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SAFETY MAVERICKS: COLLISION AVOIDANCE SYSTEMS IN LOAD AND HAUL

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ISSUES IN COLLISION AVOIDANCE

Mine safety is a journey, with each step building on and integrating with the previous steps. Implementing a Level-9 vehicle intervention system requires first adopting Levels 1-8. Photo: Wabtec

North American Mining *discusses collision avoidance in surface load and haul operations with experts from Hexagon, Matrix Design Group, and Wabtec.*

by Jonathan Rowland

Load-and-haul operations present "significant challenges" for collision avoidance, as Mitch Tanzer, Wabtec Digital Mine's global commercial director, told North American Mining. This is due to a mine's "complex and dynamic nature" with a high volume of vehicle interactions, particularly in dump zones and haul roads, where heavy equipment – haul trucks, wheel dozers, and shovels – operate in proximity.

"These vehicle interactions increase the collision risk, especially when environmental factors like dust, rain, or fog compromise visibility. Changing road conditions, varying vehicle speeds, third-party contractors, and the presence of personnel on foot further add to the dynamic nature of mining operations and complicate collision avoidance efforts."

These risks are compounded "when factoring in human error," noted Josh Savit, principal advisor, Mining, Hexagon. "Operators must maintain constant awareness of their surroundings, which can be challenging during long, monotonous shifts. Fatigue, distraction, and miscommunication can all contribute to collisions."

Human factors can also prevent the effective implementation of collision avoidance technologies, added Brian Jones, Matrix Design Group's VP of sales and marketing, who noted that operator buy-in can be a challenge. "Camera-based systems must also be kept clean in dusty mining environments to function correctly – which requires regular human intervention."

"It is important to understand that collision avoidance systems (CAS) are, thus, only part of the answer," continued Savit. Any zero-harm strategy "must be backed by a proven change management methodology to ensure a meaningful safety culture prevails. Even the best systems integrating collision avoidance and operator awareness systems will never be 100% effective. Operators must still be engaged and re-engaged in a continuous improvement cycle."

The best collision avoidance strategies "involve a combination of advanced technology, robust operational practices, and human-factors engineering," agreed Wabtec's Tanzer, who provided the following breakdown of these three elements:

- Advanced CAS solutions include instant heading on take-off, curved beams, and accurate positioning that minimizes nuisance alarms. Real-time system health checks ensure the system's reliability. Diagnostics and fault reporting

enable prompt maintenance and reduce the risk of system failure.

- Robust operational practices include implementing mining best practices, change management, training programs, and regular maintenance plans.
- Human factors engineering (HFE) involves designing products and systems so people can use them safely, comfortably, and efficiently. HFE is vital for operator acceptance and trust in the technology. Creating user interfaces that provide clear, context-specific alerts, such as voice instructions and simple graphics on the display monitor, enables operators to respond effectively to collision threats.

CAS and autonomous haulage systems

Autonomous haulage systems (AHS) appear to offer a route to reduce the risk of collisions significantly, as they remove the primary contributing factor to most accidents: human error. According to Tanzer, however, the picture is more complex, firstly noting that there is no such thing as an entirely automated mine environment – and likely will not be anytime soon.

"By the end of 2025, more than 1,800 haul trucks are expected to be operating in AHS. However, that still leaves many manned haul trucks in operation," the Wabtec expert reminded us. "Even if a mine's haul trucks are all automated, many other vehicles operate at a mine, such as light vehicles, dozers, scrapers, graders, and fuel trucks, that are not automated. From an operational point of view, there will also be times and areas within a mine that do not allow for AHS functionality, such as maintenance areas and areas beyond the geofence."

Tanzer explained that these hybrid environments – where some vehicles are automated and others are not – pose additional challenges for collision avoidance. "Current AHS solutions often use proprietary protocols that prevent interoperability with third-party CAS technologies. This creates duplication and potential failure modes, such as when an AHS machine switches from autonomous to manned operation, but the operator fails to activate the CAS."

Mining autonomy involves "more than deploying the latest sensors and machine learning algorithms," added Hexagon's Savit, who described it as "orchestrating the fleet and understanding the broader mission and daily production goals." In that context, "each truck's payload, interactions with other equipment, and ultimate destination are critical data points in ensuring it arrives at the right place, at the right time, with the right payload."

According to Savit, Hexagon believes better situational awareness is the key to interactions between autonomous and manned machines. "Many existing AHS are rules-based systems, moving the truck from point A to point B on a defined route. We are working on more aware autonomy at several projects, which include autonomous world perception to enable object detection and operator vehicle-to-vehicle and vehicle-to-person awareness. Ultimately, Level-9-type vehicle interactions will likely evolve into advanced driver assistance systems (ADAS) capability in mining and remove some current limitations around AHS and manned fleet interactions."

This could mean "non-autonomous vehicles being able to maintain greater optimum speeds when in the autonomous zone, for example, or having shorter following distances than are currently allowed," continued Savit. "The situation today is more often full autonomy or manned operations, but technology should allow us to move towards mixed, assisted decision-making for operators, combined with semi-autonomous operations. That said, unlike for road users, there is a production mission involved in mining, so everything must be done with productivity in mind – and all the fleet orchestration that entails."

Autonomous haulage systems appear to offer a route to reduce the risk of collisions significantly, as they remove the primary contributing factor to accidents: human error. Image: Hexagon

The age of artificial intelligence

One of the technologies that may facilitate this improved situational awareness is artificial intelligence (AI). According to Chris Adkins, mining sales manager at Matrix Design Group, "advances in AI modeling and algorithms, along with hardware evolutions, will improve the performance and customization of CAS. This may materialize in the speed, distance, and accuracy in which people, vehicles, and items are detected."

An example is AI smart cameras, which are "enhancing the landscape in which CAS operate," according to Wabtec's Tanzer. "Functions such as edge and void detection, fatigue monitoring, and the ability to detect people and objects without tags elevate workplace safety to a new level. With good interoperability, customization, and open APIs, these solutions offer a reduced time to value because, as a system is commissioned, it can derive immediate benefits from increased proximity detection."

However, as a CAS solution for mining, "AI smart cameras have limitations and compromises," added Tanzer. "They are yet to deliver the range capability required for heavy vehicles and lack the functionality of advanced features, such as curved beams, system health checks, and voice-based alerts. There is also a tendency for AI smart camera companies to offer limited support and services, so there are trade-offs like most products and services in the technology space."

Hexagon's Savit noted that "with good data and analytics, the time between system implementation and measuring value can be shortened from years to months or weeks in some cases." AI can also provide additional insight when identifying data correlations that might not otherwise

User interfaces should provide clear, context-specific alerts, enabling operators to respond effectively to collision threats. Pictured: Hexagon's Core display.

have been noticed, for example, between a safety event or breakdown in a particular location and the equipment or road condition. "Often, mines never identify the root cause of such issues, but the extra level of insight that connected processes provide can help address this."

According to Savit, "Hexagon believes that AI and the capabilities it provides will have a growing impact on mine fleet management and safety. Optimizing engines, predictive maintenance, user-experience workflows, and processes, such as short interval control, will be significantly enhanced by AI in the future. Advanced sensors and sensor fusion are also expected to unlock value in fleet management and performance, particularly for autonomous operations."

This last point highlights the wider operational benefits a CAS provides. "While a safer workplace inherently minimizes personnel downtime and boosts productivity, protecting equipment from collisions also enhances its availability, lowering downtime due to incidents," said Matrix VP Brian Jones. "The data acquired from these platforms can also be used for production reporting and optimization efforts without additional hardware or software systems."

"Collision avoidance is not just about keeping vehicles from interacting too closely for safety reasons," agreed Savit. "Maintaining distance between machines also makes for a much more fluid operation, which benefits traffic flow, cycle time, and overall productivity. For example, we have seen users decide rights of way based on CAS data; other mines have increased speed limits, confident they can appropriately and safely manage this through the system."

"The data and analytics derived from continuous monitoring also allow mines to anticipate potential hazards and make better decisions, further enhancing operational efficiency," concluded Tanzer. "For instance, CAS analytics can identify risky operator behavior, enabling corrective actions that improve overall site safety and productivity."

The costs of CAS

Although implementing a CAS at a mine requires significant upfront costs, all our experts agreed on the substantial long-term returns such a system provides, especially when weighed against the costly disruption and reputational harm caused by equipment damage and injury.

"Primary costs include purchasing and installing hardware and software and integrating these systems with existing mine site controls," noted Tanzer. "Additional ongoing costs are related to system maintenance, operator training, and software updates to ensure the system remains effective and reliable.

According to Matrix's Chris Adkins, specific expenses that a CAS can mitigate include:

- Safety violation penalties. The U.S. Mine Safety and Health Administration (MSHA) has implemented a 2.6% increase in civil penalties to account for inflation. A willful violation now carries a fine of $11,823, while the maximum penalty for a flagrant breach has skyrocketed to $332,376.
- Injury-related costs. The financial burden of injuries is substantial. On average, a medically consulted injury costs $42,000, while a fatality costs $1.39 million, according to the National Safety Council.
- Indirect costs of injuries. These often comprise the bulk of total injury-related expenses and are typically uninsured and unrecoverable. Examples include benefits paid to injured workers for absences not covered by workers' compensation, wage costs related to time lost through work stoppage, related overtime costs of other workers, administrative time, training costs for replacement workers, and lost productivity.
- Insurance premium increases. Accidents may significantly raise premiums for liability, workers' compensation, and business interruption insurance, further compounding the financial impact.

Regulations and CAS

While MSHA has not directly mandated CAS in U.S. surface mines, the agency's Powered Haulage and Equipment Program includes several relevant requirements for mines to:

- Identify and analyze hazards and reduce the resulting risks related to the movement and operation of surface mobile equipment.
- Identify currently available and newly emerging feasible technologies that enhance safety at the mine and evaluate whether to adopt them.
- Train miners and other persons at the mine to perform work to identify and address or avoid hazards related to surface mobile equipment.

"CAS can be used to fulfill each of these requirements," noted Matrix's Jones.

Regulation in other parts of the world is also driving adoption. "South Africa has established safety standards and guidelines that mining operations must adhere to, while, in other parts of the world, governments and regulators have provided guidelines and frameworks to encourage companies to self-mandate," said Wabtec's Tanzer. "Mining companies outside South Africa must recognize the advantages of operating without a mandate by proactively implementing best practices and safety improvements at their mine sites. Such steps will help satisfy governments and regulators without establishing a formal mandate."

For example, in Australia, the New South Wales government has introduced the MDG-2000 Guideline, which "outlines what is required when selecting and implementing collision

management systems, ensuring compliance with safety standards," Tanzer continued. "Besides the framework, regulatory bodies emphasize the need for functional safety and operational integration, pushing mining companies to adopt capable solutions that align with global initiatives such as EMESRT, the Earth Moving Equipment Safety Round Table, and ICMM's Innovation for Cleaner, Safer Vehicles. These standards ensure CAS technologies are effective and operationally integrated with existing mine site controls, enhancing their reliability and performance."

Selecting and implementing a CAS

Several critical considerations should guide CAS selection and implementation to ensure alignment with industry best practices. First is the level of existing vehicle interaction at the mine site. "Successful implementation of any CAS depends on the readiness and maturity of the baseline controls at the mine site," explained Tanzer. "Understanding EMESRT Levels 1-6 controls is essential, as inadequate baseline controls can render the technology less effective or even introduce additional risks."

"We see safety as a journey with the customer," said Hexagon's Savit, taking up a similar point. "For example, we would not offer our Level-9 vehicle intervention system to any mine that has not already been on that journey. We recommend that operations use Levels 7 and 8 for at least six months to a year to understand those systems before taking the final step."

"The system's functional performance and technical requirements must align with industry standards such as EMESRT and ICMM," continued Tanzer. "The system must also be integrated with existing controls rather than functioning as a standalone solution. The installation process should follow a structured project approach. Thorough scoping exercises, stakeholder engagement, change management, and training programs for operators and maintenance crews are critical success factors. Finally, the mine site should consider the long-term maintenance and scalability of the system, ensuring it can adapt to changing operational needs."

"While EMESRT is a linear process, we view layered safety as a cyclical, continuous improvement process," added Savit. "Revisiting customers helps increase 'stickiness,' meaning keeping up with the latest technology and ensuring it is used and applied most effectively. Supporting customers with change management and data delivery is essential to a layered safety offering."

Critical, yes, but not a silver bullet

"The mining industry tends to be conservative, but once something is proven, adoption can be swift," said Savit. "Regulation, like that being adopted by South Africa's Department of Mineral Resources and Energy mentioned earlier, is also moving fast. As an indication of adoption, the EMESRT standards, including Levels 7, 8, and 9, are now commonly used and understood in mining."

While this is positive for mine safety and operational effectiveness, it's essential to understand that simply installing CAS technology is insufficient. Wabtec's Tanzer concluded that "successful collision avoidance requires a holistic approach integrating technology with people, processes, and existing controls. Continuous monitoring, maintenance, and optimization are also essential to ensure long-term effectiveness and operator trust in these systems."