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USING NEAR-MISS EVENTS TO CREATE TRAINING VIDEOS

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ABSTRACT

Haul truck fatal accidents and injuries continue to be a significant concern for the mining industry. However, the availability of high-quality training materials continues to be limited. Near-miss incident accounts, if packaged well, could help fill this gap, because for every fatality, there are hundreds of reportable accidents and thousands of undocumented near misses. Researchers from the National Institute for Occupational Safety and Health (NIOSH) collected detailed accounts of 21 near-miss incidents in virtual interviews with mineworkers at surface mining operations across the country. From these interviews, researchers created four simulation videos. The videos bring these events to life through first-person retelling and various visual perspectives of actual events. Each video exemplifies a critical safety message and a common haul truck hazard. This paper describes the process of taking narratives and turning them into impactful visual stories. NIOSH plans to co-release these simulation videos with the Mine Safety and Health Administration (MSHA) to the mining industry to raise awareness and ultimately help reduce haul truck-related accidents and fatalities in mining.

INTRODUCTION

Mobile equipment is a major safety concern in the mining industry. The movement, size, and speed of this equipment can be hazardous to other vehicles, other mineworkers, and to the operators themselves. Additionally, the mobile nature of the equipment exposes its operators to a wide array of hazards across the mine site and through changing conditions. In December 2021, the Mine Safety and Health Administration (MSHA) reopened public comment on the proposed rule to require mine operators to establish a written safety program for mobile equipment at surface operations [1]. While the rule has not been promulgated further, the reopening of the comment period underscores the safety concerns around these pieces of equipment. In support of this view, an analysis by MSHA showed that incidents involving mobile haulage accounted for more than half of the fatal accidents in mining in 2020 [2].

Haul trucks account for a large part of the mobile equipment on mine sites. Specifically, haul trucks are estimated to account for over 45% of all equipment in mining [3]. Thus, it is not surprising that they are also related to a significant part of the accidents and injuries in mining each year. In 2021, 6 of the 23 fatal accidents were related to haulage trucks [4, 5]. This is a continuation of the trend where 5 and 6 of the 27 fatal accidents in 2018 and 2017, respectively, were haul truck related [4, 5].

As evidenced by the data, mobile equipment and haul truck accidents in particular persist despite the concerted efforts from various groups to prevent them. Previous analyses have attributed these accidents to loss of vehicle control, lack of hazard recognition ability, and human performance [6-11]. More recently, researchers at the National Institute for Occupational Safety and Health (NIOSH) found that most of the 91 haul-truck-related fatal accidents from 2005 to 2018 resulted from a haul truck interacting with an environmental hazard (e.g., colliding with a berm, slipping on ice), and many of these events were initiated by the operator's loss of situational awareness or loss of control [12].

Nevertheless, analysis of fatal accidents is often limited because the primary witness to the events—the operator—is typically deceased [9,12]. However, lower-severity accidents and near-miss incidents may provide a potentially untapped resource to focus safety efforts. Beginning in the 1930s, Heinrich originally suggested that there was a relationship between fatal accidents, serious injuries, and near misses that is now referred to as the "safety triangle," because in his estimation for every fatality there are hundreds of accidents and thousands of near misses [13]. Despite mixed results in reproducing the specific ratio, the concept has generally been proven true empirically supported [14] and has been shown to be specifically applicable to mining [15].

Research has also found that near misses are a leading indicator of the potential for serious accidents [16]. As such, it has also been shown that developing and promoting a near-miss reporting system can help improve safety culture and increase positive behavior changes [17]. An effective near-miss reporting system also allows organizations to tap into the valuable information from experienced employees. Further investigation of these incidents can provide additional information and a fuller context to the safety challenges.

In the case of haul trucks, NIOSH researchers have begun to follow up the surveillance analysis of fatal accidents to clarify why haul truck accidents continue to occur. NIOSH researchers are using the knowledge elicitation techniques including cognitive task analyses (CTA) and the critical decision methodology (CDM) to interview haul truck operators [18]. These interviews provided a better understanding of how haul truck operators perceive hazards, skills and expertise, and training, and how they respond to challenging or nonroutine scenarios. The CDM interviews specifically focus on lessons learned from near-miss experiences from the operator's perspective.

Critical Decision Method

The critical decision method (CDM), as described by Klein et al. [19], is a retrospective interview strategy that has been used to elicit information from experienced personnel in a variety of domains including the engineering, aviation, firefighting, military, and medical sectors. The strategy utilizes a series of questions or probes to document the perspectives and decision-making strategies of individuals involved in real-life situations. By exploring these situations, researchers can document specific details, challenges, subtle cues, and mental strategies (e.g., decision making, planning, and sensemaking) that might not be uncovered using other methods [20]. Within the context of the mining industry, Horberry and Cooke found the CDM to be a useful tool in better understanding the mindset of personnel involved in incidents and uncovering important details not typically found within traditional incident investigation reports [21].

The CDM not only reveals detailed information about incidents from the perspective of experienced personnel, but according to Klein et al., the CDM was also designed to "have applied value in terms of training, system design, or development" [19]. The application of CDM to develop training programs has been shown to be beneficial in various domains, including ambulance dispatchers, aircraft pilots, and white-water rafting guides [22]. The analysis of personnel in challenging or nonroutine events provides valuable information to support improvements in the outcomes of similar situations through changes in process design. Additionally, the process of establishing precise timelines through the retelling of these events in CDM interviews can be useful in understanding decision-making processes and developing effective training materials [22].

Videos as Effective Training Materials

Due to the storytelling nature of the CDM method, incident re-creation videos are a natural output. Development of these videos has the potential to fill the need for high-quality training materials. In NIOSH's mine safety stakeholder meetings held in the late 1990s, safety trainers expressed a major concern for the need for more and better training materials [23]. Even after over two decades, the need for better training programs continues to be identified as a recurring theme in mining safety research [24-26].

Numerous studies have demonstrated that videos can be a highly effective educational tool [27-30]. Some of the characteristics of effective training videos are that they are: short (less than six minutes), conversational, include context, and signal important information [31]. In the case of near-miss re-creations, conversational tone and context are inherent because of their story-telling nature.

Not surprisingly, stories, regardless of medium, have also been shown to be a powerful way for people to learn through the experiences of others [32, 33]. Shared stories of actual experiences provide structure and direction to listeners and are more engaging than formal instruction, making it easier to remember and put what was learned into practice [23]. The components of an effective educational story include [33]:

1. *Context*: the story should include motive or background before a specific concept is introduced
2. *Interest*: the story engages learners without accomplishing any specific teaching outcome
3. *Importance*: the story underscores a concept, typically by showing what can go wrong if it is ignored
4. *Authority*: the story provides evidence for a concept
5. *Realism:* the story helps the learner put themselves in a similar situation.

Near-miss incident re-creations have the potential to take advantage of the proven training benefits of both the video medium and storytelling in general if conventions are followed. As video stories, near-miss re-creations bring learners closer to experiential learning that has been shown to improve workers' safety behavior. For example, near-miss experiences have been shown to improve hazard recognition in similar situations [34].

This paper describes the development of near-miss re-creation videos based on CDM narratives for the purpose of providing engaging, authentic, and realistic training materials to the mining sector. These videos include the perspectives of haul truck operators, strategies, and lessons learned from each incident.

METHODS

As part of a larger study to characterize haul truck health and safety issues, researchers developed a semi-structured CDM interview guide to better understand how haul truck operators respond to challenging or nonroutine scenarios. During a CDM interview, participants are asked to recall a specific incident in which they were directly involved that was particularly challenging or when their knowledge and skill played a role in the outcome of the incident. Once an incident was identified, a timeline was constructed to establish a precise sequence of events. Later phases of the interview used different kinds of probes and strategies to help the participant recall the events in detail, with the end goal of documenting the incident from the perspective of the interviewee.

Participants

To recruit haul truck operators currently employed at surface mine sites in the United States, researchers utilized both convenience and snowball sampling methods [35]. Mining companies were first contacted via email or phone communication to determine interest in participating in the study. If a mining company expressed interest, researchers worked with the mine management (e.g., mine manager, health and safety professional) to identify potential study candidates. If the potential candidate agreed to participate, a 1-hour meeting time was scheduled for the interview to be conducted over Zoom for Government. Prior to the start of the interview, researchers obtained informed consent according to the Institutional Review Board (IRB) approved protocol.

Participants in the CDM interviews included 21 employees from a variety of mines of differing geographic regions, sizes, and commodities throughout the United States including one small surface coal mine, two medium-sized surface coal mines, seven small surface stone, sand, and gravel mines, and one large metal mine. Each participant was currently employed as a haul truck operator at the respective mine site. As shown in Table 1, the median mining industry experience was 20 years, while the median haul truck operating experience was 15 years.

Table 1. Haul Truck Operator Experience [Median (Interquartile Range)]

Total Participants	21
Mining Experience [yrs.]	20 (6.5 – 26)
Mine Site Experience [yrs.]	5 (3 – 20.5)
Haul Truck Experience [yrs.]	15 (3.75 – 21)
Haul Truck Site Experience [yrs.]	4.5 (3 – 11.25)

Data Collection

All interviews took place using the Zoom for Government platform during each participant's regular work shift and lasted approximately one hour. Each interview was conducted one-on-one with members of the research team. There was a minimum of two researchers present, one serving as the interview lead and the other acting as notetaker. All interviews were audio recorded and transcribed for data analysis.

VIDEO CREATION

Narrative Selection

To identify near-miss accidents appropriate for video re-creation, the CDM interviews were first reviewed by researchers to identify narratives that reflected the most common haul truck-related fatal accident types that occur in the mining sector. Specifically, Bellanca et al. [12] identified that the most common haul truck-related fatal accident types from 2005–2018 were vehicle-environment interactions, followed by vehicle-person, person-vehicle-environment, and vehicle-vehicle interactions. Table 2 details the accident types that were identified in the CDM interviews compared with the reported prevalence of fatal accidents. It is important to note that while the incidents were not specifically selected during the interview to match the prevalence, efforts were made to capture as much variety as possible. (i.e., when trying to decide between more than one near miss described by a participant, the most interesting and unique incident that could be readily recalled was selected).

Table 2. Percentage of Accident Types.

	Fatal Accidents [6]	**CDM* (n=23)**
Vehicle-Environment	54%	43%
Vehicle-Person	15%	4.5%
Person-Vehicle-Environment	11%	13%
Vehicle-Vehicle	9%	35%
Environment-Vehicle	2%	4.5%

* Two near misses are counted twice to account for all possible outcomes.

Once categorized, the near-miss incidents in each category were reviewed to determine which narratives were most suited for a visual re-creation. As a part of this review, researchers used the following prioritized criteria:

1. *Clear message*: Narratives with a hazard, skill, or training point that was identified by the expert participant were targeted.
2. *Visual component*: Narratives with one or more components that would benefit from a visual representation to clarify the events were targeted (e.g., spatial relations or juxtaposition of objects).
3. *Level of complexity*: Narratives that were too complex or too simple were excluded (e.g., too many heuristics).
4. *Level of generalizability:* Narratives that focused on specific equipment or environmental factors were excluded (e.g., specific truck operation).
5. *Availability of assets*: Narratives involving 3D assets that could be easily made, acquired, or modified were ultimately selected.

Based on these criteria, one main narrative was selected as the basis for each of the top four accident types. Researchers reviewed the transcript and timeline of these selected interviews to identify key events and details that were then used to create a storyboard. The storyboard included the key facts (e.g., equipment used, location), main events, participant quotes, and suggested camera angles that could then be used to create the assets and sequence the video.

3D Model Asset Creation

The 3D representations of the mining equipment in the videos were initially purchased from TurboSquid—an online 3D model repository. The vehicles were modified with 3DS Max software to add additional geometry and details, functionality such as object rotation points, UV mapping, and unit/scale setup. Additional assets, such as rigged characters and animations, were obtained from Mixamo or created from scratch with 3DS Max. The animations used an Inverse Kinematics (IK) skeleton to produce keyframe animations. Additionally, Adobe (Substance) Painter was used to create the realistic physically-based-rendered (PBR) textures and materials for all environmental and equipment assets in preparation for implementation into Unity game using the dynamic High-Definition Render Pipeline to render realistic lighting and shadows (Figure 1).

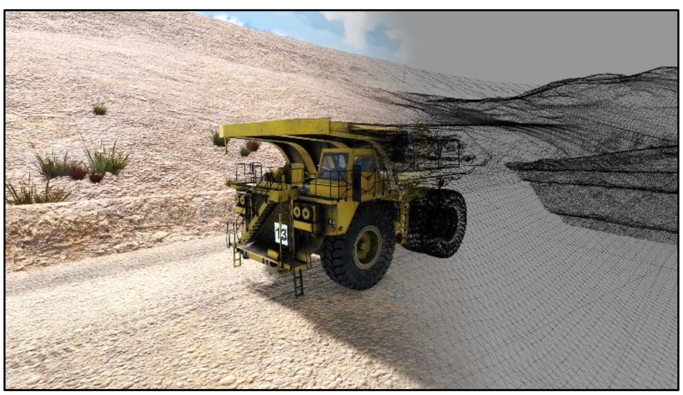

Figure 1. Screen capture from Unity displaying the underlying geometry of the environment and equipment on the right transitioning to the final rendering on the left. The screen capture is taken from video 4: "It's not a Race."

Similarly, the surface stone, sand, and gravel mine environment used in videos 1 and 3 was also purchased from TurboSquid. It was created using photogrammetry and modified using 3DS Max. This same mine was extensively modified in 3DS Max (i.e., geometry and resolution improvements) as well and Adobe Painter and Photoshop (i.e., texture and coloring detail) to create the surface coal mine for video 2. The surface mine environment for video 4 was modeled from scratch in 3DS Max using reference photos of surface dump sites and textured with Adobe Painter.

Video Sequencing

The game development engine Unity not only facilitates the creation of immersive interactive environments, but it can facilitate the rapid creation of video sequences using the developed 3D assets. The engine Unity provides a feature called "Timeline" which allows assets within a scene to be activated, deactivated, and animated using keyframes. Rather than creating an interactive application, the engine can export the arranged sequence into a video format for further editing and refinement.

For these near-miss reconstruction videos, many virtual haul trucks were simulated within Unity using its built-in physics engine. These haul truck simulations were then saved as animation clips and sequenced within the timeline feature which allowed for more precise timing of the motion of the haul trucks to reflect the near misses more accurately. Previously developed human animations were also placed within the timeline to re-create the responses of miners within the scene (e.g., a haul truck driver needing to brake suddenly to avoid a collision). The cameras used to capture the video itself were also animated within the timeline to allow for dynamic camera motions like camera pans and precisely timed camera changes to emphasize action within the simulation. This method enables the rapid creation of video content and allows for rapid iteration. After the video sequence is generated in Unity, the video is imported into a video editing software (i.e., Adobe Premiere) where sound effects and voice narration are then synchronized with the video.

Video Narration

In parallel with the development of the visual components of the near-miss re-creation, researchers developed scripts to narrate the event. The scripts for all four videos followed the same format: common introduction, specific introduction, first-person narrative, take-away message, and best practices. The narrative scripts were developed to enhance the impact of the finished videos by adhering to the tenets of effective video creation and storytelling. That is, the words work in concert with the visual elements to complete or enhance the five components: context, interest, importance, authority, and realism [33].

Context is achieved through the use of a common introduction that informs listeners of the purpose of the background of the video series. It is also supported by the visual introduction that sets the stage for the story by providing an overview of the area of the mine where the incident will occur. The common introduction is:

> *MSHA tracks accidents, injuries, and fatalities across the mining industry, but what about all those close calls that go unreported? A near miss is one bad thing away from being another statistic. There are hundreds of accidents and thousands of near misses for every fatality. This video series draws from actual near misses shared by haul truck operators across the country.*

The common introduction also gives the video authority by supporting the authenticity of the scenario. The common introduction identifies that the scenario is taken from interviews with actual haul truck operators. This fact also emphasizes that the event actually happened and was a critical lesson learned by haul truck operators.

Interest and realism are addressed by the first-person narrative form. Each video re-tells what the operator was doing, seeing, and feeling as the events of the incident play out on the screen. Specific words and phrases were taken verbatim from the CDM interview transcripts to add to the authenticity and realism of the story.

Lastly, the importance of lessons learned is incorporated through the dramatic visuals, first- and third-person repetition, and best practices. Each video includes an implication of what could have happened, underscoring how close the near miss was (e.g., view from the edge of the highwall) or how real the danger was (e.g., truck engulfed in flames). These consequences are paired with a take-away message. Each of the four videos incorporates a simple theme at the start of the video to prime the viewer for the deeper message contained in the action. Then, the opening theme is repeated at the end of the video to drive home the main idea. This moderate repetition of messaging was deliberately included because it has been shown to lead to more thought and understanding, and thus improve persuasion to take the action specified by the MSHA best practices at the end of each video [36].

Together, these videos are intended to communicate vigilance, proactivity, decision making, and communication strategies that have been identified by expert haul truck operators as important for safe operation.

NEAR-MISS VIDEOS

Through this development process, researchers created four near-miss incident re-creation videos that each focused on a critical skill or area of expertise identified by haul truck operators in different locations. Each video is summarized below.

Video 1: "It's the Little Things"
Accident Type
Vehicle-environment

Location
Haul road at a surface stone, sand, and gravel mine

Description
A haul truck operator hit a bump in the road causing the passenger door to pop open. He reached out to close the door, jerked the steering, and nearly went through the berm into the pit.

Message
This video is an example that involves a haul truck traveling down a haul road where small hazards can lead to big consequences … [1st person narration] … This time the driver was able to drive away, but next time he may not be so lucky. Small hazards can have big consequences. It is important to have good housekeeping practices and maintain your roads; don't let yourself get distracted while driving; and don't let mistakes repeat themselves. Operators and management should work together to get problems fixed as soon as possible.

Figure 2. Still frame from video 1:"It's the Little Things," where the operator is reaching to close the door that popped open and is not wearing a seat belt.

Video 2: "Think on your Feet"
Accident Type
Person-vehicle-environment

Location
Haul road at a surface coal mine

Description
A haul truck operator learned that his truck was on fire from a passing water truck operator and exits the truck using his wheel as a step after the fire suppression fails to activate.

Message
This video is an example that involves a haul truck catching on fire, where maintaining situational awareness saved this operator's life … [1st person narration] … The driver was able to escape safely because he knew what his options were and was able to change his plans when things didn't work out. Knowing your truck is critical to being able to think on your feet to find a creative solution. It is important to inspect your truck before you operate it and don't drive it if there are any safety concerns. Also, pay attention to changing conditions and look out for your fellow mineworkers. Operators and management should work together to make sure everyone is staying safe.

Figure 3. Still frame from video 2: "Think on your Feet," where the flames engulf the operator's cab when he stops the truck.

Video 3: "Don't Make Assumptions"
Accident Type
Vehicle-vehicle & Vehicle-person

Location
Parking area at a surface stone, sand, and gravel mine

Description
Several haul trucks are parked in close proximity, taking a break. A mechanic parks in the blind spot on the right side of one of the haul trucks to perform work. The haul truck operator runs over the mechanic's truck when resuming work.

Message
This video is an example that involves a haul truck running over a light-duty vehicle where assumptions had dangerous consequences … [1st person narration] … In this example, the mechanic assumed that the haul truck operator knew that he was there even though he parked in his blind spot, and the haul truck operator assumed that the mechanic had left because he saw another light-duty vehicle even though he did not check. It is important to practice positive communication, maintain situational awareness, and follow parking policies and procedures. Though no one was injured here, if the mechanic had been on the other side of his truck or the operator had turned his wheels slightly, the consequences could have been fatal. Operators and management should work together to ensure that everyone understands the rules and knows the location of their fellow mineworkers.

Figure 4. Still frame from video 3: "Don't make Assumptions," where the haul truck is about to run over the door on the mechanic's light-duty vehicle.

Video 4: "It's not a Race"
Accident Type
Vehicle-vehicle

Location
Dumpsite at a surface metal mine

Description

A haul truck operator approached a dump site with a cross-traffic pattern. As the operator realizes that the unloaded truck leaving the dump is not going to stop, the operator slams on the breaks to avoid a collision.

Message

This video involves a haul truck racing to get out of the dump area where a collision was narrowly avoided … [1st person narration] … The cross-traffic pattern at this dump site presents an additional hazard to drivers. While this risk can be mitigated with signage and right-of-way rules, communication and situational awareness are key. Racing to get through the intersection is not only dangerous, but the resulting hard stops are also bad for the operator and equipment. It is important to maintain good communication with other operators around the site, especially at pinch points. Also, follow procedures for right of way, avoid rushing, and look out for other mineworkers. Operators and management should work together to make sure vehicles can maintain safe distances.

Figure 5. Still frame from video 4: "It's not a Race," where an unloaded haul truck nearly collides with a loaded haul truck.

DISCUSSION

This paper describes the development and methodology of near-miss incident re-creation videos as a potentially untapped source of training materials for the mining industry. Though other incident re-creations have been produced for mining such as those that frequently accompany investigation reports from the New South Wales regulator [37], what makes these different from other incident re-creations is the who, how, and what contributed to their development.

These near-miss incident re-creation videos directly employ the expertise of haul truck operators with firsthand experience of an actual event—*the who*. As described above, the authenticity afforded by the direct account of a haul truck operator is an important factor in making effective training [33]. The first-person format used in these videos also allows the operators to speak directly to other operators (i.e., trainees), which can help normalize the discussion of hazards and incidents at the mine [38] and offer credibility to the trainer.

Another key feature of this video series is the level of realism generated by *the how* of the video creation. The use of high-quality 3D assets and simulation provide the potential to increase engagement and interest in these videos. Being able to see the event unfold from a holistic perspective also opens up the potential for greater understanding of the progression of the events and hazards present at the site. Furthermore, the overview depictions employed here may not be possible with other media due to the dangerous nature of the situation or the cost prohibitive nature of other options.

Lastly—*the what*—the choice of using near misses, as opposed to fatal or serious accidents, as the basis of these videos has not commonly been seen. Additionally, near-miss reporting typically does not contain sufficient detail to generate a full re-creation, and as described by the participants in the study, many mines do not have any formal near-miss reporting at all. This lack of detailed information can result in truncated discussions or false assumptions. The use of the CDM interviews for these videos facilitated the intentional capture of the perceptions, cognitions, and lessons learned from these events. This allowed for the better capture of motives (e.g., speeding up to beat another truck) and causes (e.g., a door popping open) that may have been missed in a similar fatal accident where the operator was killed. Using near misses is also advantageous in terms of proactivity. In this case, you don't have to wait for a fatal accident to develop impactful training that will hopefully prevent one.

Beyond the methods, the videos themselves speak to the vigilance, proactivity, decision making, and communication strategies identified by haul truck operators. A recurrent theme which surfaced repeatedly was that of situational awareness. Situational awareness is defined as the perception, comprehension, and projection of objects in the environment [39]. In other words, being able to see, feel, hear, touch, and smell what is going on around you, understand what it all means, and know what to do about it. The four videos describe specific events where the operator needs to know what is going on around them and take safe actions. Whether it is noticing small hazards, being aware of the condition of your truck, or being aware of those around you, these videos give specific examples of what to look for or situations that can get you in trouble.

These videos also acknowledge the coordination across mining organizations and need for levels of controls to ensure the safety of everyone. As Reason describes it, "the pursuit of safety is not so much about preventing isolated failures, either human or technical, as about making the system as robust as is practicable in the face of its human and operational hazards…" [40]. The examples shown in these videos demonstrate both control successes and failures and the importance of having protections in place to prevent an accident.

LIMITATIONS

Though these videos were developed following the empirically tested criteria of video creation and storytelling, they have not been evaluated for training effectiveness. Research should be done to verify that these specific materials achieve the desired results. Another limitation was that in the process of the creation of the videos a few noncritical details were changed from the CDM interviews to enable better visual depictions. For example, in Video 2, researchers changed the operator who observed the truck on fire from a blade operator to a water truck operator because a 3D model of a blade was not readily available. Finally, it is also important to note that each video reflects the perspective of a single operator. Researchers did not confirm or communicate with any other individuals about the events described. Finally, while these operators are experts, memory recall can diminish over time.

CONCLUSION

Taken together, the interplay of the features of these near-miss incident re-creation videos has the potential to tell impactful stories and provide quality training materials. The use of the CDM to gather actual near-miss accounts as source material demonstrates the importance of listening and understanding the challenges faced by operators and frontline workers. The use of high-quality 3D assets and simulation provide context and perspective beyond traditional materials. Lastly, the narration techniques bring the stories to life. These videos try to make the safety ideas more tangible so that operators can pinpoint specific behaviors or thought processes they can adopt to operate more safely. Ultimately, NIOSH plans to co-release these simulation videos with MSHA to the mining industry with the aim of reducing injuries and fatalities.

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DISCLAIMER

The findings and conclusions in this paper are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of any company name or product does not constitute endorsement by NIOSH.

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