model's rate of implementation and the attendance and participation in the COP was surprisingly high. Monthly COP meetings for the first 2 years averaged more than 50 attendees who represented most of the U.S. electric power generation and delivery sector. In the meetings, the COP group reviewed challenging incidents to arrive at a group consensus, developed implementation resources, and discussed and voted on proposed changes to the model. After 2 years of implementation, no major changes were made to the model beyond a few minor clarifications and the addition of external references for toxic chemical exposure analysis. This stability is a testament to the robustness of the SCL model and the veracity of the underlying decision framework.

The adoption of the model has been remarkable. A survey of the EEI membership at the end of 2022 revealed that more than 70% of responding companies (n = 32) began integrating the SCL model and 20% planned to use the model in 2023. More than 14,000 SCL model cases have been submitted to the EEI repository and a live dashboard has been created so that the COP members may inspect and interrogate the data.

Lessons Learned From Implementation

The COP group convened to document lessons learned from 2 years of implementation. These findings are based on general trends but do not represent a complete consensus of experience. Five key lessons are shared because they may be helpful to an organization considering or beginning to use the SCL model.

1) Follow the SCL model exactly and answer all questions before reaching a decision. One of the most common sources of confusion and misclassification occurs when questions are skipped or assumptions are made instead of collecting all the evidence. All four primary questions (and their subquestions) should be answered carefully and completely before a classification is made.

2) Avoid what-if scenarios when classifying. When beginning to use the SCL model, analysts tend to consider how changes in hazard circumstances and proximity would change the classification of the event. Although interesting, what-if scenarios should not be considered in the formal classification of the event or observation. Instead, the analyst should consider only the facts and avoid fabrications.

3) The SCL model should be used for learning, not for the creation of new metrics. There is often an initial desire to create metrics from the SCL model. For example, some organizations have considered measuring a PSIF rate. Unfortunately, such a metric is problematic for two reasons. First, PSIF rates are not unidirectional. That is, a high PSIF rate could equally be the result of poor safety performance or the presence of a strong reporting culture, and a low PSIF rate could be the result of strong performance or underreporting. Second, if PSIF rates are tracked and directly or indirectly incentivized, learning may be severely compromised.

4) Provide strong training and the opportunity to calibrate. Effective use of the SCL model requires both training and practice. Specifically, analysts should be trained on how to estimate energy magnitude and assess direct controls. The authors have found that learning is accelerated and performance improves when challenging cases are reviewed as a group with a knowledgeable facilitator. Several companies saw value in having both widespread training across the safety team and deeper expertise for a smaller group of internal subject matter experts.

5) Develop a reporting and learning process that aligns with the SCL categories. SCL model questions can be added into the reporting logic in most safety management systems. Specifically, logic associated with the four yes/no questions can be programmed to automatically classify incidents. Further, since the SCL model is designed to support learning, organizations may wish to develop a learning response program that aligns with the SCL categories. For example, full learning teams may be deployed for high-energy SIF, low-energy SIF, and PSIF events and lower levels of investigation may be deployed in higher volume for success and exposure observations. Although many EEI companies are aligning their systems accordingly, remember that some impactful events such as high-energy SIF events may be relatively weak learning opportunities while success and exposures may provide rich opportunities. Therefore, companies should maintain a degree of flexibility to optimize learning.

Learning from SIFs is challenging because they are so rare that it is virtually impossible for one company to uncover meaningful trends alone. Thus, the safety profession must expand learning opportunities and create mechanisms to share data across traditional organizational boundaries.

Conclusion

Many safety professionals share the same vision: elimination of SIFs. Unfortunately, despite significant efforts, SIF rates have plateaued or even increased over the past decade. Learning from SIFs is challenging because they are so rare that it is virtually impossible for one company to uncover meaningful trends alone. Thus, the safety profession must expand learning opportunities and create mechanisms to share data across traditional organizational boundaries. To this end, a team of safety leaders and academic researchers was convened by EEI to define PSIF in the context of other high-potential learning opportunities. The result was a classification model and a corresponding set of intensional (objective and rule-based) definitions.

The SCL model incorporates elements from energy-based safety, controls assessment and human performance. As compared to existing list-based definitions of PSIF, the model enables objective, consistent and reliable classification of incidents and observations. The model's structure also facilitates robust data sharing and trending.

Since the inception of the SCL model, EEI has created a COP where cases are reviewed, revisions to the model are considered, and data are shared and analyzed for the greater good. More than 14,000 SCL model cases have been submitted and are being analyzed. The work has garnered attention from external stakeholders. For example, the Interstate Natural Gas Association of America Foundation (INGAA Foundation, 2021) includes the model in its *Guidance for Serious Injury and Fatality Prevention* report, the American Gas Association has hosted workshops, and the California Public Utility Commission (CPUC, 2022) now mandates PSIF reporting and explicitly cites the SCL model as an acceptable option.

Every model has flaws, and the SCL model is certainly no exception. Therefore, the EEI COP will continue to revisit and revise the model as new knowledge and creative ideas emerge. The authors present the model after 2 years of implementation in hopes that it will reach a broader audience and transcend industrial sectors and geographies. If the learning community expands, so will the chances of eventually eliminating SIFs from workplaces. **PSJ**

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References

American Burn Association. (2023). Scald injury prevention educator's guide. https://bit.ly/48PjM8E

California Public Utilities Commission (CPUC). (2022). Safety performance metric reports. https://bit.ly/3Sy9DaT

Campbell Institute. (2018, Nov. 14). Serious injury and fatality prevention: Perspectives and practices. National Safety Council. https://bit.ly/3HwuTXV

Conklin, T.E. (2019) *The 5 principles of human performance: A contemporary update of the building blocks of Human Performance for the new view of safety.* PreAccident Media.

DEKRA. (2019). Determining serious injury and fatality potential [White paper]. https://bit.ly/3vLtbPX

Edison Electric Institute (EEI). (n.d.). Issues and policies: The power to prevent serious injuries and fatalities. https://bit.ly/3SgtpGi

Hallowell, M.R., Alexander, D. & Gambatese, J.A. (2017). Energy-based safety risk assessment: Does magnitude and intensity of energy predict injury severity? *Construction Management and Economics, 35*(1-2), 1-14. https://doi.org/10.1080/01446193.2016.1274418

Hallowell, M., Quashne, M., Salas, R., Jones, M., MacLean, B. & Quinn, E. (2021, April). The statistical invalidity of TRIR as a measure of safety performance. *Professional Safety, 66*(4), 28-34.

Hallowell, M. (2023). Safety classification and learning (SCL) model (White paper). Edison Electric Institute. https://bit.ly/3mFRw5C

Heinrich, H.W. (1931). *Industrial accident prevention: A scientific approach*. McGraw-Hill.

Horan, R.J., Jr. (2017). Learning from potential serious injuries and fatalities. *Incident Prevention*. https://bit.ly/3ue9Kib

International Astronomical Union (IAU). (2006). Resolution B5: Definition of a planet in the solar system. https://bit.ly/42bsDyO

Interstate Natural Gas Association of America Foundation (INGAA Foundation). (2021). Guidance on serious injury and fatality prevention. https://bit.ly/3SxR31p

Kahneman, D., Sibony, O. & Sunstein, C.R. (2021). *Noise: A flaw in human judgment.* William Collins.

National Aeronautics and Space Administration (NASA). (n.d.). What is a planet? https://solarsystem.nasa.gov/planets/in-depth

National Fire Protection Association (NFPA). (2024). Standard for electrical safety in the workplace (NFPA 70E). https://bit.ly/3SuRMBy

NIOSH. (2019, Oct. 8). Immediately dangerous to life or health (IDLH) values. www.cdc.gov/niosh/idlh/intridl4.html

National Safety Council (NSC). (n.d.). All injuries. https://injuryfacts.nsc.org/all-injuries/overview

Reason, J. (1990). *Human error.* Cambridge University Press.

Reed, R.J. (1978). *North American combustion handbook: A basic reference on the art and science of industrial heating with gaseous and liquid fuels.* North American Manufacturing.

U.S. Bureau of Labor Statistics (BLS). (2022, Dec. 16). Census of fatal occupational injuries news release. www.bls.gov/news.release/archives/cfoi_12162022.htm

Vincent, J. (2022). *Beyond measure: The hidden history of measurement.* W.W. Norton.

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