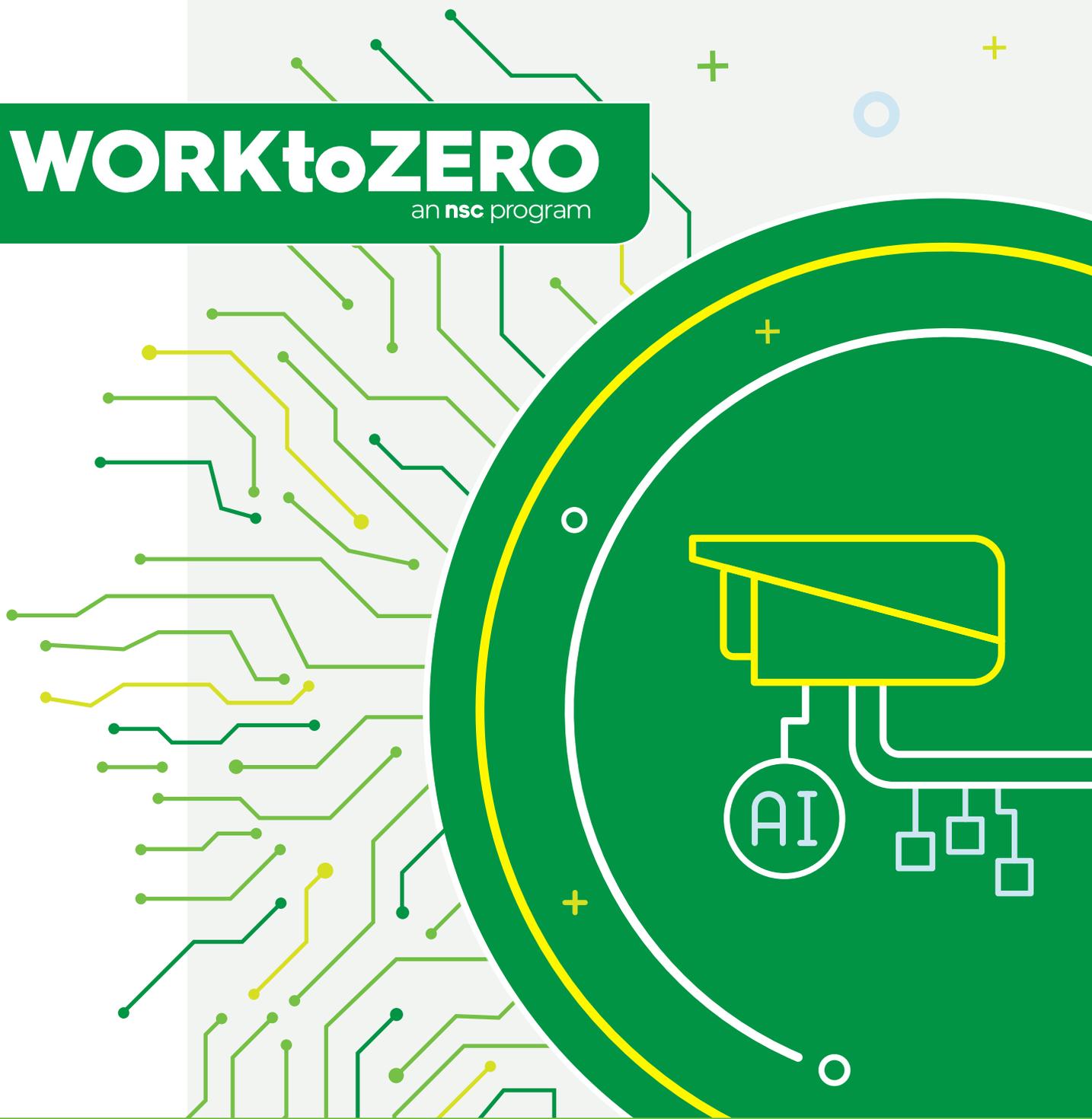


# WORKtoZERO

an nsc program



## Using Computer Vision as a Risk Mitigation Tool

# Executive Summary

Every worker deserves the promise of returning home safely from work at the end of each day, but nationwide 3.4 fatalities occur per every 100,000 full-time equivalent workers. In 2019, the National Safety Council launched its Work to Zero initiative, supported by a grant from the McElhattan Foundation, to focus on combatting the lagging decline in workplace fatalities and serious injury events. The end goal of the Work to Zero initiative is to eliminate workplace fatality risk through the use of technology.

This report finds computer vision technology, paired with sophisticated risk prediction algorithms, is capable of accurate, consistent and automatic monitoring of worker personal protective equipment (PPE), risk identification, and the detection of violence and weapons in the workplace. In addition, this technology can be used to help monitor fatigue, substance impairment and other impairing conditions when driving. Comprehensive software is available and easy to deploy across various industrial environments – from construction to warehousing to manufacturing – taking existing closed circuit television (CCTV) feeds and providing intuitive, actionable dashboards for safety leaders.

As with all technology, there are barriers to implementing computer vision technology, namely around pricing and privacy concerns. However, numerous existing systems and packages are currently on the market, which can help drive prices lower. Further, many of these systems offer the ability to anonymize employee information and likeness for enhanced privacy. It is recommended that employees at all employment levels are involved in the process of trialing and implementing new technology to voice potential concerns.

## Key Findings:

- 1. Computer vision, also referred to as camera or video analytics, is simple in concept.** Cameras are paired with Artificial Intelligence (A.I.) and machine learning tools to identify and communicate the root causes of workplace incidents. This technology can rapidly review old footage to find and serve relevant post-incident images and clips.
- 2. Currently, the most effective object detection computer vision systems are based on deep learning.** This allows A.I. enabled cameras to better identify key objects, including those that may lead to incidents or help prevent injury.
- 3. Many systems offer the ability to monitor employees in their workspace, learning their habits and understanding what activities may lead to incidents.** Computer vision technologies continuously learn these associations and turn them into tags to monitor and analyze moving forward.
- 4. Computer vision tracks and logs data associated with a workplace injury and uses that information to predict when incidents could potentially happen.** Accordingly, it is ideal for industries with material movement and heavy machinery, such as manufacturing, logistics, construction sites and industries maintaining warehouses.
- 5. Numerous use cases for computer analytics exist, such as:** identifying when and where PPE is or is not being used, identifying safety hazards, tracking the spread of infection and predicting the possibility of workplace violence.
- 6. Several benefits to adopting computer vision technologies are present, such as the ability to support risk mitigation for human operators, increased accuracy in data collection and its application toward creating preventative measures.** Computer vision also has workplace health applications including monitoring ill employees as well as who they have interacted with and objects they may have come in contact with. Some computer vision systems can also be trained to recognize best practices during emergency situations.

# Introduction and Background

## Work to Zero

Despite concerted efforts to reduce serious injuries and fatalities (SIF), workplace fatalities have not seen a drastic reduction in the United States. Between 1992 and 2020, the OSHA recordable injury rate dropped from 8.9 injuries per 100 workers to 2.7 injuries per 100 workers, a nearly 70% decrease (Injury Facts, 2021). In the same period, the workplace fatality rate (preventable fatalities) dropped only 17%, with 4,113 preventable fatalities occurring in the workplace in 2020 (Bureau of Labor Statistics, 2021). There were 4,764 total fatal work injuries recorded in the United States in 2020, an 11% decrease from 5,333 in 2019, although this is likely due in part to the economic disruptions triggered by the COVID-19 pandemic. Between 2019 and 2020, the fatal work injury rate fell from 3.5 to 3.4 per 100,000 full-time equivalent workers. Thus, the expansive efforts by companies to reduce workplace injuries do not seem to translate into impactful reductions in workplace fatalities.

Recognizing this trend, in 2019 the National Safety Council (NSC) kicked off its Work to Zero initiative, supported by a grant from the McElhattan Foundation, to focus on combatting the lagging decline in workplace fatalities and serious injury events. The end goal of the Work to Zero initiative at NSC is to eliminate workplace fatality risk through the use of technology. Using decades of insight, data, and leveraging the expertise of its membership and network, Work to Zero will identify promising technology innovations geared towards eliminating workplace fatality risks within our lifetime.



**Computer vision is a field of artificial intelligence that trains computers to interpret and understand the visual world. Using digital images from cameras and videos and deep learning models, machines can accurately identify and classify objects – and then react to what they “see.”**

## Digital Technology as an Approach to Reducing Workplace SIF Events

In 2020, the Work to Zero initiative released its first white paper detailing the top eighteen hazardous workplace situations (e.g. work at height, machinery operation, confined space entry) and associated situational risks (e.g. falls, struck-by, hazardous gas exposure). The report went further and identified the systemic contributing factors (e.g lack of training, fatigue and work design) that can exacerbate risk within these hazardous situations. Next, NSC worked with Verdantix researchers to identify over 100 relevant EHS technologies helpful in mitigating both situational and systemic risks and mapped these risks in ways surveyed EHS professionals perceived to be most effective.

The initial Work to Zero report identified several key technologies garnering the most interest and value among the surveyed professionals. In addition, safety leaders within the Campbell Institute at NSC have demonstrated interest in assessing and evaluating certain technologies – such as virtual reality, wearables, sensors and unmanned aerial vehicles (drones). This report is one in a series of reports taking a more focused look at specific risks and an associated promising technology.

This priority technology report will look at the use of computer vision technology for identifying injury and fatality risks in the workplace. It will cover the various use cases associated with computer vision and its ability to prevent injury, the spread of illness and fatalities. Additionally, it will explore the identified and proposed benefits of this technology as well as the limitations and risks associated with adoption. Finally, this report will shine some light on the vendor landscape associated with computer vision's application to the workplace.

## Computer Vision's Role in Workplace Safety

Closed Circuit Television (CCTV) systems operate around the globe, utilized in applications ranging from security to workplace safety. Currently, CCTV systems are, by and large, manually operated where a person or team of people has to sit down and watch video or wade through images to discover the information needed to do their jobs. For instance, in cases of workplace safety, an individual would have to sit down after an incident and search video for the incident event and make observations as to what led to it. The information would then be passed on to relevant personnel to take note of and to address any existing gaps in the management system.

Manually operated CCTV systems, however, offer untapped data potential (Han, S. et al., 2013). With the development of Artificial Intelligence (A.I.) technologies, coupled with CCTV, users can train systems to understand situations leading to injuries or fatalities in the workplace, enabling better prevention in the future (SDM, 2020). The technology can target potential risks by identifying, classifying and indexing objects in video surveillance and turning them into quantifiable data delivered to safety professionals as actionable insights. Computer vision technologies can better capture trends leading to incidents, creating valuable intelligence for both employers and employees in building a safer work environment (Verdantix, 2022).

## Research Approach

**The methodology of this paper consisted of two separate actions:**

- **Identification of case studies, clinical trials and use cases for computer vision technologies**
- **Development of a market landscape shortlist of relevant vendors associated with this technology**

Data for this paper came from literature reviews of several academic and industrial journals related to this technology (see References). Additionally, Verdantix researchers utilized case studies and interview data from previously published reports and interviews (Verdantix, 2021). The vendor shortlist was compiled through a search of Verdantix market databases and external research. Vendors were selected based on the size and maturity of the firm, demonstrable use cases and applicability to the U.S. market to present a snapshot into some of the available solutions in the marketplace. Further, vendors were assessed by their computer vision technology's ability to identify risks, specifically PPE and workplace violence. This paper will focus on aspects of computer vision technology specifically tailored to identifying, quantifying and reporting workplace incidents that may lead or have led to illness, injury or death.

## Introduction to Computer Vision

Computer vision, also referred to as camera or video analytics, is simple in concept. Rather than having humans live-monitoring and spending hours post-incident viewing video and images, trying to learn what caused workplace incidents and attempting to prevent them in the future, cameras (e.g. CCTV and other image or video data) are paired with A.I. and machine learning tools to identify and communicate the root causes of workplace incidents. This technology can rapidly review old footage to find and serve relevant post-incident images and clips (Verdantix, 2022).

**Key advances in computer vision's capabilities have allowed it to become an essential tool for managing risk. Currently, the most effective object detection computer vision systems are based on deep learning, allowing A.I. enabled cameras to better identify key objects that may lead to incidents (e.g. working at height, moving machinery, unstable items on shelves) or ones that may help prevent injury (e.g. hard hats, high-vis vests and other PPE). The speed, number and accuracy of computer vision technologies have greatly improved, allowing systems to monitor multiple workers and threats to their safety, and to ensure the information leads to timely prevention (Verdantix, 2022).**

Research and design in object identification and tracking have naturally evolved into human activity recognition. Today, many systems offer the ability to monitor workers in their workspace, learning their habits and understanding what conditions lead to incidents. This allows for better understanding, training and observation to prevent future incidents. In all these situations, computer vision technologies turn associations, whether static objects or people, into tags to watch and analyze moving forward.

Due to its ability to track and log data associated with a workplace injury, as well as being able to instantly use that information to predict when incidents can potentially happen, computer vision is ideal for industries regularly moving material or using heavy machinery, such as manufacturing, logistics, construction sites and industries maintaining warehouses (Zhang, Shi, & Yang, 2020).

## Use Cases

Computer vision technologies are useful in identifying when and where PPE is being utilized. For instance, if a warehouse requires the use of hard hats or high-visibility vests in specific areas, computer vision can be trained to identify the requirement area and whether or not the appropriate PPE is being used. If a person is not properly wearing their hard hat, this can be flagged instantly, allowing management to intervene and ensure safe work conditions and compliance with utilization of PPE as stated in the organization's policy.



**Numerous use cases for computer analytics exist, such as: identifying when and where PPE is or is not being used, identifying safety hazards, tracking the spread of infection and predicting the possibility of workplace violence.**

Computer vision can also identify safety hazards. The technology can be trained to identify when objects may be a risk. For instance, using the same warehouse example, if the aisles are meant to be kept clear of obstructions, the A.I. enabled cameras can identify when a box or a ladder is left out for a period of time. The item can then be flagged as a potential injury risk to those operating machinery or individuals working the floor. Additionally, systems can automatically recognize when an employee is working at height without approval and provide alerts to the safety professional. Finally, the technology can be used to identify any other potentially hazardous conditions (Shin, Jin, & Kim, 2021), such as spills, loose flooring, debris, etc. (Cheng & Wang, 2018), which can be instantly pushed to employees via mobile alerts. This proactive hazard recognition allows employees to intervene and address existing hazards, preventing the potential for injuries in the future.

One of the most recent uses for computer vision has arisen out of the COVID-19 pandemic. Employers have become more sensitive to the risks of infection to their employees and business operations. Video analytics, in this context, have been used to monitor if employees, vendors and clients are practicing social distancing and perform retrospective proximity and time-based exposure estimation by tracing known infectious individuals throughout a facility. Alerts to gaps in COVID-19 protocols can be instantly triggered, allowing management to take the necessary steps to prevent the spread of illness and ensure any individuals exposed to the virus are given adequate notice to prevent further spread and seek medical attention, if necessary (Verdantix, 2022).

Finally, computer vision is useful in identifying and preventing workplace violence. In some instances, computer vision technology can detect items that may be used to harm other people, such as weapons. It can also detect anomalies in the workplace, such as unwanted guests and unusual behaviors, triggering actions downstream. The predictive ability allows employers to take actions that may prevent confrontation from spiraling into fatalities.

It is important to note that by using computer vision, timely reinforcement of policies can be achieved. This allows for awareness and education around hazard recognition. Instead of focusing on reprimanding the workforce, this type of technology has very valuable use cases for educational training and risk identification for EHS professionals (Verdantix, 2022).

## Vendor Landscape

Most vendors reviewed in this paper have advanced capabilities with regard to worker location tracking and the ability to recognize worker appearance features, such as wearing different types of PPE. These core functionalities have been utilized to various extents for analyzing foot traffic patterns, loitering, proximity to other workers and producing alerts for workers in unauthorized areas. All vendors have dashboards to serve quick visualizations to safety professionals through a web browser or app portals. Some vendors also offer facial recognition or other identification functionality with varying levels of customization of privacy features. Additionally, some solution providers offer object, vehicle and other workspace recognition features.

All vendors appear to be utilizing established computer vision technologies (proximity, object/person recognition) and applying simple rules (spatial distance estimation) to serve seemingly advanced insights and statistics to relevant stakeholders. Some vendors offer advanced prioritization capabilities to help safety officers address the most urgent issues first.

**We assessed these vendors utilizing the below criteria:**

- 1. Risk identification**
- 2. PPE identification**
- 3. Identifying workplace violence**

Vendor	Country	Capabilities
BriefCam	Boston, United States	Full Risk and PPE Identification, Limited Workplace Violence ID
ArmourSense	Caesarea, Israel	Full Risk and PPE Identification, Limited Workplace Violence ID
Intenseye	New York, United States	Full Risk and PPE Identification, Limited Workplace Violence ID
Newmetrix	Cambridge, United States	Full Risk Identification, Limited PPE and No Workplace Violence



# Benefits of Leveraging Computer Vision

One of the greatest benefits of adopting computer vision technologies is the ability to support risk mitigation for human operators. Humans inevitably miss things when they are looking at images in support of workplace safety and the process can be extremely time-consuming. Computer vision can track multiple variables and notify operators of issues they may not have caught. Rather than replacing humans altogether, computer vision empowers operators to identify trends, abnormalities and anomalies, allowing them to take appropriate action in preventing injury and death. Utilizing computer vision as an additional resource allows EHS professionals to focus their time on other priorities.

Accuracy in data collection and using it to create preventative measures is another key benefit. As computer vision is 'always watching,' the system can accurately track and record data on events, such as near misses or recurring incidents. The ability to assess and track these cases allows the technology to predict where similar incidents may occur and thus prevent future incidents. A.I. and machine learning techniques are also effective at finding patterns in concurrent data streams, potentially revealing links between events in a workplace that increase the chance of injury or death.

With regards to illness, computer vision can track where ill employees are, who they have interacted with and objects they may have come in contact with. The employer can then notify other employees of their potential exposure and allow them to take the necessary course to prevent illness or to help recover if they have already contracted the illness. Using this technology also allows management to protect the identity of the person who originally spread the illness, as well as aid in disinfection efforts in targeted spaces to prevent further spread.

**Some computer vision systems can be trained to recognize best practices during a procedure by observing good practices as reference, assisting with worker training and highlighting deviations with visual overlays of heat maps and path lines. With additional annotations added by experienced staff, triggered automatically when process issues are detected, it can help improve the learning experience and maximize the utility of subject matter experts.**

Finally, computer vision solutions can help in emergency situations. For instance, the technology can be trained to recognize when a person stays in a space for an unusual amount of time, triggering an alert to the operator to first analyze the video and then physically inspect it. For instance, if a person falls down with an injury or illness, the system will alert the person responsible to inspect and call for help (BriefCam, 2020).

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**Rather than replacing humans altogether, computer vision empowers operators to identify trends, abnormalities and anomalies, allowing them to take appropriate action in preventing injury and death. Utilizing computer vision as an additional resource allows EHS professionals to focus their time on other priorities.**



# Considerations in Using Computer Vision for Workplace Safety

## Barriers to Adoption

As with any technology, computer vision does face some barriers that prevent its widespread adoption. One obstacle comes in the form of price. In some cases, computer vision systems require expensive equipment and installation. For some small and medium-sized companies, the costs may be too much. However, solutions to this issue exist. In some cases, vendors have been able to reduce costs by developing computer vision systems that leverage cloud-powered software and integrations with existing CCTV video management systems. Some vendors can even deliver insights from any data source, including from smartphones and handheld video cameras, regardless of quality.

The second major barrier to adoption is privacy. In recent years, the EU's adoption of GDPR rules limit the data that can be collected on individuals and how it is used. Computer vision runs into this challenge as it collects images with people's likeness, creating a variety of data points that track and predict a person's behavior, sometimes sending this data to cloud platforms for additional processing and storage, and sharing with third parties – the data GDPR aims to protect. Further, individual employees tend to be worried the potential lack of privacy may lead to them being punished for any breach of workplace safety. To help in these situations, it is imperative employers and safety professionals come to agreements with their employees over the usage of the technology. This includes being transparent about it at all stages, and even utilizing the aspects of computer vision that anonymize each individual.



## Limits of the Technology

There are two limiting factors with regard to computer vision technologies. The first is video quality. The current image quality on CCTV networks is not the best; lower pixel density in many existing camera systems leads to a grainy, unclear video feed. Low image quality greatly reduces the ability of A.I. software to identify subtle features like PPE and track objects. However, camera image quality is improving yearly. Over time, small lenses have gotten stronger, allowing for clearer images, from which A.I. software can track and categorize workplace safety risks (Verdantix, 2022).

While intensive research has gone into A.I. and machine learning methods for processing visual data, such as images and video, the technology still lacks the ability to consistently respond appropriately to unfamiliar situations the way some human CCTV monitors would. Most systems are capable of tracking common objects (e.g. forklifts, pallets, people, animals) and attributes (e.g. PPE, weapons), and apply relatively simple rules (e.g. proximity, time, IFTT) to deliver helpful insights. However, the ability to distinguish between a conversation among workers and a friendly hug compared to verbal hostility escalating to a fistfight is not yet technically possible (Verdantix, 2022).

The second major limiting factor that stands in the way of wider adoption of computer vision technologies is the camera's field of view. Currently, many camera systems have a focused field of vision, either by design in the system's layout or by the physical constraints of the cameras themselves. A limited field of vision prohibits the computer vision system from obtaining a full picture of the workspace and limits its ability to track a wider range of variables and prevent injury. However, one way to negate this downside would be to employ multiple cameras focused on different fields, and training the A.I. to learn the relationship between each view, thus creating a full picture of the target workspace (Tong, Wu, & Tseng, 2021).



## Conclusion and Future Direction

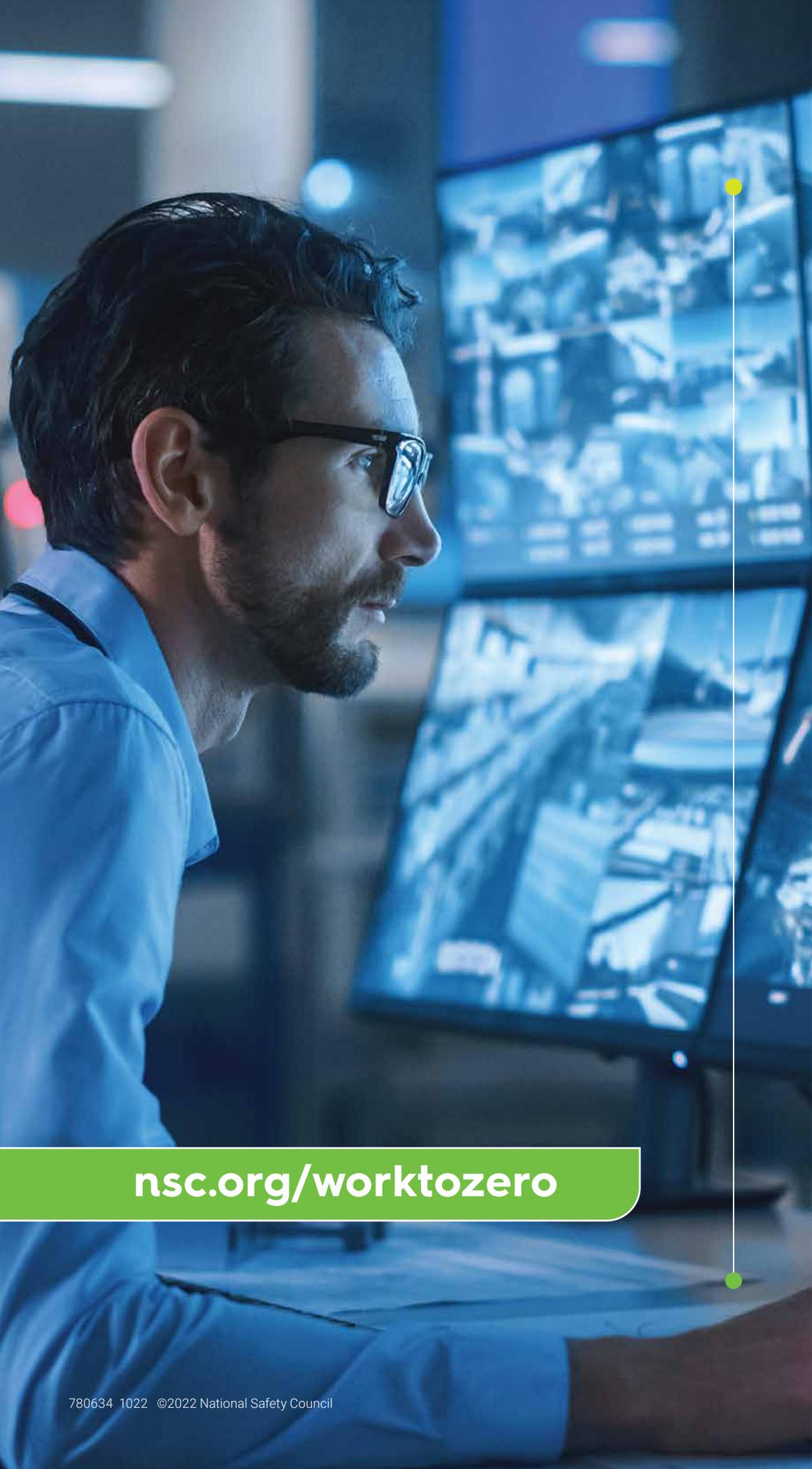
Computer vision technology, with the assistance of cloud computing, robust data synchronization systems and pre-trained A.I. and machine learning systems, is ready to deploy and deliver a real return on investment in terms of reducing the risk of workplace injury. Leading vendors offer straightforward integration with popular existing CCTV video management systems, with scalable cloud-accelerated deployment options and per-camera pricing.

By automatically collecting the most common relevant clips from multiple video feeds, workplace computer vision software can greatly increase the efficacy of previously human-monitored CCTV systems and augmenting existing staff with powerful tools to allow them to focus on solving more complex problems. With A.I. and machine learning improving rapidly, vendors will be able to offer pre-trained systems with the ability to detect and provide alerts for more nuanced scenarios observed through images and video feeds across industrial facilities – and deliver more relevant recommendations on how to improve workplace safety further.



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