WORK TO ZERO

Safety Technology 2020:

Mapping Technology Solutions for Reducing Serious Injuries and Fatalities in the Workplace

Executive Summary

The goal of the Work to Zero initiative at the National Safety Council (NSC) is to eliminate workplace fatalities through the use of technology. Based on existing data, expert insight and feedback from environmental, health and safety (EHS) professionals, NSC identified the top eighteen hazardous workplace situations (e.g., work at height, confined space entry, machinery operation) and associated situational risks (e.g., falls, struck by, arc flash) that account for the greatest amount of workplace fatalities across different industries, job types and worker activities.

Next, NSC identified the systemic contributing factors (e.g., lack of training, fatigue, poor equipment design) that sometimes exacerbate risk within those same hazardous situations. NSC also identified a list of over one hundred relevant EHS technologies that could help mitigate both the situational and systemic risks and mapped these technologies to the risks in ways that the surveyed EHS professionals perceived to be most effective.

The top hazardous situations were work at height, workplace violence, and repair and maintenance tasks. The most used safety technologies were robotics (e.g., drones), sensors/detectors (e.g., radio–frequency ID sensors) and software (e.g., control of work software). EHS technology adoption criteria and barriers are also discussed. Future Work to Zero studies will examine the effectiveness of specific EHS technologies at reducing serious injury and fatality risk exposure and develop best practices for new technology adoption and implementation for reducing workplace fatalities.

Introduction and Background

The United States used to be a very dangerous place to work. By some measures, the U.S. remains a dangerous place to work, despite some concerted efforts to address workplace fatalities (e.g., Hofmann, Burke, & Zohar, 2017). The first systematic review of workplace fatalities in the U.S. took place in Allegheny County, PA when Crystal Eastman observed the number of fatalities of steelworkers for one year from July 1906 to June 1907 (Eastman, 1910). During that timeframe, Eastman recorded 526 workplace fatalities in that county. One hundred ninety–five of those deaths were steelworkers. By contrast, two ferrous metal foundries workers died on the job in 2017 across the entire country (Bureau of Labor Statistics, 2018). Other industries experienced similar drastic reductions in fatalities as well. For example, approximately 19,000 people died from work-related injuries in 1928 compared with 5,147 deaths in 2017, an almost 73% decrease in workplace deaths over a 90 year period (Bureau of Labor Statistics, 2018; Center for Disease Control and Prevention, 1999; Corn, 1992).

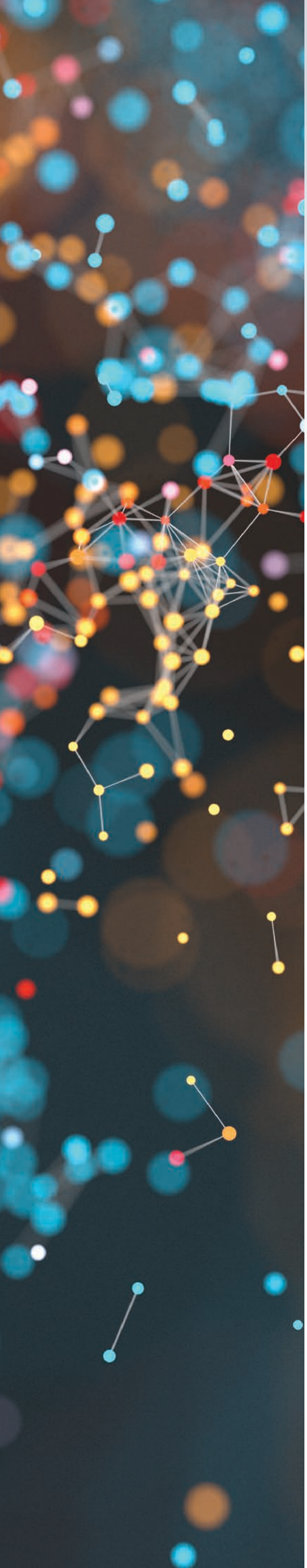
To many, this decline in workplace fatalities over the past century is evidence of progress in worker safety. Indeed, many efforts over the years have contributed to a safer work environment including workers' compensation protection laws, the establishment of worker safety oversight through several government agencies, focus on safety controls and safety training, and more recent attempts to promote and establish workplace safety culture within organizations (e.g., Hofmann et al., 2017). A closer look at recent workplace injury and fatality trends, however, depicts a slightly different story.

Over the past 25 years, the OSHA recordable injury rate dropped from 8.9 injuries per 100 workers to 2.8 injuries per 100 workers, a 67% decrease (National Safety Council, 2018). In the same time span, the workplace fatality rate (preventable fatalities) only dropped 26%, with 4,414 preventable fatalities occurring in the workplace in 2017 (Bureau of Labor Statistics, 2018). The stagnant trend in workplace fatalities (and even slight increase in fatalities over the past 10 years), especially compared to the steady decrease in workplace injuries, is cause for concern for many environmental, health and safety (EHS) professionals (Ivensky, 2016; Martin & Black, 2015). Efforts to reduce workplace injuries do not seem to have the same impact on reducing workplace fatalities.

Part of the explanation for the different trends in workplace injuries versus fatalities is that not all injuries and fatalities are created equal. Heinrich's Safety Triangle theory suggested that for every major injury in the workplace there are 29 minor injuries and 300 non–injury incidents, or unplanned events that did not result in injury, illness or damage but had the potential to do so (e.g., near miss) (Campbell Institute, 2018; Heinrich, 1959; National Safety Council, 2013). If organizations focus on preventing the non–injury incidents, then the minor and major injuries will decrease as well. Not all non–injury incidents, however, have the potential to become serious injuries or fatalities. By focusing prevention efforts on reducing all non–injury incidents, organizations could be misidentifying the root causes of and contextual factors that could lead to serious injuries and fatalities.

Therefore, a recent trend in EHS practices is to identify the non-injury incidents and near misses that have the potential to become serious injuries or fatalities depending on changes in contextual factors (Campbell Institute, 2018; Krause & Bell, 2015). Sometimes these contextual factors are simple, like performing a job at height versus on the ground. For example, a maintenance worker who trips and falls carrying a heavy piece of equipment might experience a first aid injury if they are at grade level. However, the same incident occurring at height has the potential to result in a much more serious and potentially life–altering injury if proper controls are not in place (e.g., fall arrest systems and proper guarding). A number of similar contextual factors can increase the potential severity of any injury including confined space entry, lockout tagout (control of hazardous energy), vehicle collision and working with machine guards/barricades. By focusing on reducing incidents and near misses with serious injury or fatality (SIF) potential, organizations are more likely to prevent serious injuries from occurring in the future.

One difficulty in mitigating risks associated with potential serious injury and fatality (PSIF) events is that the risks associated with PSIFs are often difficult to eliminate and it is difficult to substitute an alternative for a worker doing a hazardous job (Conklin, 2017; Loud, 2016). For example, many jobs across several industries rely on employees working off the ground.



The same job done on the ground versus off the ground drastically changes its potential for becoming a serious injury or fatality (e.g., Hallowell, Bhandari, & Alruqi, 2019). However, many safety interventions for mitigating risks with working at height typically involve personal protective equipment (PPE) or administrative controls (training, etc.). In an ideal setting, the most effective way to mitigate risks associated with working at height would be to eliminate the need to perform the task in the first place or substitute out the human doing the work, especially difficult tasks for particular industries (e.g., electric utilities linemen).

One solution that some organizations are turning to is leveraging technology that can address some of the risks and hazards that are particularly relevant for fatality prevention. For example, in a recent National Safety Council membership survey, 100% of participants indicated a strong interest in knowing more about new safety technology and how to implement the technology within their workplaces. In addition, safety leaders within the Campbell Institute at the National Safety Council continue to demonstrate interest in assessing and evaluating technologies – such as augmented and virtual reality, sensors and wearables, drones and robotics, machine learning and analytics. Although many companies adopt new technologies to reduce costs and boost productivity, several organizations want to see validation of new tools that can reduce risk and achieve improved outcomes, enabling organizations to get to zero preventable deaths in the workplace.

On both ends of the spectrum, from small businesses to Fortune 500 companies, employers continue to seek an increased understanding on how new technology can improve workplace safety. As a result, the National Safety Council launched its Work to Zero initiative with a mission to eliminate death in the workplace through technology. Aligned with the Council's overall vision to eliminate preventable deaths in our lifetime, Work to Zero focuses on using research, data and practical insight to better understand the most effective and feasible technological innovations in safety and getting this information in the hands of employers, small and large, to reduce life–altering incidents and fatalities in the workplace.

An initial challenge in thinking about using technology to prevent workplace fatalities is deciding what kind of technology is most effective. Technology options have grown exponentially in today's Industry 4.0 market where advances in connecting people through internet of things (IoT) platforms makes it possible to measure and analyze real–time behavior with much more precision than could be done 10 years ago (e.g., Karakhan & Alsaffar, 2019). Organizations looking for new technology solutions, however, can fall into the trap of "shiny object syndrome" where people are persuaded that the latest and greatest technology is what is best and most effective. This is not necessarily the case. Indeed, there are many potential barriers to technology implementation and adoption, especially from a safety perspective, that need to be considered prior to implementing a new piece of technology.

Research Approach

The methodology for this study involved a two–pronged approach to SIF prevention by identifying:

1) Workplace situations, or contextual factors, with the greatest potential for serious injuries and fatalities to occur

2) Relevant technologies for reducing risks within each of these hazardous workplace situations

Data for this paper came from four major sources of information: the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (CFOI), qualitative phone interviews with 32 EHS professionals from large corporations, expert EHS technology opinion from Verdantix researchers (Verdantix, 2019) and an online survey of 113 EHS professionals from varying sizes and maturity levels of different organizations and industries. NSC used the BLS and qualitative interview data to create the hazardous situation categories along with their associated situational and systemic risks. Verdantix provided information on more than 100 relevant EHS technologies and their associated risk mitigation potential. NSC then used the online survey to gauge the perceived relevance of each situational and systemic risk to each hazardous situation and to estimate the perceived effectiveness of the different technologies at mitigating risk for each hazardous situation.

Therefore, NSC incorporated existing data, observational data, interview data and survey data to create and validate the framework for mapping technological solutions to the top risks with potential for SIF. The goal with this initial white paper is to provide a starting point for EHS professionals who are either looking to advance their innovation strategy or simply get their foot in the door when it comes to using technology to prevent serious injuries and fatalities.

Top Hazardous Workplace Situations

NSC definition of hazardous situation:

any situation where work is performed with the potential for a serious injury or fatality to occur

NSC used several methods to identify contextual factors, including the top hazardous workplace situations and associated contributing factors that lead to serious injuries and fatalities including existing BLS data, relevant literature on systemic risk factors (e.g., SIF precursors) and qualitative interviews with over 30 EHS professionals. The NSC definition of hazardous situation is any situation where work is performed with the potential for a serious injury or fatality to occur (e.g., working at height).

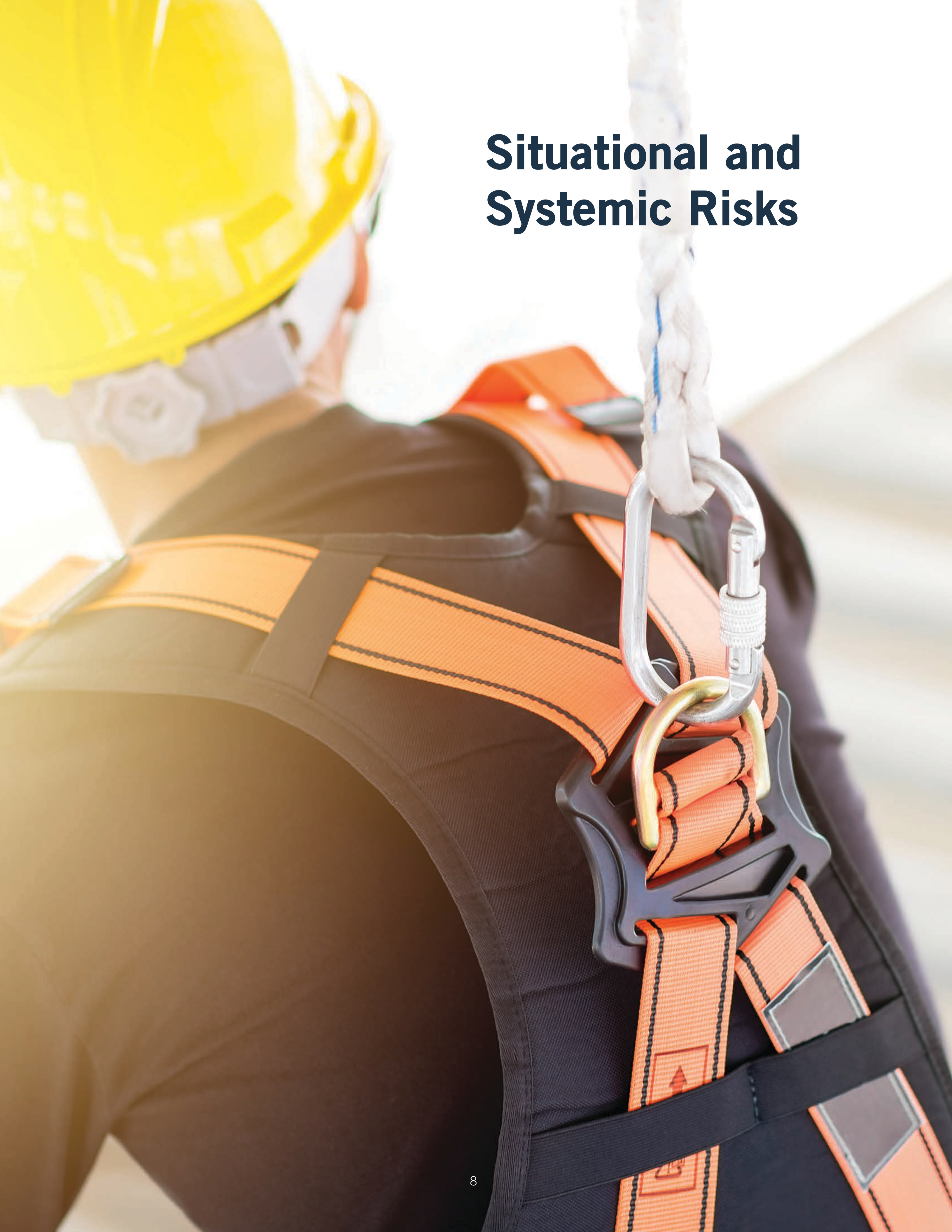
Within each hazardous situation, NSC identified both situational and systemic risks. Situational risks are the risks inherent to the situation or the proximate cause of injury (e.g., fall to a lower level, struck by an object, electrocution). Systemic risks are the risks that can contribute to injury in the hazardous situation but are not direct causes of injury (e.g., worker fatigue, lack of training, poor safety culture). Because workplace injuries do not occur in a vacuum, it was prudent to address both situational as well as systemic contributing factors. Indeed several technology solutions have potential to mitigate both kinds of risks, a point discussed later.

Data from the Census of Fatal Occupational Injuries (Bureau of Labor Statistics, 2018) provided a starting point for identifying the top hazardous situations as of 2017. NSC used a combination of BLS characteristic types (e.g., worker activity, event or exposure, and primary or secondary source) to account for the greatest number of non–transportation–related workplace fatalities. Because NSC has a robust coalition dedicated to eliminating death on the road (e.g., Road to Zero), NSC focused its efforts in this paper on eliminating workplace fatalities that are not the direct result of roadway injuries. As Work to Zero grows, NSC will identify areas of collaboration with groups interested in eliminating roadway deaths, such as Road to Zero. NSC contextualized workplace fatalities within hazardous situations rather than looking at fatalities by industry or by event or exposure, as is typically depicted in government statistical representations (e.g., Bureau of labor Statistics (BLS) data). By doing so, NSC was able to consider situations that apply across several different industries (e.g., working at height) and give the greatest likelihood of identifying the hazards/risks with the greatest potential for serious injuries and fatalities. As a starting point, NSC decided to retain situations that could account for at least one percent of non–transportation workplace fatalities, which left 18 hazardous situations **(see Table 1)**. Because NSC did not want to exclude any hazardous situations relevant to particular industries (e.g., hot work/welding and machinery operation/manufacturing) and wanted to display the full potential of relevant technologies across different types of worker activity, NSC retained the full list of 18 hazardous situations for the technology mapping.

To supplement the BLS CFOI data, NSC interviewed 32 EHS professionals at the director level or higher from several different industries including construction, oil and gas, electric generation and utilities, chemical, manufacturing, pharmaceuticals and mining. These industry professionals had more than 400 years of combined safety experience and provided their opinions on their top hazardous situations, associated risks and the relevant EHS technologies used in their facilities to mitigate said risks. Specifically, participants were asked to indicate the top three hazardous situations in their workplace, the top three situational risks associated with each hazardous situation and the top three systemic risks associated with each hazardous situation. Participants were also asked what types of technology they are currently using or planning to use to mitigate any of the risks they described.

The top hazardous situations identified by the NSC sample of EHS professionals differed slightly from what was estimated based on BLS data. For example, NSC participants mentioned work at height (50% mentioned), electrical work (50%), machinery operation (34%), heavy equipment operation (25%) and confined space entry (25%) as the top hazardous situations. However, differences between the NSC sample and BLS estimates are most likely a reflection of the industries represented in the NSC sample, which did not include much representation from retail (workplace violence), logging or agriculture, for example. Therefore, NSC retained the original list of 18 hazardous situations because there were no newly identified categories of hazardous situations provided by the interviewees.

Situational and Systemic Risks



Within each of these hazardous situations, NSC also identified the most common situational risks that lead to serious injuries and fatalities. Many of the risks were identified by examining the BLS CFOI data along with the information gleaned from the qualitative interviews. NSC identified the top three to five systemic risks (i.e., the proximate causes of SIF) and top three to five systemic risks (i.e., factors that contribute to SIF but do not directly cause injury) within each hazardous situation **(see Table 2)**.

Although the situational risks are inherently dependent on the situation, there was significant overlap of specific risks across different hazardous situations. For example, fall to lower level, struck by and electrical contact were some of the top–reported situational risks. The most commonly mentioned systemic risks were worker fatigue, leadership or culture failure, worker behavioral failure, risk normalization and non–routine work. In other words, serious injuries and fatalities are perceived to have the greater potential to occur when workers are fatigued (see nsc.org/Fatigue), when organizations do not place a high value on safety or promote a strong safety culture and when workers do not stick to the prescribed routines for specific work. Additionally, several interviewees mentioned that workers with several years of experience can become normalized to the risk inherent to a specific job. Workers who have gone for long stretches of time without an incident are most likely to think that something bad will not happen to them. In a similar fashion, workers with very little experience or those engaging in non–routine work may not be fully aware of the risks inherent with a job and may errantly assume the risks are not present.

Table 1. Non–Roadway workplace fatalities in 2017 split by hazardous situation with associated BLS characteristic descriptions

Hazardous Situation	BLS Description	BLS Type	Approx.# of Non–Roadway Deaths (2017)	Approx. % of Non–Roadway Deaths (2017)
Work at Height	Falls/Jumps to Lower Level	Event or Exposure	681	22.59%
Workplace Violence	Intentional Injury by Other Person	Event or Exposure	400	13.27%
Repair and Maintenance	Repair, Maintenance	Worker Activity	374	12.40%
Construction and Installation	Construction, Assembling, Dismantling	Worker Activity	369	12.24%
Logging Equipment Operation	Logging, Trimming, Pruning	Worker Activity	171	5.67%
Tending a Retail Establishment	Tending an Establishment, Waiting on Customers	Worker Activity	159	5.27%
Electrical Work	Exposure to Electricity	Event or Exposure	133	4.41%
Emergency Response	Protective Services Activities	Worker Activity	132	4.38%
Vehicle Pedestrian Interactions	Pedestrian Vehicular Incident	Event or Exposure	106	3.52%
Process Safety Operations	Chemicals and Chemical Products excluding drugs/alcohol	Primary and Secondary Source	99	3.28%
Cleaning	Cleaning, Washing	Worker Activity	96	3.18%
Loading and Unloading	Loading, Unloading Materials	Worker Activity	90	2.99%
Confined Space Entry	Confined Spaces	Primary and Secondary Source	83	2.75%
Inspections	Inspecting or Checking	Worker Activity	67	2.22%
Heavy Equipment Operation	Operating Heavy Equipment	Worker Activity	60	1.99%
Excavation	Excavating Machinery	Primary and Secondary Source	38	1.26%
Machinery Operation	Operating Machinery	Worker Activity	30	1.00%
Hot Work	Welding	Worker Activity	25	0.83%

Table 2. Situational and systemic risks for each hazardous workplace situation		
Hazardous Situation	**Situational Risks**	**Systemic Risks**
Work at Height	Fall to lower level Fall at same height Injury of sudden arrest of lifeline Falling objects – to those at height or below	Adverse weather Lack of training Fatigue Worker well–being Administrative control – leadership failure Scaffolding/platform failure
Workplace Violence	Intentional harm by other – physical violence – violence due to robbery – weapon violence	Unsafe workspace Lack of security measures Lack of workplace awareness Lack of training or supervision
Repair and Maintenance	Struck by machinery Machine energization Crushing risk Fall from height	Machinery malfunction Machinery guarding failure Lockout/tagout failure Improper training Permit to work failure Fatigue Leadership failure
Construction and Installation	Moving objects – Struck by machinery Fall from height Slips and trips Trench collapse Electric shock/arc flash Crushed by – Materials and machines Inhalation – Airborne materials Scaffolding collapse Machine entanglement Vehicle strike – Forklift/equipment	Lack of safety training Administrative/management failure Safeguard/guarding failures Terrain dangers Inclement weather Equipment improperly stored/locked Lockout/tagout failure Lack of spotter or communication Fatigue Inspection failures
Logging Equipment Operation	Struck by tree Struck by equipment Fall from height Bodily harm – Saws, cutting Crushed by Machinery malfunction Vehicle strike – Equipment or trailers	Inclement weather – wind and rain Machine failure Lack of safeguarding Improper tree felling techniques Lack of training Unaware of location of workers and machinery Cluttered work areas
Tending a Retail Establishment	Intentional harm by other Fires Struck by vehicle or equipment Fall from ladders	Unsafe workspace Lack of security measures Lack of workplace awareness Lack of training or supervision Improper ladder handling Blocked paths of egress
Electrical Work	Electrocution/arc flash Machine energization Fall from height Struck by machinery Fire Explosion	Improper training Improper electrical prep Unaware of voltage level Machinery malfunction Improper grounding Improper PPE
Emergency Response	Fire risk Explosion risk Intentional harm from others Oxygen deprivation	Unaware of surroundings and site Improper training Leadership failure Fatigue
Vehicle Pedestrian Interactions	Moving vehicle – strike – crush – pin	Lack of training for workers Lack of awareness of drivers Lack of awareness of workers Alarm or signaling failure Blocked vision/cluttered workspace

Table 2. Situational and systemic risks for each hazardous workplace situation		
Hazardous Situation	**Situational Risks**	**Systemic Risks**
Process Safety Operations	Exposure to gases Exposure to hazardous liquids Oxygen deprivation Explosions Fires	Valve or container failures Permit to work failure Inadequate containment Lack of training Lack of worker awareness Engineering failure Faulty electrical equipment
Cleaning	Fall from height Associated confined space risk Struck by machinery or equipment Chemical burns and exposure Machine crushing or entanglement	Improper storage of cleaning chemicals Improper ladder or scaffolding usage Lack of worker awareness Fatigue Training failure
Loading and Unloading	Struck by vehicle Struck by equipment i.e. forklift Crushed by moving load Pinning risks	Improper training Improper load storage Uneven terrain Loading dock hitch failure Improper forklift or machinery operation Fatigue Improper lifting techniques
Confined Space Entry	Oxygen deprivation – Material Oxygen deprivation – Gases Trench collapse Fire risk Explosion risk Drowning Hazardous gas inhalation	Lack of training Improper egress paths Lack of fresh air providing equipment Improper PPE – ventilators Leadership failure Lone worker – no worker awareness Faulty equipment – sparks and flames Fatigue
Inspections	Fall from height Associated confined space risk Struck by machinery or equipment	Improper training Lack of site awareness Fatigue Fall protection failure Scaffolding/ladder failure Improper PPE – ventilators
Heavy Equipment Operation	Struck by debris Struck by vehicle Struck by equipment part Equipment tip page/overturn Electrical shock/arc flash Crushed by equipment	Fatigue Improper training Lack of awareness of operators and workers Hazardous terrain Poorly secured loads Machinery guarding failure Unknown hazardous debris
Excavation	Struck by machine Crushed by machine Trenching collapse Oxygen deprivation Landslides	Fatigue Improper training Lack of awareness of operators and workers Hazardous terrain Poor trench design/guarding Inclement weather – rain and wind
Machinery Operation	Struck by machinery Entangled in machinery – clothing Entangled in machinery – body part Electrical shock/arc flash Energized machine incident Crushed by machinery or load	Unclear communication – operators & workers Lockout/tagout failure Machine guarding failure Training failure Leadership failure Fatigue Improper clothing/PPE
Hot Work	Fire risk – materials Fire risk – machinery Explosion risk – environmental gases Explosion risk – compressed gases Burns from torches Oxygen deprivation	Improper training Lack of site awareness Improper gas containment Valve and process safety failure Improper PPE Fatigue

Top Environmental, Health and Safety Technologies

In partnership with Verdandix, NSC cultivated a list of more than 100 technologies believed to be particularly relevant for mitigating workplace safety risks. As a global leader in EHS safety technology, Verdantix leveraged its strong history of research on EHS software to provide a starting point for identifying the most relevant technologies. In addition to the work done with Verdantix, NSC also asked the EHS professional sample group about their current and planned use of EHS technologies, any implementation or adoption barriers they have faced when trying to use new technology and the relevance of different criteria for adopting new technology (e.g., cost vs. effectiveness).

In identifying technologies that could be relevant for mitigating serious injury and fatality risks, NSC focused particularly on technologies that could serve as mature controls (i.e., on the top of the hierarchy of controls pyramid). For example, there are many technological advances in the personal protective equipment (PPE) realm, but the more effective technological solutions are going to be those that help eliminate the risk or remove the human from the hazardous situation. NSC also considered engineering and administrative controls provided by technology, understanding that these interventions, while potentially useful in the end, might not provide the most effective immediate impact on serious injury and fatality (SIF) reduction.

Table 3. Most common currently used EHS technologies from sample of EHS professionals

Category	% of participants used
Robotics	71%
Sensors/detectors	47%
Software	35%
Wearables	29%
Equipment	24%
Content	18%
Mobile Apps	18%
Analytics	12%
Data Management	6%

The 100+ technologies generally fall into 11 categories: analytics, content, data management, equipment, exoskeletons, mobile apps, PPE, robotics, sensors/detectors, software and wearables. Descriptions of these categories and example technologies are in Appendix A. In the NSC sample of EHS professionals, the most common currently used EHS technologies were robotics, sensors and detectors, and software **(see Table 3)**.

Although robotics and sensors are by far the most widely used technologies in the sample, several companies mentioned they either had started or would soon be starting pilot programs testing other types of new technologies. For example, the most widely mentioned technologies that companies wanted to pursue were virtual and augmented reality training, artificial intelligence and big data trending, and wearables for fatigue and total worker health. In addition, there were a number of technologies mentioned with lingering questions regarding their effectiveness and/or scalability with exoskeletons at the top of the list. Particularly with exoskeletons, several EHS professionals mentioned that front-end workers disliked them because they felt restricted in performing their jobs properly and comfortably.

NSC also asked participants to indicate the degree to which they found different criteria important when deciding whether to implement new technology (e.g., cost vs. effectiveness). As one can see in Table 4, the sample of EHS professionals reported that effectiveness, relevance and ease of use for workers were the top criteria when deciding to implement new technology. Many of the interviewees expressed that having the more advanced technology does not matter if field workers will not use them. Of least importance was the maturity of technology and/or technology company and upfront cost of the technology. These findings suggest that many organizations are willing to take a chance and potential financial risk on a startup company and/or technology if there is real, demonstrated potential to reduce injuries or save lives.

Table 4. Average importance rating for each technology adoption criteria

How important are each of the following criteria when evaluating technologies that could mitigate or eliminate the risks your workers face?	Average Importance (1 to 5 scale)
Effectiveness of the technology at mitigating risks	4.85
Relevance of technology to top organizational hazards/risks	4.67
Ease of use for workers	4.62
Lifetime cost of the technology	3.79
Scalability of the technology	3.77
Ease of implementation of the technology	3.67
Upfront cost of the technology	3.29
The maturity of the technology and/or technology vendor	2.86

An important caveat here is that the NSC sample consisted of large, mature companies with ample resources to devote to investing in new technology. Small- to medium–sized companies will most likely need to prioritize criteria like upfront and lifetime cost more than the companies NSC interviewed. Future research in the Work to Zero initiative will focus on the needs and perceived barriers for technology adoption for small- and mid-sized companies in particular.

NSC also asked its participants about perceived barriers for adopting and implementing new technologies to mitigate safety risks. The participants provided a wide range of barriers, but the most common were:

- **Adaptability of technology to specific organizational needs** – Technology companies often claim their products can meet the needs of their customers without considering all of the caveats certain industries might have up front before they can begin using the technology. For example, some organizations in chemical operations need explosion-proof devices, which can eliminate the possibility of certain wearable or mobile app technology.
- **Limited number of use cases and examples of successes with technology** – Several participants mentioned they would like to pursue new technology but cannot find enough examples or case studies of using the new technology effectively. More information is needed to understand the implementation strategies and barriers that go along with adopting new technology.
- **Resistant workforce** – Several participants mentioned they have struggled with getting their employees to embrace new technology, especially technology that drastically changes the way they have to perform their job (e.g., exoskeletons). Longer tenured employees are often resistant to change and other participants mentioned their employees have expressed concerns regarding data privacy and security (e.g., wearable technology and big data analytics).
- **Limited knowledge of what technology is available** – Perhaps the biggest barrier to technology adoption is that many companies simply do not know what options are available. Several participants mentioned this was a big struggle for them and imagined it would be a struggle for small- and medium-sized companies as well. Therefore, exposure and education on what technologies are available and what they can do will be a key piece of the puzzle moving forward.

Hazardous Situations, Situational and Systemic Risks and EHS Technology Mapping

To provide a cohesive overview and connection between the identified hazardous situations, situational and systemic risk factors and relevant EHS technologies, NSC surveyed an additional 100 EHS professionals through an online survey delivered to Verdantix and Campbell Institute online mailing lists. In the online survey, participants were asked to rate the relevance of different situational and systemic risks for the three hazardous situations with which they were most familiar. After rating the relevance of the risks, participants were asked to rate the perceived effectiveness of different EHS technologies at mitigating those risks. Therefore, NSC was able to collect new data on risk perception as well as validate the categorization and group of EHS technologies as more or less relevant for different types of risks in different hazardous situations.

To display all of this information in a digestible format, NSC created graphic representations of how the technologies relevant for each hazardous situation can address the different situational and systemic risks relevant to that situation. For each hazardous situation (e.g., Work at Height), NSC provided a list of technologies in order of perceived effectiveness at reducing work at height injuries and fatalities. The situational and systemic risks are listed in order of relevance to the hazardous situation.

Several different technologies are relevant to the same risks and the same risks can be addressed using different technologies. Some identified risks do not have an obviously identified technological solution, or at least not a perceived solution based on the NSC sample of EHS professionals. In addition, the mapping of technology to risk is just a starting point for thinking about how to use EHS technology to reduce workplace fatalities and serious injuries. The data represented here are not representative of all workplace hazards, risks or technologies.

As a note, not every single possible connection between technology and systemic or situational risks is represented in these diagrams. NSC organized the risks and technologies based on reported relevance of the EHS professional online sample. Therefore, it is likely there are some situational and systemic risks addressed with technology for some hazardous situations but not for others. If a technology can address a situational or systemic risk in one hazardous situation, it is safe to assume that the same technology could also address the same situational or systemic risk in another hazardous situation, even if it is not specifically represented in the diagrams.

SITUATIONAL RISKS
Fall to lower level
Falling objects
Injury from sudden arrest of lifeline
Fall at same level

more

relevance

less

SYSTEMIC RISKS
Worker behavioral failure
Leadership failure
Scaffolding/platform failure
Lack of training
Fatigue
Worker well–being
Adverse weather

Situational Risks and Systemic Risks

The situational risks with the greatest relevance to serious injuries and fatalities (SIF) for work at height were fall to lower levels (95% of participants rated as very or moderately relevant), falling objects (87%) and injury from sudden arrest of lifeline (73%). The systemic risks with the greatest relevance to SIF for work at height were worker behavioral failure (97%), leadership failure (95%) and scaffolding/platform failure (87%). Finally, the technologies perceived to be most effective for mitigating work at height risks were mobile and stationary anchor points (92%), aerial lifts and platforms (89%) and self–retracting lines (82%).

Technologies

NSC identified four technologies (mobile and stationary anchor points, aerial lifts and platforms, self–retracting lines, and unmanned aerial vehicles that have potential to mitigate falls to lower level but only one technology with potential to mitigate worker behavioral failure (VR and digital training). Half of the technologies were relevant for situational risks and half were relevant to systemic risks yet none of the technologies were perceived as relevant for both types of risks.

Mobile anchor points can reduce falls to lower levels by allowing workers to attach fall arrest systems to a roof with weighted anchors that do not require penetration of the structure. Aerial lifts and platforms can reduce falls to lower levels by giving workers more stability and flexibility in their movement without having to traverse a structure. Self–retracting lines can be connected to anchors and automatically stop a fall to reduce injuries caused by dangerous amounts of slack in a lifeline from abrupt falls. Finally, drones can reduce falls to lower levels by removing the worker from the height altogether, particularly in the case of inspections of materials and structures off the ground. VR training, which utilizes virtual reality headsets to train workers on complex or dangerous tasks by immersing them into a 3D environment procedurally generated to deliver specific training requirements in an immersive and efficient way, can reduce risks associated with worker behavioral failure and lack of adequate training.

more

perceived effectiveness

less

TECHNOLOGIES
MOBILE AND STATIONARY ANCHOR POINTS Equipment
AERIAL LIFTS AND PLATFORMS Equipment
SELF-RETRACTING LINES Equipment
PERMIT TO WORK TECHNOLOGIES Mobile Apps
UNMANNED VEHICLES OR ROBOTS Robotics
DOWNED WORKER DEVICES Wearables
VR AND DIGITAL TRAINING Content
FATIGUE MONITORING WEARABLES Wearables

Workplace Violence

13% of non-roadway fatalities

SITUATIONAL RISKS	relevance	SYSTEMIC RISKS
Intentional physical violence to colleague	more	Lack of workplace awareness
Weapon violence		Lack of training or supervision
Violence due to robbery		Lack of security measures
Purposeful negligence	less	Unsafe workspace location

Situational Risks and Systemic Risks

The situational risks with the greatest relevance to serious injuries and fatalities (SIF) for workplace violence were intentional physical violence to colleague (92% of participants rated as very or moderately relevant), weapon violence (85%) and violence due to robbery (85%). The systemic risks with the greatest relevance to SIF for workplace violence were lack of workplace awareness (100%), lack of training or supervision (100%) and lack of security measures (92%). Finally, the technologies perceived to be most effective for mitigating workplace violence risks were real–time response management (100%), video cameras (92%) and wearable or app–based panic buttons (92%).

Technologies

NSC identified three technologies (real–time response management, wearable panic buttons and video behavior analytics) that have potential to mitigate the top perceived situational workplace violence risks and three technologies with potential to mitigate the top systemic workplace violence risks (video cameras, video behavior analytics and video facial analytics). Several of the technologies were relevant to both situational and systemic risks associated with workplace violence.

Real–time response management mobile apps can reduce workplace violence risks by helping protect workers during emergency response situations. These apps utilize the mobile phones' location tracking and communication functionality to give responders better visibility of who is at risk and where they are located without relying on the worker to report their status. Video cameras, both body-worn and fixed mount, can reduce workplace violence risks by utilizing machine learning and artificial intelligence to monitor for workplace abnormalities including the ability to detect patterns of physical behavior and movement that could indicate physical violence without workers needing to identify aggressive behaviors directly. Wearable or mobile app-based panic buttons can reduce workplace violence risks allowing workers to immediately alert emergency personnel when a dangerous or life-threatening situation arises.

perceived effectiveness	TECHNOLOGIES
more	REAL-TIME RESPONSE MANAGEMENT Mobile Apps
	VIDEO CAMERAS Analytics
	WEARABLE OR APP-BASED PANIC BUTTONS Wearables
	BODY-WORN CAMERAS Wearables
	VIDEO BEHAVIOR ANALYTICS Analytics
	DOWNED WORKER DEVICES Wearables
	PROXIMITY SENSORS Sensors/Detectors
less	VIDEO FACIAL ANALYTICS Analytics

12% of non-roadway fatalities

Repair and Maintenance

SITUATIONAL RISKS
Machine energization
Struck by machinery
Entangled in machinery
Electrocution/Arc Flash
Fall to lower level

more

relevance

less

SYSTEMIC RISKS
Lack of training or supervision
Fatigue
Machinery malfunction
Permit to work failure
Engineering failure
Machine guard failure

Situational Risks and Systemic Risks

The situational risks with the greatest relevance to serious injuries and fatalities (SIF) for repair and maintenance were machine energization (100% of participants rated as very or moderately relevant), struck by machinery (100%) and entangled in machinery (100%). The systemic risks with the greatest relevance to SIF for repair and maintenance were lack of training or supervision (93%), fatigue (86%) and machinery malfunction (86%). Finally, the technologies perceived to be most effective for mitigating repair and maintenance risks were machinery cutoff light curtains (79%), power management systems (71%) and permit to work technologies (71%).

Technologies

NSC identified three technologies (machinery cutoff light curtains, power management systems and passive/active exoskeletons) that have potential to mitigate the top perceived repair and maintenance situational risks. Three technologies with potential to mitigate the top repair and maintenance systemic risks (permit to work technologies, augmented reality displays and asset management software) were also found.

Machinery cutoff light curtains can reduce repair and maintenance risks by safeguarding personnel near moving machinery like presses, winders and palletizers at the point of operation and in the perimeter of the machine through automatic stoppage of machinery when the light field is interrupted. Power management systems can reduce repair and maintenance risks by controlling electrical functions and managing capacity and load shedding to ensure electrical and arc flash safety. Permit to work technologies can reduce systemic risks associated with repair and maintenance by centralizing permit to work authorization and clearance including procedures to request, review, authorize, document and most importantly, de-conflict, tasks to be carried out by front line workers. Finally, augmented reality displays can reduce lack of training risks by using glasses or a headset to project augmented reality content into the worker's field of vision to provide schematics, details and safety information.

more

perceived effectiveness

less

TECHNOLOGIES
MACHINERY CUTOFF LIGHT CURTAINS Equipment
POWER MANAGEMENT SYSTEMS Equipment
PERMIT TO WORK TECHNOLOGIES Mobile Apps
FALL PROTECTION KITS Equipment
AUGMENTED REALITY DISPLAYS PPE
COLLABORATIVE ROBOTS Robotics
ASSET MANAGEMENT SOFTWARE Software
PASSIVE OR ACTIVE EXOSKELETONS Exoskeletons

Construction and Installation

12% of non-roadway fatalities

SITUATIONAL RISKS
Fall to lower level
Control of energy
Electrocution
Struck by machinery
Trench collapse
Crushing risks
Struck by vehicle

more

relevance

less

SYSTEMIC RISKS
Leadership failure
Lack of training
Lack of workplace awareness
Fatigue
Low visbility
Terrain dangers
Machine guard failure

Situational Risks and Systemic Risks

The situational risks with the greatest relevance to serious injuries and fatalities (SIF) for construction and installation were fall to lower level (100% of participants rated as very or moderately relevant), control of energy (100%) and electrocution (100%). The systemic risks with the greatest relevance to SIF for construction and installation were leadership failure (100%), lack of training (78%) and lack of workplace awareness (67%). Finally, the technologies perceived to be most effective for mitigating construction and installation risks were VR and digital training (78%), proximity sensors (67%) and fall protection kits (67%).

Technologies

NSC identified five technologies (proximity sensors, fall protection kits, location geofencing, lone worker monitoring and workzone intrusion detection) that have potential to mitigate the top perceived construction and installation situational risks. Six technologies with potential to mitigate the top construction and installation systemic risks (VR and digital training, proximity sensors, location geofencing, lone worker monitoring, workzone intrusion detection and heat stress monitors) were also found. Several of the technologies NSC examined were directly relevant to both situational and systemic construction and installation risks.

VR training, which utilizes virtual reality headsets to train workers on complex or dangerous tasks by immersing them into a 3D environment procedurally generated to deliver specific training requirements in an immersive and efficient way, can reduce risks associated with lack of adequate training. Proximity sensors can reduce construction and installation risks by detecting when an object, machinery or person enters a set proximity of the device to alert workers or a centralized monitoring platform. Fall protection kits can reduce construction and installation risks by providing a harness, straps and lines that can be deployed on a per-worker basis for managing risks associated with fall from heights. Similar to proximity sensors, location geofencing and workzone intrusion detection can reduce construction risks by alerting workers and other personnel when an employee enters a potentially dangerous area on a worksite.

more

perceived effectiveness

less

TECHNOLOGIES
VR AND DIGITAL TRAINING Content
PROXIMITY SENSORS Sensors/Detectors
FALL PROTECTION KITS Equipment
LOCATION GEOFENCING Wearables
LONE WORKER MONITORING Mobile Apps
WORKZONE INTRUSION DETECTION Analytics
HEAT STRESS MONITORS Wearables
ENCLOSED HEAVY EQUIPMENT CABS Equipment

6% of non-roadway fatalities

Logging Equipment Operation

SITUATIONAL RISKS
Struck by tree
Struck by equipment
Struck by vehicle

more

relevance

less

SYSTEMIC RISKS
Inclement weather
Lack of workplace awareness
Fatigue

Situational Risks and Systemic Risks

NSC did not have any participants in the sample who provided ratings for logging equipment operation risks and technologies. Therefore, NSC estimated the associated risks and relevant technologies for this hazardous situation. The situational risks with the greatest estimated relevance to serious injuries and fatalities (SIF) for logging equipment operation were struck by tree, struck by equipment and struck by vehicle. The systemic risks with the greatest estimated relevance to SIF for logging equipment operation were inclement weather, lack of workplace awareness and fatigue. Finally, the technologies estimated to be most effective for mitigating logging equipment operation risks were workzone intrusion detection, inclement weather warning apps and enclosed heavy equipment cabs.

Technologies

NSC identified four technologies (workzone intrusion detection, enclosed heavy equipment cabs, body–worn cameras and location geofencing) that have potential to mitigate logging equipment operation situational risks. Three technologies with potential to mitigate logging equipment operation systemic risks (inclement weather warning applications, location geofencing and fatigue monitoring wearables) were also found. Location geofencing was the only technology perceived to be directly relevant to both situational and systemic logging equipment operation risks.

Workzone intrusion detection can reduce logging equipment operation risks by alerting workers and other personnel when an employee enters a potentially dangerous area on a worksite. Inclement weather apps are mobile apps that can warn workers of impending weather issues, such as lightning strikes, and monitor and predict potential for weather–related hazards. Enclosed cabs help to reduce logging risks by protecting workers with enclosed hoods and cabs either specially designed or standard for heavy equipment to reduce the potential risk from falling objects, machinery strikes or imbalanced loads. Finally, location geofencing wearables can reduce logging related risks by tracking workers and warning them when they enter specified geofenced sites that may be hazardous or restricted.

more

perceived effectiveness

less

TECHNOLOGIES
WORKZONE INTRUSION DETECTION Analytics
INCLEMENT WEATHER WARNING APPLICATION Mobile Apps
ENCLOSED HEAVY EQUIPMENT CABS Equipment
BODY-WORN CAMERAS Wearables
LOCATION GEOFENCING Wearables
FATIGUE MONITORING WEARABLES Wearables

Tending a Retail Establishment

5% of non-roadway fatalities

SITUATIONAL RISKS
Fall to lower level
Fires
Struck by vehicle or equipment
Intentional physical violence to colleague

more

relevance

less

SYSTEMIC RISKS
Cluttered work area
Lack of workplace awareness
Unsafe workspace location
Lack of security measures

Situational Risks and Systemic Risks

The situational risks with the greatest relevance to serious injuries and fatalities (SIF) for tending a retail establishment were fall to lower level (100% of participants rated as very or moderately relevant), fires (100%) and struck by vehicle or equipment (100%). The systemic risks with the greatest relevance to SIF for tending a retail establishment were cluttered work area (100%), lack of workplace awareness (67%) and unsafe workspace location (67%). Finally, the technologies perceived to be most effective for mitigating retail risks were fire and smoke detectors (100%), material handling robots (100%) and panic or alert buttons (67%).

Technologies

NSC identified three technologies (fire and smoke detectors, panic or alert buttons, and lone worker monitoring that have potential to mitigate the top perceived retail establishment tending situational risks. Three technologies with potential to mitigate the top retail establishment tending systemic risks (video behavior analytics, lone worker monitoring and body-worn cameras) were also found. Lone worker monitoring was directly relevant to both situational and systemic retail establishment tending risks.

Fire and smoke detectors can reduce retail establishment tending fire risks by alerting workers to the presence of fire and smoke in the workplace. Panic and alert buttons can reduce retail establishment tending risks by allowing users to indicate an emergency situation via a mobile app, typically associated with lone worker technologies, which has a panic button or safety check features that will alert emergency response centers or management. Video cameras, both body-worn and fixed mount, can reduce workplace violence risks by utilizing machine learning and artificial intelligence to monitor for workplace abnormalities. These include the ability to detect patterns of physical behavior and movement that could indicate physical violence without workers needing to identify aggressive behaviors directly.

more

perceived effectiveness

less

TECHNOLOGIES
FIRE AND SMOKE DETECTORS Sensors/detectors
MATERIAL HANDLING ROBOTS Robotics
PANIC OR ALERT BUTTONS Mobile apps
ERGONOMIC MONITORING Wearables
VIDEO BEHAVIOR ANALYTICS Analytics
LONE WORKER MONITORING Mobile Apps
BODY-WORN CAMERAS Wearables

4% of non-roadway fatalities

Electrical Work

SITUATIONAL RISKS
Electrocutions/arc flash
Machine energization
Fall to lower level
Explosions
Fires
Struck by vehicle or equipment

more

relevance

less

SYSTEMIC RISKS
Improper electrical preparation
Lack of training
Improper PPE
Lack of workplace awareness
Improper grounding
Permit to work failure
Machinery malfunction

Situational Risks and Systemic Risks

The situational risks with the greatest relevance to serious injuries and fatalities (SIF) for electrical work were electrocutions/arc flash (100% of participants rated as very or moderately relevant), machine energization (100%) and fall to lower level (92%). The systemic risks with the greatest relevance to SIF for electrical work were improper electrical preparation (92%), lack of training (92%) and improper PPE (92%). Finally, the technologies perceived to be most effective for mitigating electrical work risks were arc flash rated protective equipment (100%), electrical insulation testers (92%) and permit to work technologies (85%).

Technologies

NSC identified five technologies (arc flash rated protective equipment, electrical insulation testers, ground fault circuit interrupters, power management systems and fire/smoke detectors) that have potential to mitigate the top perceived electrical work situational risks. Four technologies with potential to mitigate the top electrical work systemic risks (electrical insulation testers, permit to work technologies, power management systems and augmented reality displays) were also found. Electrical insulation testers and power management systems were directly relevant to both situational and systemic electrical work risks.

Arc flash rated personal protective equipment can reduce electrocution and arc flash risks by giving the worker protective shielding, masks and gloves rated for various levels of arc flashes. Electrical insulation testers are handheld or stationary tools for monitoring insulation and absorption levels of an electrical device to ensure proper electrical safety before work. Power management systems can reduce electrical work risks by controlling electrical functions and managing capacity and load shedding to ensure electrical safety. Permit to work software and mobile apps can reduce electrical work risks by centralizing permit to work authorization and clearance including procedures to request, review, authorize, document and de-conflict tasks to be carried out by front line workers. Finally, augmented reality displays can reduce electrical work risks by using glasses or a headset to project augmented reality content into the worker's field of vision to provide schematics, details and safety information.

more

perceived effectiveness

less

TECHNOLOGIES
ARC FLASH RATED PROTECTIVE EQUIPMENT PPE
ELECTRICAL INSULATION TESTERS Sensor/Detectors
PERMIT TO WORK TECHNOLOGIES Mobile apps
GROUND FAULT CIRCUIT INTERRUPTERS Equipment
POWER MANAGMENT SYSTEMS Equipement
AUGMENTED REALITY DISPLAYS PPE
PANIC OR ALERT BUTTONS Mobile apps
FIRE AND SMOKE DETECTORS Sensors/Detectors

Emergency Response

4% of non-roadway fatalities

SITUATIONAL RISKS	relevance	SYSTEMIC RISKS
Fires	more	Lack of training
Struck by vehicle or equipment		Leadership failure
Explosions		Lack of workplace awareness
Oxygen deprivation		Low visibility
Fall to lower level		Fatigue
Intentional physical violence to colleague	less	Improper PPE

Situational Risks and Systemic Risks

The situational risks with the greatest relevance to serious injuries and fatalities (SIF) for emergency response were fires (89% of participants rated as very or moderately relevant), struck by vehicle or equipment (83%) and explosions (78%). The systemic risks with the greatest relevance to SIF for emergency response were lack of training (94%), leadership failure (88%) and lack of workplace awareness (83%). Finally, the technologies perceived to be most effective for mitigating emergency response risks were lone worker monitoring (83%), vital signs monitors (78%) and air supplying respirators (72%).

Technologies

NSC identified four technologies (lone worker monitoring, air supplying respirators, digital floorplan and mapping, and panic or alert buttons) that have potential to mitigate the top perceived emergency response situational risks. Three technologies with potential to mitigate the top emergency response systemic risks (lone worker monitoring, vital signs monitors, and digital floorplan and mapping) were also found. Lone worker monitoring and digital floorplan and mapping technologies were directly relevant to both situational and systemic emergency response risks.

Lone worker monitoring can reduce emergency response risks as a mobile app that protects lone workers through real–time location tracking and communication between emergency response teams. Vital signs monitors can reduce emergency response risks via a wearable device, typically a band worn on the wrist, that tracks workers activity, sleep and vital monitoring for worker wellbeing. In particular, fatigue symptoms can be monitored via this wearable device. Especially relevant for emergency response risks are digital floorplan and mapping technologies. This technology gives emergency response personnel the ability to assess floorplans and the structure layout of buildings that can help emergency responders locate victims and find entrance and exit routes more efficiently.

perceived effectiveness	TECHNOLOGIES
more	LONE WORKER MONITORING Mobile Apps
	VITAL SIGNS MONITORS Wearables
	AIR SUPPLYING RESPIRATORS PPE
	DIGITAL FLOORPLAN AND MAPPING Software
	PANIC OR ALERT BUTTONS Mobile Apps
less	BODY-WORN CAMERAS Wearables

Vehicle Pedestrian Interactions

SITUATIONAL RISKS
Struck by vehicle
Crushed by vehicle
Vehicle pinning

more
relevance
less

SYSTEMIC RISKS
Lack of workplace awareness
Cluttered or tight work spaces
Low visibility
Lack of training
Alarm or signaling failure

Situational Risks and Systemic Risks

The situational risks with the greatest relevance to serious injuries and fatalities (SIF) for vehicle pedestrian interactions were struck by vehicle (100% of participants rated as very or moderately relevant), crushed by vehicles (100%) and vehicle pinning (86%). The systemic risks with the greatest relevance to SIF for vehicle pedestrian interactions were lack of workplace awareness (100%), cluttered or tight work spaces (93%) and low visibility (93%). Finally, the technologies perceived to be most effective for mitigating vehicle pedestrian interaction risks were worker traffic barriers (100%), proximity sensors (100%) and workzone intrusion devices (100%).

Technologies

NSC identified four technologies (worker traffic barriers, proximity sensors, workzone intrusion detection and vehicle telematics) that have potential to mitigate the top perceived vehicle pedestrian interaction situational risks. Four technologies with potential to mitigate the top vehicle pedestrian interaction systemic risks (worker traffic barriers, proximity sensors, location geofencing and lone worker monitoring) were also found. Worker traffic barriers and proximity sensors were directly relevant to both situational and systemic vehicle pedestrian interaction risks.

Worker traffic barriers can help reduce vehicle pedestrian interaction risks by providing a protective, solid barrier that keeps moving vehicles from easily entering a work zone near a roadway. Proximity sensors can reduce vehicle pedestrian interaction risks by detecting when a vehicle enters a set proximity of the device to alert workers or a centralized monitoring platform. Proximity sensors can be set as a fixed proximity around a work site or worn as a wearable device to alert workers if they cross into potentially dangerous areas. Workzone intrusion detection can reduce vehicle pedestrian interaction risks by alerting workers and other personnel when an employee enters a potentially dangerous area on a worksite. Vehicle telematics and speed limiters can reduce vehicle pedestrian interaction risks by maintaining proper vehicle speeds and alerting drivers when they are entering or driving near a work site.

more
perceived effectiveness
less

TECHNOLOGIES
WORKER TRAFFIC BARRIERS Equipment
PROXIMITY SENSORS Sensors/Detectors
WORKZONE INTRUSION DETECTION Analytics
VEHICLE SPEED LIMITERS Sensors/Detectors
LOCATION GEOFENCING Wearables
LONE WORKER MONITORING Mobile Apps
VEHICLE TELEMATICS Sensors/Detectors

Process Safety Operations

3% of non-roadway fatalities

SITUATIONAL RISKS
Exposure to hazardous liquid/gas
Fires
Explosions
Oxygen deprivation

more

relevance

less

SYSTEMIC RISKS
Lack of training
Permit to work failure
Fatigue
Inadequate containment
Valve or container failures
Faulty electrical equipment
Engineering failure

Situational Risks and Systemic Risks

The situational risks with the greatest relevance to serious injuries and fatalities (SIF) for process safety operations were exposure to hazardous liquid/gas (91% of participants rated as very or moderately relevant), fires (83%) and explosions (70%). The systemic risks with the greatest relevance to SIF for process safety operations were lack of training (88%), permit to work failure (88%) and fatigue (87%). Finally, the technologies perceived to be most effective for mitigating process safety operation risks were digital gas monitors (100%), process safety software (84%) and infrared monitors (79%).

Technologies

NSC identified four technologies (digital gas monitors, process safety software, supplied air respirators and automatic doorway spill barriers) that have potential to mitigate the top perceived process safety operation situational risks. Four technologies with potential to mitigate the top process safety operation systemic risks (process safety software, infrared monitors, asset management software and chemical/drum scanning applications) were also found. Only process safety software was perceived to be directly relevant to both situational and systemic process safety operation risks.

Digital gas monitors can help reduce process safety operations risks by relaying gas detection information to a centralized backend platform for remote monitoring of chemical worker safety. These devices can be in either handheld or wearable configurations. Process safety software is used to prevent fires, explosions and accidental chemical releases in chemical process facilities or other facilities dealing with hazardous materials such as refineries, and oil and gas production installations. This software can monitor threshold capacities for hazardous gases and liquids and alert personnel when unsafe levels are reached. Infrared monitors can help reduce process safety operation risks via a handheld device to monitor surface temperatures using infrared laser technology and eliminate the need for contact measurements. Chemical/drum scanning apps can read barcodes/QR codes to validate contents of drums or storage tanks to reduce the risk of accidental chemical release or improper handling.

more

perceived effectiveness

less

TECHNOLOGIES
DIGITAL GAS MONITORS Sensors/Detectors
PROCESS SAFETY SOFTWARE Software
INFRARED MONITORS Sensors/Detectors
BARRIER MANAGEMENT SOFTWARE Software
ASSET MANAGEMENT SOFTWARE Software
SUPPLIED AIR RESPIRATORS PPE
CHEMICAL/DRUM SCANNING APPLICATIONS Mobile Apps
AUTOMATIC DOORWAY SPILL BARRIERS Equipment

SITUATIONAL RISKS
Machine crushing or entanglement
Chemical burns and exposure
Confined space risks
Struck by machinery or equipment

more

relevance

less

SYSTEMIC RISKS
Lack of workplace awareness
Engineering failure
Improper storage
Lack of training

Situational Risks and Systemic Risks

NSC did not have enough participants in the sample who provided ratings for cleaning risks and technologies to make any strong descriptive claims. Therefore, NSC estimated the associated risks and relevant technologies for this hazardous situation. The situational risks with the greatest estimated relevance to serious injuries and fatalities (SIF) for cleaning were machine crushing or entanglement, chemical burns and exposure, and general confined space risks. The systemic risks with the greatest estimated relevance to SIF for cleaning were lack of workplace awareness, engineering failure and improper storage. Finally, the technologies estimated to be most effective for mitigating cleaning risks were fall protection kits, air purifying respirators and heat stress monitors. NSC identified one technology (air purifying respirators) that has potential to mitigate cleaning situational risks.

Technologies

Air purifying respirators can reduce situational risks associated with cleaning, especially those working with harsh chemicals or in confined spaces by filtering air particulates and contaminants using specific filters of various levels before inhalation by users. Heat stress monitors can reduce other risks that might be associated with cleaning, especially those working outdoors or in high temperature indoor environments. Specifically, heat stress monitors track the skin temperature and sweating rate of employees in high heat or outdoor environments to reduce risk of heat stroke and illness.

more

perceived effectiveness

less

TECHNOLOGIES
FALL PROTECTION KITS Equipment
AIR PURIFYING RESPIRATORS PPE
HEAT STRESS MONITORS Wearables

Loading and Unloading

3% of non-roadway fatalities

SITUATIONAL RISKS
Fall to lower level
Crushed by moving load
Struck by vehicle
Struck by machinery or equipment
Pinning risk

more

relevance

less

SYSTEMIC RISKS
Lack of workplace awareness
Improper load storage
Improper lifting techniques
Lack of training
Fatigue
Improper machine operation
Uneven terrain

Situational Risks and Systemic Risks

The situational risks with the greatest relevance to serious injuries and fatalities (SIF) for loading and unloading were fall to lower level (100% of participants rated as very or moderately relevant), crushed by moving load (100%) and struck by vehicle (100%). The systemic risks with the greatest relevance to SIF for loading and unloading were lack of workplace awareness (100%), improper load storage (100%) and improper lifting techniques (100%). Finally, the technologies perceived to be most effective for mitigating loading and unloading risks were automatic dock/bay locks (100%), proximity sensors (100%) and vehicle telematics (100%).

Technologies

NSC identified six technologies (automatic dock/bay locks, proximity sensors, vehicle telematics, location geofencing, fall protection kits and exoskeletons) that have potential to mitigate the top perceived loading and unloading situational risks. Three technologies with potential to mitigate the top loading and unloading systemic risks (proximity sensors, location geofencing, and ergonomic monitoring wearables) were also found. Proximity sensors and location geofencing were directly relevant to both situational and systemic loading and unloading risks.

Automatic dock/bay locks can reduce loading and unloading risks by automatically securing trucks to docking bays reducing the risk of trucks or other equipment pulling away from the docks. Ergonomic monitoring wearables can reduce loading and unloading risks by monitoring worker unsafe lifting and posture throughout the day. These monitors are typically worn on the body or lower back and are able to track ergonomic behavior over time so that trends in posture can be observed and corrected. Robotic material handling arms can reduce loading and unloading risks by using a robot for the handling and picking of materials on a worksite to reduce material crushing or pinning risks and ergonomic risks. Finally, passive back exoskeletons can reduce loading and unloading risks by decreasing the risk of force and torque on the lower and upper back to lessen musculoskeletal injuries associated with lifting and bending. Combinations of exoskeletons (leg, shoulder, hand) can also be used in conjunction with the back exoskeleton to reduce other ergonomic risks.

more

perceived effectiveness

less

TECHNOLOGIES
AUTOMATIC DOCK/BAY LOCKS Equipment
PROXIMITY SENSORS Sensors/Detectors
VEHICLE TELEMATICS Sensors/Detectors
LOCATION GEOFENCING Wearables
ERGONOMIC MONITORING WEARABLES Wearables
FALL PROTECTION KITS Equipment
ROBOTIC MATERIAL HANDLING ARMS Robotics
PASSIVE AND ACTIVE EXOSKELETONS Exoskeletons

Confined Space Entry

3% of non-roadway fatalities

SITUATIONAL RISKS
Oxygen deprivation – gases
Oxygen deprivation – material
Trench collapse
Explosions
Fires
Drowning

more

relevance

less

SYSTEMIC RISKS
Leadership failure
Lack of workplace awareness
Lack of training
Improper PPE
Improper egress paths
Faulty equipment
Fatigue

Situational Risks and Systemic Risks

The situational risks with the greatest relevance to serious injuries and fatalities (SIF) for confined space entry were oxygen deprivation gases (100% of participants rated as very or moderately relevant), oxygen deprivation material (96%) and trench collapse (91%). The systemic risks with the greatest relevance to SIF for confined space entry were leadership failure (95%), lack of workplace awareness (95%) and lack of training (86%). Finally, the technologies perceived to be most effective for mitigating confined space entry risks were digital gas detectors (95%), unmanned vehicles or robots (86%) and air supplying respirators (86%).

Technologies

NSC identified five technologies (digital gas monitors, unmanned vehicles or robots, air supplying respirators, air purifying respirators and lone worker monitoring) that have potential to mitigate confined space entry situational risks. One technology with potential to mitigate confined space entry systemic risks (lone worker monitoring) was also found. Lone worker monitoring was directly relevant to both situational and systemic confined space entry risks.

Digital gas monitors can reduce confined space entry risks by relaying information, through either a handheld or wearable device, to a centralized backend platform for remote monitoring of worker safety. Digital gas monitor technology allows workers to assess gas levels in confined spaces before entering. Unmanned vehicles (drones) can reduce confined space entry risks by removing the worker from the hazardous confined space situation. Confined space drones are typically controlled by humans, but some more advanced drones can be programmed to automatically conduct inspections inside of confined spaces. Air supplying respirators can reduce confined space entry risks by providing air directly to the users via external sources or compressed oxygen. Air purifying respirators filter out air particulates and contaminants using specific filters of various levels before inhalation occurs. Lone worker monitoring can reduce confined space entry risks by using real–time location tracking and communication between emergency response teams or management directly to the worker.

more

perceived effectiveness

less

TECHNOLOGIES
DIGITAL GAS MONITORS Sensors/Detectors
UNMANNED VEHICLES OR ROBOTS Robotics
AIR SUPPLYING RESPIRATOR PPE
RESCUE AND RETRIEVAL SYSTEMS Equipment
FIRE AND SMOKE DETECTORS Sensors/Detectors
AIR PURIFYING RESPIRATORS PPE
LONE WORKER MONITORING Mobile Apps

Inspections

2% of non-roadway fatalities

SITUATIONAL RISKS
Confined space risks
Fall to lower level
Struck by machinery or equipment

more

relevance

less

SYSTEMIC RISKS
Lack of training
Improper fall protection
Lack of workplace awareness
Faulty equipment
Fatigue
Scaffolding/ladder malfunction
Improper PPE

Situational Risks and Systemic Risks

The situational risks with the greatest relevance to serious injuries and fatalities (SIF) for inspections were confined space risks (100% of participants rated as very or moderately relevant), fall to lower level (92%) and struck by machinery or equipment (92%). The systemic risks with the greatest relevance to SIF for inspections were lack of training (92%), improper fall protection (85%) and lack of workplace awareness (92%). Finally, the technologies perceived to be most effective for mitigating inspection risks were digital gas detectors (100%), vital signs monitoring (85%) and lone worker monitoring (77%).

Technologies

NSC identified six technologies (digital gas monitors, vital signs monitoring, air supplying respirators, fall protection kits, unmanned vehicles or robots and air purifying respirators) that have potential to mitigate inspection situational risks. Three technologies with potential to mitigate inspection systemic risks (vital signs monitoring, lone worker monitoring and fall protection kits) were also found. Vital signs monitoring and fall protection kits were directly relevant to both situational and systemic inspection risks.

Digital gas monitors can reduce inspection risks by relaying information, through either a handheld or wearable device, to a centralized backend platform for remote monitoring of worker safety. Digital gas monitor technology allows workers to assess gas levels in confined space before entering. Vital signs monitoring can reduce inspection risks by tracking vital information like heart rate, respiration and blood pressure in real time. Vital sign information collected from these monitors can be used to track exposure to oxygen deprivation and other confined spaced related risks particularly relevant for inspection work. Fall protection kits and unmanned vehicles or robots can also reduce inspection risks for inspections at height (see Work at Height diagram for more information).

more

perceived effectiveness

less

TECHNOLOGIES
DIGITAL GAS MONITORS Sensors/Detectors
VITAL SIGNS MONITORING Wearables
LONE WORKER MONITORING Mobile Apps
AIR SUPPLYING RESPIRATOR PPE
RESCUE AND RETRIEVAL SYSTEMS Equipment
FALL PROTECTION KITS Equipment
UNMANNED VEHICLES OR ROBOTS Robotics
AIR PURIFYING RESPIRATORS PPE

Heavy Equipment Operation

2% of non-roadway fatalities

SITUATIONAL RISKS
Crushing risk
Struck by vehicle
Equipment tippage/overturn
Electrical shock/arc flash
Struck by equipment part
Struck by debris

more

relevance

less

SYSTEMIC RISKS
Lack of workplace awareness
Lack of training
Hazardous terrain
Poorly secured loads
Machine guard failure
Faulty equipment
Unknown hazardous materials and debris

Situational Risks and Systemic Risks

The situational risks with the greatest relevance to serious injuries and fatalities (SIF) for heavy equipment operation were crushing risks (100% of participants rated as very or moderately relevant), struck by vehicle (100%) and equipment tippage/overturn (80%). The systemic risks with the greatest relevance to SIF for heavy equipment operation were lack of workplace awareness (100%), lack of training (80%) and hazardous terrain (80%). Finally, the technologies perceived to be most effective for mitigating heavy equipment operation risks were proximity sensors (100%), enclosed heavy equipment cabs (80%) and worker location tracking (80%).

Technologies

NSC identified four technologies (proximity sensors, enclosed heavy equipment cabs, worker location tracking and location geofencing) that have potential to mitigate both heavy equipment operation situational and systemic risks.

Proximity sensors can help reduce heavy equipment operation risks by alerting personnel if they are in danger of a collision, typically utilizing associated stationary or equipment mounted sensors. Fixed or stationary sensors can detect when an object, machinery or person enters a set proximity of the device to alert workers or a centralized monitoring platform. Worker location tracking and location geofencing can also reduce collision and struck by risks for heavy equipment operation. Location tracking wearables help keep track of where workers are located in real time so that workers or management can be alerted when they enter a hazardous work area. Location geofencing goes one step further and warns employees when they enter specified geofenced sites that may be hazardous or restricted, without the need for continuous human monitoring of worker location.

more

perceived effectiveness

less

TECHNOLOGIES
PROXIMITY SENSORS Sensors/Detectors
ENCLOSED HEAVY EQUIPMENT CABS Equipment
WORKER LOCATION TRACKING Wearables
FATIGUE MONITORING WEARABLES Wearables
LOCATION GEOFENCING Wearables

Excavation

1% of non-roadway fatalities

SITUATIONAL RISKS
Trench collapse
Oxygen deprivation
Struck by equipment part
Struck by vehicle
Struck by debris

more

relevance

less

SYSTEMIC RISKS
Lack of workplace awareness
Poor trench design
Lack of training
Hazardous terrain
Faulty equipment
Inclement weather

Situational Risks and Systemic Risks

The situational risks with the greatest relevance to serious injuries and fatalities (SIF) for excavation were trench collapse (100% of participants rated as very or moderately relevant), oxygen deprivation (100%) and struck by equipment part (100%). The systemic risks with the greatest relevance to SIF for excavation were lack of workplace awareness (100%), poor trench design (100%) and lack of training (75%). Finally, the technologies perceived to be most effective for mitigating excavation risks were real-time response management (100%), proximity sensors (75%) and worker location tracking (75%).

Technologies

NSC identified three technologies (proximity sensors, worker location tracking and inclement weather warning applications) that have potential to mitigate excavation situational risks. Three technologies with potential to mitigate excavation systemic risks (proximity sensors, lone worker monitoring and inclement weather warning applications) were also found. Proximity sensors and inclement weather warning applications were directly relevant to both situational and systemic excavation risks.

Proximity sensors can help reduce excavation risks by alerting personnel if they are in danger of a collision with an object, typically utilizing associated stationary or equipment mounted sensors. Fixed or stationary sensors can detect when an object, machinery or person enters a set proximity of the device to alert workers or a centralized monitoring platform. Wearable location tracking can also reduce collision and struck by risks for excavation. Location tracking wearables help keep track of where workers are located in real time so that workers and/or management can be alerted when they enter a hazardous work area. Inclement weather reporting applications are particularly relevant for addressing trench collapse risks where materials can be compromised by rain and other precipitation.

more

perceived effectiveness

less

TECHNOLOGIES
REAL-TIME RESPONSE MANAGEMENT Mobile Apps
PROXIMITY SENSORS Sensors/Detectors
WORKER LOCATION TRACKING Wearables
LONE WORKER MONITORING Mobile Apps
FATIGUE MONITORING WEARABLES Wearables
INCLEMENT WEATHER WARNING APPLICATIONS Mobile Apps

SITUATIONAL RISKS	relevance	SYSTEMIC RISKS
Crushed by machinery or load	more	Lockout/tagout failure
Entangled in machine – body part		Machine guarding failure
Energized machine incident		Lack of worker and operator communication
Struck by equipment part		Faulty equipment
Electrical shock/arc flash		Lack of training
Entangled in machine – clothing		Fatigue
	less	Improper PPE

Situational Risks and Systemic Risks

The situational risks with the greatest relevance to serious injuries and fatalities (SIF) for machinery operation were crushed by machinery or load (100% of participants rated as very or moderately relevant), entangled in machine - body part (100%) and energized machine incident (100%). The systemic risks with the greatest relevance to SIF for machinery operation were lockout/tagout failure (100%), machine guarding failure (100%) and lack of worker and operator communication (100%). Finally, the technologies perceived to be most effective for mitigating machinery operation risks were automation of processes through robotics (100%), point of operation light curtains (100%) and perimeter access control light curtains (100%).

Technologies

NSC identified three technologies (automation of process robotics, point of operation light curtains and perimeter access control light curtains) that have potential to mitigate machinery operation situational risks. Three technologies with potential to mitigate machinery operation systemic risks (VR and digital training, computer vision fatigue monitoring wearables) were also found.

Assembly robots are autonomous robots for manual assembly of products or items on lines and of manual handling of components to remove ergonomic risks to workers. These robots along with mobile industrial robots, which are multi-functional use robots that can be easily moved through worksites, can help reduce machinery operation risks by eliminating the need for workers to physically interact with the potentially hazardous machinery. Perimeter access control light curtains can reduce machinery operation risks via opto-electronic devices that are used to safeguard personnel in the vicinity of moving machinery with the potential to cause harm such as presses, winders and palletizers, and, in this case specifically, the perimeter. Similar light curtains can be used at the point of operation of the machinery as well. Finally, computer vision utilizes machine learning and AI (artificial intelligence) to monitor for workplace abnormalities or guidelines from video feeds (i.e. wearing correct PPE in a required space), which can also reduce machinery operation risks.

perceived effectiveness	TECHNOLOGIES
more	AUTOMATION OF PROCESS Robotics
	POINT OF OPERATION LIGHT CURTAINS Equipment
	PERIMETER ACCESS CONTROL LIGHT CURTAINS Equipment
	VR AND DIGITAL TRAINING Content
	COMPUTER VISION Analytics
less	FATIGUE MONITORING WEARABLES Wearables

Hot Work

1% of non-roadway fatalities

SITUATIONAL RISKS
Explosion risk – compressed gases
Explosion risk – environmental gases
Fire risk – materials
Fire risk – machinery
Burns from torches

more

relevance

less

SYSTEMIC RISKS
Improper gas containment
Lack of workplace awareness
Lack of training
Faulty equipment
Valve or container failure
Improper PPE
Fatigue

Situational Risks and Systemic Risks

The situational risks with the greatest relevance to serious injuries and fatalities (SIF) for hot work were explosion risks from compressed gases (100% of participants rated as very or moderately relevant), explosion risks from environmental gases (100%) and fire risks from materials (100%). The systemic risks with the greatest relevance to SIF for hot work were improper gas containment (100%), lack of workplace awareness (100%) and lack of training (100%). Finally, the technologies perceived to be most effective for mitigating hot work risks were wearable gas monitors (100%), permit to work applications (100%) and fire resistant PPE (100%).

Technologies

NSC identified four technologies (wearable gas monitors, fire resistant PPE, welding robots and process hazard analysis software) that have potential to mitigate hot work situational risks. Two technologies with potential to mitigate hot work systemic risks (fire resistant PPE and process hazard analysis software) were also found. Both fire resistant PPE and process hazard analysis software were perceived to be directly relevant to situational and systemic hot work risks.

Wearable gas monitors can reduce hot work risks by alerting workers to the presence of hazardous levels of gases in the atmosphere to prevent explosion risks. Permit to work applications can reduce hot work risks by providing permit to work authorization and clearance including procedures to request, review, authorize, document and most importantly, de-conflict, tasks to be carried out by front-line workers. Permit to work software is particularly helpful for keeping hazardous situations from presenting themselves in the first place. Welding robots can reduce hot work risks by automating arc-welding and spot–welding applications, thereby removing the worker from the hazardous situation. Process hazard analysis software can help reduce hot work risks via software for organized and systematic assessments of the potential hazards associated with the hot work process.

more

perceived effectiveness

less

TECHNOLOGIES
WEARABLE GAS MONITORS Wearables
PERMIT TO WORK APPLICATIONS Mobile Apps
FIRE RESISTANT PPE PPE
AUTOMATION OF PROCESS Robotics
WELDING ROBOTS Robotics
PROCESS HAZARD ANALYSIS SOFTWARE Software

Discussion and Future Directions

The goal of the Work to Zero initiative at NSC is to eliminate workplace fatalities through the use of technology. As a starting point for this work, NSC needed to come up with a way to synthesize and categorize the situations in which fatalities are occurring on the job. Based on existing data, expert insight and feedback from EHS professionals, NSC decided to orient this work around hazardous workplace situations (e.g., confined space entry, machinery operation). NSC situated most workplace fatalities into one of 18 different hazardous situations that are relevant across different industries, job types and worker activities.

Next, NSC identified the inherent situational risks that lead to serious injuries and fatalities in those different hazardous situations (e.g., fall, struck by) and the systemic contributing factors (e.g., lack of training, fatigue) that sometimes exacerbate risk within those same hazardous situations. Finally, NSC identified a long list of relevant EHS technology that could help mitigate both the situational and systemic risks and mapped these technologies to the risks in ways that the surveyed EHS professionals perceived to be most effective.

NSC was able to generate some valuable insights regarding hazardous workplace situations, their associated risks and potentially relevant technologies. In general, the top hazardous situations (e.g., work at height) and their relevant situational risks (e.g., fall to lower level) were not terribly surprising findings. For the past several years, citations related to fall protection have topped the OSHA violations list, even as recently as 2019.

Clearly, working at heights is a big issue with high potential for serious injuries and fatalities. The sample of EHS professionals surveyed agreed this was one of their top concerns and have developed technology solutions aimed at addressing working at height risks. One of the most widely used and planned to be implemented technologies related to working at heights is unmanned aerial vehicles. These are one of the lesser expensive technologies that offer immediate risk reduction by eliminating the need for some workers to even leave the ground.

Interestingly, workplace violence, which accounts for the second most workplace fatalities, was rarely mentioned in the professional interviews or survey. Because workplace violence is not dependent on a specific job or task, employers may have a difficult time prioritizing solutions to address these sorts of risks. Although the NSC sample did not include much representation from retail or other public–facing industries, that does not mean EHS professionals are not looking for ways to address workplace violence risks. Some of the most promising solutions for workplace violence revolve around video behavioral and facial analytics. With this technology, real–time behavioral data can be assessed through live video feeds as well as through archival footage to identify trends and patterns in movement that could indicate hostility, fighting and other forms of violence. To adequately address the causes of fatalities in the workplace, employers and technology providers should focus on addressing the situations where the most fatalities are occurring, which includes risks related to workplace violence.

Of course, different industries and companies have varying priorities when it comes to implementing new technology to address risk. As NSC found in this research, employers vary greatly in the extent to which they have a formalized plan for technology testing and adoption. Large companies with dedicated resources for research and development as well as testing can afford to test several types of new technology and potentially work with technology vendors to create tailor–made tech applications. Smaller companies may not have this luxury. Therefore, the more attention and dedication paid to developing best practices for technology adoption and implementation, the more small- to medium-sized companies are going to be able use new technology.

The NSC research suggests it is also crucial to understand how systemic risks fit into the technology picture. Employees do not work in a bubble. They bring the stresses of their lives, relationships and responsibilities into the workplace and are sometimes working several jobs to make ends meet. Therefore, systemic risks like worker fatigue or lack of awareness should be addressed through technology as well.

Several new technologies, particularly in the wearables category, can go a long way in measuring and assessing worker health and well–being. This can help ensure workers are fit for duty and getting the help they need, if, and when, they need it. On the organizational end, several people in the NSC sample mentioned that safety starts and ends with leadership and culture. In other words, organizational leadership sets the tone for safety prioritization. New technologies designed to mitigate risks may not do any good if the employees using the equipment believe their employers, managers or supervisors do not actually care about their safety.

Although NSC better understands how EHS professionals think about the risks associated with different hazardous situations and relevant technologies for mitigating those risks, the journey of Work to Zero is just getting started. The next research steps involve conducting field studies examining the effectiveness of different EHS technologies on reducing actual serious injuries and fatalities in the workplace. Specifically, NSC plans to collect and synthesize case studies of different companies who have implemented new technology to address a serious safety concern, particularly related to the top three to five hazardous situations.

As a later step, NSC plans to recruit organizations to implement a specific new technology and measure its effectiveness over the course of several months at reducing SIF and SIF exposures. Additionally NSC will plan to create a best practices paper on new technology adoption and implementation based on what mature companies are doing in this space. It will detail the successes and pitfalls of new technology adoption. Knowing that organizations adopt new technologies for reasons besides safety (e.g., productivity, efficiency, cost reduction), NSC will explore how safety and other technology drivers can be synergistically connected to make workplaces safer, more efficient and healthier overall. Finally, NSC will create resources for organizations to help them increase their exposure to and engagement with new EHS technologies.

As the Work to Zero initiative expands and increases its efforts around getting to zero fatalities in the workplace, NSC will be looking for more opportunities to promote technology innovation in the world of environmental, health and safety. **To learn more about Work to Zero, how to get involved and how to support this effort, please visit nsc.org/worktozero.**

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Appendix A: EHS Technology Definitions and Examples

Active Exoskeletons

Active exoskeletons are wearable, external mechanical structures that enhance the power or endurance of a person, are powered by a system of electric motors, batteries and actuators, and/or are some combination of such technologies.

- Active Hand Exoskeletons
- Mounted Exoskeleton Arm
- Person Mounted Exoskeleton Arm
- Powered Back Exoskeletons
- Powered Leg Exoskeletons

Asset Performance Technology

Asset Performance Technology (APM) is software and digital technology to manage the health, safety and operations of assets at a worksite.

- 3D BIM Visualizations
- Asset Performance Management
- Digital Floorplan and Mapping

Augmented Reality

Augmented reality (AR) is an interactive experience of a real–world environment into which sensory information is overlaid or augmented. Augmented reality can enhance natural environments using headsets, mobile devices, camera displays and video feeds. In the scope of this section, AR software includes the content created for AR displays and AR software platforms. Augmented reality is typically deployed via head–mounted displays (HMD). HMD's are display devices that are worn on the head or as part of a helmet and have a small display optic in front of one eye or both eyes. In the case of augmented reality, the devices typically are optical head–mounted displays (OHMD), which are transparent goggles or glasses that allow augmented content and digital information to be superimposed onto the display. Augmented reality can be displayed via handheld mobile devices (e.g. Pokemon Go) and other popular applications.

- AR Safety Content
- Augmented Reality HMD

Confined Space Technology

This encompasses technologies used to protect workers in a confined space environment by providing air, removing particulates and gases, warning employees of hazardous situations and monitoring those workers.

- Air Purifying Respirators
- Air Supplying Respirator
- Confined Space Air Blower

EHS Software and Applications

EHS software and applications are digital platforms and databases that help manage, store, initiate and execute environmental, health and safety related processes. EHS software typically consists of a variety of auditing, safety management, risk management, incident management, sustainability, environmental and compliance related functions. Corresponding mobile applications are typically deployed.

- Chemical Drum/Tank Scanner
- EHS Audit App
- EHS Software
- Inclement Weather Warning
- Job Hazard Analysis
- Ladder Safety App
- Online Safety Data Sheet
- Permit to Work
- Real-Time Response Management
- Safety Micro-Learning
- Safety Observation

Electrical Safety Equipment

This encompasses a variety of electrical safety equipment used to protect workers from electrical hazards including fires, arc flashes and electrocutions through equipment management and personal protective equipment.

- Arc Flash Rated Protective Equipment
- Flame Resistant Protective Equipment
- Ground Fault Circuit Interrupters (GFCI)
- Power Management Systems
- Real-Time Ground Continuity Monitor (GCM)

Fall Protection Systems

Fall protection systems are systems of various options of arrestor lines, harnesses, structures and devices intended to prevent employees from falling off, onto or through working levels and protect employees from falling objects.

- Fall Protection Kits
- Fall Rescue and Retrieval System
- Lifeline Fall Protection
- Mobile Anchor Points
- Rigid Rail Fall Protection Systems
- Safety Harnesses
- Self–Retracting Lines

Hazardous Environment Sensing Equipment
Environmental sensing equipment are analytical instruments that can be mobile or stationery and capture data on parameters such as electrical rating, humidity, temperature, volatile organic compounds, particulates, radiation and greenhouse gases (GHGs).

- Automatic Doorway Spill Barriers
- Chemical Leakage Sensors
- Connected Digital Gas Monitors
- Dosimeter
- Dust and Particle Sensors
- Electrical Insulation Tester
- Flame Detector
- Handheld Gas Monitor
- Handheld Infrared Monitor
- Smoke Detector
- Vehicle Speed Limiters
- Voltage Testers

Material Moving Technology
This encompasses motorized technology that provides workers any easier way of transporting materials through workplaces. These technologies can be automated material handlers or manual machinery and technology to assist workers.

- Autonomous/Self-Driving Trucks
- Motorized Pallet Jacks
- Telehandler

Operational Risk/Risk Management Software
Operational risk management software is software that uses risk assessment, risk decision making and implementation of risk controls, which results in acceptance, mitigation or avoidance of risk. ORM is the oversight of operational risk, including the risk of loss resulting from inadequate or failed internal processes and systems, human factors or external events.

- Control of Work Software
- Digital Twin for Industrial Facilities
- Management of Change (MOC)
- Process Hazard Analysis (PHA)

Passive Exoskeletons
Passive exoskeletons are wearable, external mechanical structures that enhance the power of its wearer. A passive system does not use any type of actuator, but rather uses materials, springs or dampers to store energy harvested by human motion. Then this energy is used as required to support a posture or a motion, most commonly focused on the lower back or upper extremities.

- Full–Body Passive Exoskeleton
- Passive Back Exoskeletons
- Passive Leg Exoskeleton (Chairless Chair)
- Passive Shoulder Exoskeletons

Personnel Lifts and Platforms
Personnel lifts are mechanical and electrical devices that elevate workers as required for specific job tasks. These devices can be vehicle mounted, machine mounted or stationary. These lifts can come in a variety of telescoping, articulating and lifting platforms, booms and buckets.

- Articulated Boom Lift
- Mobile Lift Tables
- Scissor Lift
- Stationary Lift Table
- Telescopic Boom Lift

Predictive and Advanced Analytics
Predictive analytics encompasses a variety of statistical techniques such as predictive modelling, machine learning and data mining for analyzing current and historical facts to make predictions about future or otherwise unknown events. It is utilized across a variety of business processes such as EHS, asset management and operational risk.

- AI Analytics and Machine Learning
- Asset Health
- Computer Vision
- Deterministic Safety Analysis
- Facial Analytics
- Fatigue Monitoring Platform
- Probabilistic Safety Assessment
- Quantitative Risk Analysis
- Safety Artificial Intelligence
- Safety Prediction

Appendix A: EHS Technology Definitions and Examples

Proximity Sensors

Proximity sensors are either stationary or mobile and detect the location of nearby objects without physical contact. These sensors can virtually fence off hazardous areas, detect impending collisions and warn employees of hazardous situations. Additionally, these can be sensors attached to or part of a machine which can automatically cut off energy sources to reduce risk of contact injuries.

- Fixed Proximity/Collision Sensor
- Location Geofencing
- Location Tracking
- Perimeter Access Control Light Curtain
- Point of Operation Light Curtains
- Vehicle Telematics
- Wearable Proximity/Collision Sensor
- Work Zone Intrusion Detection

Robotics for Safety Processes

Robots are programmable machines capable of carrying out a complex series of actions automatically. Robots can be programmed or guided externally with control devices. Robots in an EHS setting typically are utilized to engineer workers out of hazardous situations or to work in conjunction with human operators to manage dangerous or repetitive tasks. A part of robotics for safety can be unmanned aerial or terrestrial vehicles, commonly known as drones, which are aircraft or land craft managed by a ground-based controller. Firms can use UAVs to inspect internal and external spaces, map topographic locations and assess site feasibility.

- Assembly Robot
- Automated Guided Vehicle
- Automated Storage Retrieval
- Autonomous Construction Robots
- Collaborative Bot (Cobot)
- Material Handling Robot
- Mobile Industrial Robots
- Palletizing Robot
- Sawing/Cutting/Grinding Robot
- UAV – Aerial Inspection
- UAV – Confined Space
- UAV – Surveying
- Welding Robot

Virtual Reality

A virtual reality (VR) device immerses the user in an environment that is entirely computer-generated but allows the individual to navigate the environment as if physically there. VR safety training can allow workers to identify hazards and take necessary actions in a very realistic and immersive simulated environment.

- VR Headset
- VR Training

Wearable Ergonomics Monitors

Wearable ergonomic monitors are sensor-equipped devices worn on a body to track ergonomic risk factors such as fatigue, well-being, lifting techniques and body position. These devices may also be embedded into exoskeletons, vests and other PPE.

- Ergonomic Monitor
- Fatigue Wearable Monitor

Wearable Hazard Sensors

Wearable hazard sensors are individual devices that can alert workers or monitoring systems within hazardous environments. These sensors can detect hazardous conditions such as gases, particulates and extreme temperature. These devices can be worn, incorporated into clothing or incorporated into existing protective equipment.

- Wearable Gas Monitor
- Wearable Thermometer

Wearable Vital Sign Monitoring

Wearable vital sign monitors are sensor-equipped devices worn by a worker that monitor bodily metrics in real time, such as fatigue, temperature, ergonomic stresses and heart rate. The devices also may be embedded in bracelets, hats, gloves, vests or shirts.

- Actigraphy Watch
- Heart Rate Monitor
- Heat Stress Monitor

Worker Monitoring Technology

Worker monitoring solutions include technology that connects workers through multifunctional Internet of Things (IoT) devices, creating a total connected workforce that can be monitored from a centralized platform. These can be wearable devices, lone worker mobile apps and associated IoT devices that allow managers to monitor and respond to emergency situations with their lone working workforce.

- Connected Worker Platform
- Contractor Management Platform
- Contractor Pre-Qualification
- Digital Site Security Tag
- Fatigue Monitoring Sensors
- Lone Worker Applications
- Panic Button – Safety Check
- Smart Shoes with Fall Detection Sensors
- Wearable Camera

ANALYTICS

AI Analytics & Machine Learning: Machine learning, a branch of artificial intelligence, is a method of data analysis that automates analytical model building, which can be used to predict and analyze safety and risk hazards.

Asset Health Analytics: Analytic software that utilizes data to monitor asset health and develop maintenance and replacement strategies.

Computer Vision: Video analytics utilizing machine learning and AI to monitor for workplace abnormalities or guidelines from video feeds (e.g., wearing correct PPE in a required space).

Deterministic Safety Analysis: Like a probabilistic safety assessment but based on well-defined guidelines and extensive rules, such as those developed by regulatory bodies.

Facial Analytics: Video driven analytics for worker and pedestrian facial features to recognize a given set of criteria to protect workers against potential public hazards.

Fatigue Monitoring Platform: Analytic software platform that utilizes IoT data collecting devices, sleep data and algorithms to predict and manage employee fatigue for monitoring and preventative/corrective actions.

Probabilistic Safety Assessment: A systematic methodology to evaluate risks associated with complex engineered technical processes (e.g., the calculated probabilities to analyze the overall risk to a nuclear power plant).

Quantitative Risk Analysis: A risk analysis that analyzes highest priority risks to determine the probability of the risk, which is then assigned a rating to develop a probabilistic analysis.

Safety Artificial Intelligence: Machine learning associated with utilization of EHS data to calculate safety risks, compliance issues and requirements.

Safety Prediction: Software analytics utilizing machine learning parsed safety data to predict and recommend actions for potential workplace risks and safety hazards.

Work Zone Intrusion Detection: Alarm associated with analytic software or hardware, typically radar or camera-based, which can alert workers to impending work zone intrusions by pedestrian or worksite vehicles.

CONTENT

3D BIM Visualizations: 3D content that enables safe planning on construction sites and early identification of hazards/risks.

Augmented Reality (AR) Safety Content: Augmented reality content, either training or directions from outside sources, delivered to workers based on job function and task. This training can be delivered via mobile devices or AR headsets (e.g., smart glasses or headsets).

Safety Micro–Learning: Short burst of training sent to workers at time of need or directly before a task, typically via mobile device, to help increase retention and impact of safety trainings.

Virtual Reality (VR) Training: VR training utilizing virtual reality headsets to train workers on complex or dangerous tasks by immersing them into a 3D environment procedurally–generated to deliver specific training requirements in an immersive and efficient way.

DATA MANAGEMENT

Connected Worker Platform: Software platform to manage worker IoT devices into a centralized location for monitoring and analysis. These platforms typically run associated analytic engines to take advantage of incoming IoT data.

Contractor Management Platform: Software platform to manage contractors daily job tasks, data collection, workflows and processes in a centralized location for better contractor visibility and safety management.

Contractor Pre-Qualification: Platform to manage contractor pre-qualifications and audit requirements to ensure that contractors are compliant with company or legal requirements for job safety.

EQUIPMENT

Articulated Boom Lift: Personnel lift platform or box that attaches to an extendable boom arm and can articulate up, over and out on worksites for higher levels of movement.

Automatic Doorway Spill Barriers: Doorway barrier that can automatically rise in the event connected sensors detect a spill or other chemical release. It can capture any harmful chemicals and contain them within the affected room.

Autonomous / Self–Driving Trucks: A truck that can be driven or controlled remotely either autonomously or manually to prevent truck crashes and collisions, and removes workers from vehicle-related risks.

Confined Space Air Blower: A mechanical air blower that can be utilized in a confined space setting using tubing and piping to circulate fresh air into a confined space to limit potential hazardous gas or asphyxiation risks.

Enclosed Cabs (Heavy Equipment): Enclosed hoods and cabs either specially designed or standard for heavy equipment to reduce the potential risk from falling objects, machinery strikes or imbalanced loads.

Fall Protection Kits: Full-scale fall protection kits include harnesses, straps and lines, which can be deployed on a per–worker basis for managing risks associated with fall from heights.

Fall Rescue and Retrieval System: Typically, a tripod lock system for manholes or confined space working, where workers are attached and can be retrieved using a mechanical or manual winch should a fall occur.

Ground Fault Circuit Interrupters (GFCI): A type of circuit breaker that shuts off electric power when it senses an imbalance between the outgoing and incoming current. The main purpose is to protect people from an electric shock caused when some of the current travels through a person's body due to an electrical fault such as a short circuit, insulation failure or equipment malfunction.

Lifeline Fall Protection: Cables installed vertically or horizontally onto anchors that can arrest the fall of workers who are working at a height.

Mobile Anchor Points: Weighted non-penetrating anchor points to attach fall protection equipment while working from a height to ensure fall arrest on workers.

Mobile Lift Tables: Pneumatic mobile tables used to raise material to higher levels or working heights on a mobile platform to reduce ergonomic risks and material falling risks.

Motorized Pallet Jacks: A motorized version of a hand pallet used to jack up pallets containing heavy loads to move and raise short distances off ground.

Perimeter Access Control Light Curtain: Opto-electronic devices that are used to safeguard personnel in the vicinity of moving machinery with the potential to cause harm such as presses, winders and palletizers, and in this case specifically in the perimeter.

Point of Operation Light Curtains: Opto-electronic devices that are used to safeguard personnel in the vicinity of moving machinery with the potential to cause harm such as presses, winder, and palletizers, and in this case specifically at the point of operations.

Power Management Systems: Power monitoring and management systems that control electrical functions and manage capacity and load shedding to ensure electrical and arc-flash safety.

Real-Time Ground Continuity Monitor (GCM): An electrical safety device that monitors the impedance to ground of a temporary circuit and can provide indication (or protective trip) in the event impedance rises to an unsafe value. A GCM is either an external testing device or a cord-mounted device that measures the electrical continuity of a circuit's path to ground.

Rigid Rail Fall Protection Systems: Rigid framework or rails, either stationary or mobile, which allow for connection of fall protection devices to protect workers working at heights.

Scissor Lift: Personnel lift, which is typically a flat platform with railing mounted onto a scissor mechanism to lift workers into the air in a vertical plane for higher stability and safety.

Self-Retracting Lines: Lifelines, connected onto anchors, which automatically stop a fall to reduce injuries caused by dangerous amounts of slack in a lifeline from abrupt falls.

Stationary Lift Table: Pneumatic stationary tables used to raise material to higher levels or working heights to reduce ergonomic risks and material falling risks.

Telehandler: A telescopic handler, telehandler or teleporter is a machine widely used in agriculture and industry. It is similar in appearance and function to a forklift. It is more a crane than forklift, with the increased versatility of a single telescopic boom that can extend forwards and upwards from the vehicle.

Telescopic Boom Lift: Personnel lift platform or box that attaches to an extendable boom and can move in a telescopic motion around a worksite to provide a wider range of movement.

EXOSKELETONS

Active Hand Exoskeletons: Powered gloves that can add strength and reinforce hand functions to reduce risk of carpal tunnel and other musculoskeletal hand related risks.

Full–Bodied Passive Exoskeletons: Full bodied passive exoskeleton containing knee, back and shoulder components in unison to reduce workload and protect from musculoskeletal injuries.

Mounted Exoskeleton Arms: Mounted arm utilized to reduce stress for manual activities for workers and typically mounted onto a stationary or mobile platform that the worker can move and control.

Passive Back Exoskeletons: Exoskeletons, worn on the back and core, that reduce the risk of force and torque on the lower and upper back to reduce risk of musculoskeletal injuries associated with lifting and bending.

Passive Leg Exoskeletons (Chairless Chair): Leg mounted passive exoskeletons that allows for sitting and bending in an optimal posture to be used at work sites and mobile.

Passive Shoulder Exoskeletons: Passive exoskeletons, worn on the shoulders, which reduce stress on the shoulder complex by minimizing load and repetitive movements.

Person Mounted Exoskeleton Arms: A wearable mounted exoskeleton arm, typically mounted onto a person or worn rig, used for manual activities to reduce workload and increase strength.

Powered Back Exoskeletons: Powered exoskeleton, worn on the back or core, to support lower and upper back and increase lifting capabilities and core strength to increase efficiency while reducing musculoskeletal injuries.

Powered Leg Exoskeletons: Powered exoskeleton, worn on the leg, which supports user weight and reduces knee stress while allowing for increased load management and stability.

MOBILE APPLICATIONS

Chemical Drum/Tank Scanner: A mobile app that can read barcodes/QR codes to validate contents of drums or storage tanks to reduce the risk of accidental chemical release or improper handling.

EHS Audit Application: A mobile application for conducting and recording EHS-related audits and assessments, typically these data are sent to an associated software platform.

Incident Report: A mobile app that allows workers to report incidents and near misses for further follow up and corrective actions at the point of the event.

Inclement Weather Warning: A mobile app that can warn workers of impending weather issues, such as lightning strikes, and monitor and predict potential for weather-related hazards.

Job Hazard Analysis: A mobile app that allows for the remote creation of a job hazard analysis of job tasks and functions to identify the major risks and hazards associated with a specific job.

Lone Worker: A mobile app that protects lone workers through real-time location tracking and communication between emergency response teams or management directly to the worker. These applications can typically involve fall detection capabilities.

Panic Button – Safety Check: A mobile app typically associated with lone worker technologies, which has a panic button or safety check feature in case of emergency that will alert emergency response centers or management.

Permit to Work: A mobile app that provides permit to work authorization and clearance, including procedures to request, review, authorize, document and most importantly, de-conflict tasks to be carried out by front line workers.

Real–Time Response Management: A mobile app that helps protect workers during emergency response situations by utilizing the phone's location tracking and communication functionality to give responders better visibility.

Safety Observation: A mobile app that can provide a mechanism for workers to record and highlight unsafe activities and hazards that might arise during work operations to flag for management review.

PERSONAL PROTECTIVE EQUIPMENT

Air Purifying Respirators: Respiratory protection systems that filter air particulates and contaminants using specific filters of various levels before inhalation by users.

Air Supplying Respirator: Respiratory protection systems that provide air directly to the users via external sources or compressed oxygen.

Arc Flash Rated Protective Equipment: Protective shielding, masks and gloves rated for various levels of arc flashes.

Augmented Reality Head Mounted Displays: Augmented reality headset, glasses or otherwise, which can project augmented reality content into user's field of vision to provide schematics, details and safety information.

Digital Site Security Tag: A digital ID tag device using radio frequency technology to allow access to specific work sites or track workers while they are at a site.

Flame Resistant Protective Equipment: Protective equipment, gloves, coveralls, etc. which are rated for specific heat and flame ratings.

Safety Harnesses: Body harnesses used for working at heights for attachment to fall protection anchors and lines.

ROBOTICS AND AUTOMATION

Assembly Robots: Autonomous robots for manual assembly of products or items on lines and manual handling of components to remove ergonomic risks to workers.

Automated Guided Vehicle: An autonomous pallet jack type robotic vehicle used to move materials and personnel around a warehouse or other worksite.

Appendix B: Glossary of EHS Technologies

Automated Storage Retrieval: Automated systems for movement, storage and retrieval of items in warehouse racking to remove workers having to be at heights and handle materials.

Autonomous Construction Robots: Automated robots that can carry heavy construction supplies to higher levels, such as during the construction of high-rise buildings.

Collaborative Bot (Cobot): Industrial robots, typically material handling, that have been designed and programmed to work in close proximately to people, including all associated fail safes and requirements.

Material Handling Robots: Autonomous robots for the handling and picking of materials on a worksite to reduce material crushing or pinning risks.

Mobile Industrial Robots: Mobile industrial robots of multi–functional use that can be easily moved through worksites and are typically used for dangerous or ergonomically risky job functions.

Palletizing Robots: Automated robots that create pallets by stacking materials.

Sawing/Cutting/Grinding Robots: Automated robots with a variety of sawing, cutting, grinding and similar operations.

UAV – Aerial Inspection: Unmanned aerial vehicles, typically controlled by humans, primarily used for inspection in aerial aspects of work (e.g., the inspection of wind turbines).

UAV – Confined Space: Unmanned vehicles, typically controlled by humans, primarily used for inspection and work in confined space, can be either terrestrial or aerial and remove the need for human intervention.

UAV – Surveying: Unmanned aerial surveying vehicles, typically controlled by humans, primarily used for surveying land and worksites. Often used in mining and forestry related industries.

Welding Robots: Automated arc-welding or spot-welding robots.

SENSORS/DETECTORS

Chemical Leakage Sensors: Sensors utilizing laser technology, camera analytics or other methods to remotely detect potential chemical or gas leaks.

Connected Digital Gas Monitors: Digital handheld or wearable gas monitors that relay information to a centralized backend platform for remote monitoring of chemical worker safety.

Dosimeter: A device that measures exposure to ionizing radiation. It has two main uses: for human radiation protection and for measurement of dose in both medical and industrial processes.

Dust and Particle Sensors: Sensors that send real-time alerts of excessive dust during construction and generate long–term analysis of projects that cause excessive dust.

Electrical Insulation Tester: A handheld or stationary tool for monitoring of insulation and absorption levels of an electrical device to ensure proper electrical safety before work.

Fatigue Monitoring Sensors: Dashboard mounted camera–based analytics that are used to monitor microsleeps and fatigue levels of drivers for early intervention.

Fixed Proximity/Collision Sensor: Fixed sensors that can detect when an object, machinery or person enters a set proximity of the device to alert workers or a centralized monitoring platform.

Flame Detector: Sensors that can identify and detect when there is abnormal heat or flames.

Handheld Gas Monitor: Handheld gas monitors that can monitor for a range of different hazardous gases.

Handheld Infrared Thermometer: Handheld devices to monitor surface temperatures using infrared laser technology and eliminate the need for contact measurements.

Smart Shoes with Fall Detection Sensors: Shoes with sensors that send alerts through the cloud for assistance when a fall is detected.

Smoke Detector: Sensors that can detect smoke.

Vehicle Speed Limiters: Vehicle speed limiters enforcing specific speed restrictions in industrial equipment and over the road vehicles.

Vehicle Telematics: Vehicle sensors that can monitor and detect vehicle collisions and movements, speed, and analyze driving trends to flag unsafe operator behavior.

Voltage Testers: Electrical testing tool to monitor specific voltage outlets of a machine or an outlet to ensure safe levels or complete de-energization before work.

SOFTWARE

Asset Performance Management: Software that tracks the performance of fixed assets to optimize their use. Companies use this type of software to extend the life of their fixed assets and to reduce the costs of maintenance.

Barrier Risk Management: Software that provides in-depth insight into asset integrity and asset health to identify any problems and recommend corrective actions.

Control of Work Software: Software for the management of business critical maintenance processes, made up of hazard identification and Risk Assessment (RA), Permit to Work (PTW) and Isolation Management (IM).

Digital Floorplan and Mapping: Digital floorplan and mapping to help first responders with evacuations in emergencies.

Digital Twin for Industrial Facilities: A digital proxy of an asset giving access to structure, context and behavior in a visualized 3D environment for better insight into asset integrity, as well as a platform for predictive analysis.

EHS Software: Software for total management of EHS related processes including incident, CAPA and EHS workflows, chemical management, risk management and safety management.

Ladder Safety App: Software for positioning ladders at a safe angle and associated training related to ladder safety and working at heights.

Management of Change (MOC): Software solution to manage changes to procedures, processes, equipment, etc. in order to mitigate risk.

Online Safety Data Sheet: Online databases of Safety Data Sheets (SDS) providing relevant safety, handling and storage information for chemicals as required by law.

Process Hazard Analysis (PHA): Software for organized and systematic assessments of the potential hazards associated with an industrial process.

Process Safety Management: Software used to prevent fires, explosions and accidental chemical releases in chemical process facilities or other facilities dealing with hazardous materials such as refineries, and oil and gas (onshore and offshore) production installations.

WEARABLES

Activity Trackers: A wearable device, typically a band worn on the wrist, which tracks worker activity, sleep and some vital monitoring for worker wellbeing.

Ergonomic Monitor: A wearable device, typically worn on the body or lower back that can monitor unsafe worker lifting and posture throughout the day.

Fatigue Wearable Monitor: A wearable device that can be worn on the body or head to monitor fatigue and microsleeps and analyze at-risk sleep behavior.

Heart Rate Monitor: A wearable heart rate monitor, typically worn on the wrist or torso, to track workers' heartbeats per minute and alert workers and management on irregularities.

Heat Stress Monitor: A heat stress monitoring wearable that can track the skin temperature and sweat rate of employees in high heat or outdoor environments to reduce risk of heat stroke and illness.

Location Geofencing: Location tracking with associated geofencing to warn employees when they enter specified geofenced sites, which may be hazardous or restricted.

Location Tracking: A location tracking wearable, worn in a variety of deployment options, to monitor the location of workers in a worksite or working remotely.

Thermometer: A wearable device that tracks body temperature to detect abnormal raises or illness.

Wearable Camera: A wearable device containing cameras and communication functionality to provide visibility and coverage for workers in the field to prevent and respond to workplace violence.

Wearable Gas Monitor: A wearable gas monitor for hands-free tracking of gas and hazardous containments, typically digital in nature.

Wearable Panic Button: A wearable device typically associated with lone worker technologies, which has a panic button or safety check feature in case of emergency that will alert emergency response centers or management.

Wearable Proximity/Collision Sensor: A wearable sensor to alert personnel if they are in danger of a collision, typically utilizing associated stationary or vehicle-mounted sensors

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