SAFETY

Keeping your distance

As mining equipment gets larger and faster, there is an increased need for operators to use proximity-detection and collision-avoidance technology to effectively overcome the equipment's blind areas. Ailbhe Goodbody investigates

Main photo: interactions between heavy machinery and light vehicles are a key source of risk in mines. The GE CAS provides 360° situational awareness of objects near vehicles

Right: common scenarios that present collision hazards in surface mines
Graphic: Modular Mining Systems

COMMON SCENARIOS

Forward Path

Take-off

Speed Limit Violations

Overtaking

Intersections

There are several scenarios in surface mining operations that can present collision hazards. Vehicle operators in mines have to accomplish difficult tasks, while increases in mine productivity have led to a proportional increase in equipment size and the number of mobile equipment units in many mines.

Hazards in the pit can include large boulders, high walls, berms, other trucks, shovels, excavators and support equipment, as well as the workers and other people on the worksite.

Evan Cardinal, applications engineer, mining at Sick, says: "Combine normal variations in environmental conditions, in-vehicle management systems, navigation systems and radio communications; the most experienced operator can be challenged by multiple distractions. Despite the best efforts of operators, accidents on mine sites remain an industry-wide problem. The reasons for accidents are diverse, so too are the collision scenarios."

Many vehicles have considerable blind spots due to their scale alone. The National Institute for Occupational Safety and Health (NIOSH), a US federal agency that conducts research and makes recommendations to prevent worker injury and ill-

ness, has studied the blind areas that operators must be aware of when operating mine equipment.

For example, Sean Martell, mining & construction sales manager at Preco Electronics, explains: "In the case of very large haul trucks, an operator will lose visibility to a hazard once the hazard is inside 46m from the rear of the vehicle, even with the use of rear-view mirrors. These massive machines need a great deal of room to manoeuvre."

In general, the main collision scenarios in surface mines are equipment-to-equipment, equipment-to-person, equipment-to-infrastructure and equipment-to-environment (loss of control) scenarios.

Surface mining uses very large equipment with significant blind areas, so heavy vehicle to light vehicle interactions are one of the most prevalent hazards.

Most commonly, accidents occur at speeds less than 8km/h and when travelling in reverse, particularly with large haulage trucks.

The ability of an equipment operator to see an approaching passenger vehicle or a vehicle parked nearby can be severely limited in many cases – examples include intersections where a berm can fully or partially obscure light vehicles, a light vehicle overtaking a heavy

vehicle on the haul road or any time a light vehicle parks near a heavy vehicle.

Todd Ruff, safety product manager at Hexagon Mining, says: "This presents a significant risk and results in one of the most common collision incidents. It is frequently listed as the highest-priority event by mines that are seeking improvements in traffic safety."

Metal-to-metal contacts in the loading area are common between shovels and other equipment that must operate in close proximity, such as trucks and dozers.

Ruff suggests: "This is a high-risk area where the dangers can be compounded by congestion and multiple activities occurring simultaneously – reversing trucks, trucks in queue, dozers and graders performing clean-up near the shovel.

"Also, the demarcation between being outside or inside the shovel's counterweight swing radius is prone to judgement errors."

Other collision risks involving two pieces of heavy equipment often comprise trucks following too closely on haul roads and reverse-motion collisions in congested areas.

Terminology

The government of New South Wales, Australia, published the MDG 2007 'Guideline for the selection and implementation of collision-management systems for mining' in February 2014, which included the following definitions:

- **CAS – Collision Avoidance System**
  The combination of technologies (i.e. SAT, PAT, PDT and CAT) that form a system.
- **CAT – Collision Avoidance Technology**
  Technology or device/s that actively scan for other vehicles or personnel and take automatic action to render the equipment.
- **PAT – Proximity Awareness Technology**
  Technologies that help to identify convergence with another vehicle, person or infrastructure (e.g. reversing mirrors, flashing lights, reversing sirens).
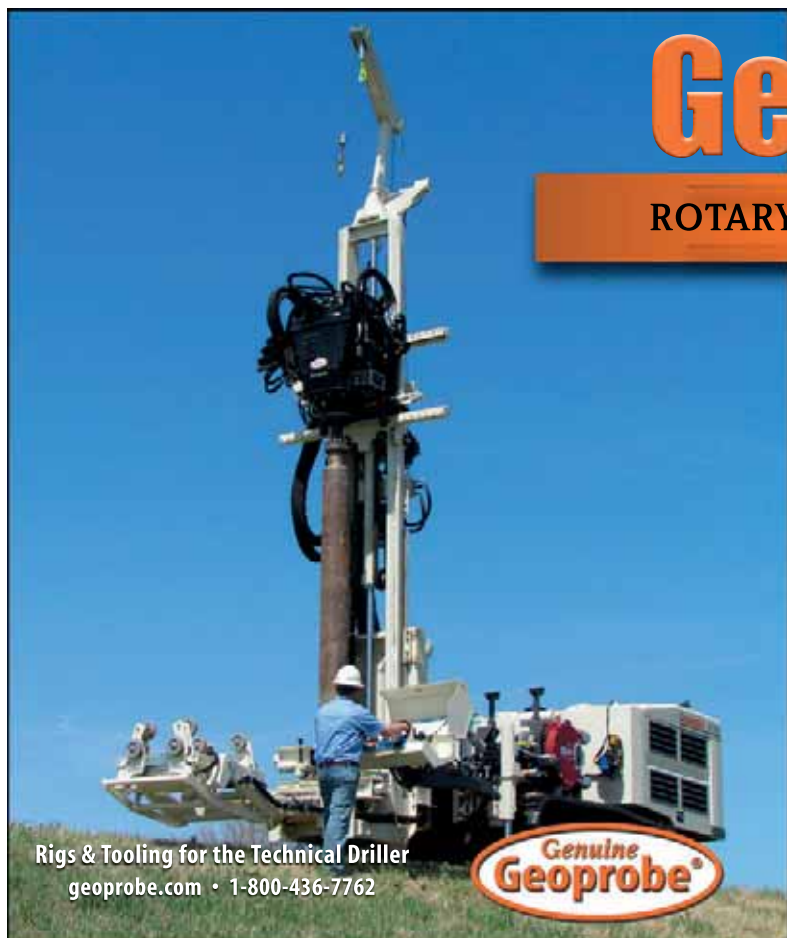- **PDT – Proximity Detection Technology**
  Technologies or devices that actively scan for other vehicles or personnel and warn of their presence. This technology does not automatically take action to prevent a collision (e.g. reversing camera with distance alarm, RFV tags, laser scanner, radar).
- **SAT – Safety Adherence Technology**
  Technologies that track and record the operation and performance of equipment for post-event analysis and training (e.g. SCADA systems, event databases, chart recorders).

Personnel on foot can also be at risk near heavy equipment any time they step out of the cab for a shift change, and in areas near maintenance shops and fuel stations.

For example, a person walking near a typical haul truck cannot be seen until they are approximately 8m away from the front of the truck. Visibility is even more limited (or even non-existent) to the right side and rear.

In addition, fatigue and distractions can play a significant role in collision hazards, especially for haul-truck operators.

Ruff says: "Micro-sleep events, or looking away from the driving task due to cell phones or other distractions, can result in lane deviations or following too close on haul roads. Extended shifts and long monotonous haulage routes contribute to this risk." ▶

Suppliers

Installing active safety systems can provide cost savings that are both short- and long-term.

By continually investing in safety and creating a culture focused on safety, companies are in a stronger position to retain personnel, create a more efficient environment and improve the productivity of the mine.

Martell notes: "Many of our customers are realising that the financial toll of an accident, including downtime, repair costs, penalties and potentially years of litigation weighs heavily on their bottom line. There is also the long-term emotional distress affecting the entire company that needs to be taken into consideration."

Mining Magazine spoke to some of the providers of proximity-detection and collision-avoidance technology to the mining industry about their offerings.

CATERPILLAR

Caterpillar has multiple proximity-detection and collision-avoidance options as part of its MineStar Detect capability set.

Vision strictly uses cameras to see what is around the machine. Cameras installed on all sides of a machine, such as a truck, or at the rear of a machine, such as a wheel loader, provide the operator with views where visibility is limited.

Object Detection is designed for machine start-up and initial movement, and it adds radars to the cameras. The radars detect fixed and mobile objects, and the system sounds an alert if the operator attempts to move in the direction of the detected object.

Proximity Awareness uses global navigation satellite system (GNSS) positioning to alert operators of nearby machines. The highly configurable system allows sites to define geo zones for avoidance, hazards and speed limits. The system also captures machine incidents and can play back the incidents for training or incident reconstruction.

Craig Watkins, MineStar commercial manager at Caterpillar, says: "We had one customer see an 87% reduction in proximity incidents and a 95% reduction in speeding events. Another customer has experienced a 67% reduction in critical proximity incidents. If a customer is willing to use the information delivered, they can achieve a significant reduction in at-risk practices and behaviour through process change, training and change management."

GE MINING

The GE Mining CAS has been developed specifically for the mining industry and allows for reliable detection in blind spots and between people, vehicles and infrastructure. Craig Hoffmann, senior product manager – collision avoidance and geospatial systems at GE Mining, explains: "The system offers the mining industry an opportunity to improve on-site safety and demonstrate their safety credentials to employees, clients and the regulatory bodies. There has not been a single injury on CAS-installed sites across the globe since GE Mining introduced the system over 12 years ago with more than 270 million hours of operation."

The GE CAS provides 360° situational awareness of objects in proximity to vehicles during stationary, slow-speed and high-speed operations in order to reduce the risk of vehicle-to-vehicle, vehicle-to-infrastructure, vehicle-to-personnel and vehicle-to-environment interactions.

The system provides real-time predictive proximity alerts with high integrity and low levels of nuisance alarms, along with powerful web-based reporting as a management tool to achieve 'zero-harm' objectives.

All vehicles using the system are fitted with a GPS receiver, vehicle-to-vehicle radio link and vehicle display unit. The system automatically detects obstacles within critical zones around a vehicle and notifies the driver with progressive audible or voice alerts and radar-style graphic alerts on the vehicle display unit.

Alarming is based on real-time predictive algorithms based on heading, speed, stopping distance, vehicle/object type, distance and geofence rules. Alarm zones are displayed visually, providing the driver with situational awareness information in order to avoid a high-risk interaction. Alarm rules are fully programmable to the mine site's requirements.

High-accuracy time-of-flight RF proximity units are used to augment GPS proximity detection for high integrity and redundancy. In addition, up to four ruggedised cameras can be installed on heavy mobile equipment as visual aids of high-risk blind spots. Cameras can be programmed to automatically switch to nominated camera views based on gearing or indicator arrows or zone of detection.

Self-test units installed on all vehicles provide real-time remote monitoring and reporting on system health, eliminating the need for test stations, and provides 'fail-safe' operation. Equipment health alerts can be sent via SMS to maintenance personnel for immediate response ▶

Cat Detect display in a truck cab

> "We had one customer see an 87% reduction in proximity incidents and a 95% reduction in speeding events"

Preco Electronics' technology is designed to help to mitigate blind-zone accidents ▶ and are logged in CAS-WEB, a web-based reporting system using a Microsoft SQL server database.

CAS-WEB can generate and view interaction reports overlaid on mine-site aerial photographs, create alerts and geofences for no-go or exclusion zones, as well as trending analysis, multiple journey replays and cluster mapping. It also generates in-vehicle monitoring system (IVMS) safety adherence reports, allows equipment health monitoring and supports SMS or email alerts via client-provided IT infrastructure.

Mine personnel are fitted with a personnel protection tag that alarms when the person enters the programmed high-risk zone of a heavy vehicle. Hoffmann says: "Both the heavy-vehicle operator and personnel on the ground receive audible and visual alerts. The personnel protection system uses the same low-frequency magnetic technology that GE uses for the underground CAS, which sees through metal and strata and is not dependent on line-of-sight for operation, providing accurate, stable and reliable proximity detection without any blind spots."

The personnel protection tag includes GPS tracking, man-down and duress alarms. The unit comes with hard-hat and belt mount options, using a belt-mounted base unit with remote alarm unit for helmet mounting.

GE CAS is installed and operational at 35 mine sites for blue-chip customers across more than 5,000 vehicle installations globally. Its users include Anglo American, BHP Billiton, South32, Rio Tinto, Vale, New-mont Mining, Glencore, Alcoa and Vedanta Resources.

GE Mining has recently been awarded a contract to install its CAS at four Antofagasta Minerals mines in Chile. Hoffmann says: "This has been a major win due to system technical superiority, integrity, real-time monitoring and reporting, integration with a third-party fatigue-monitoring solution and the GE brand and technology roadmap."

MODULAR MINING SYSTEMS

Modular released its first-generation proximity-detection system in 2006, as a part of a suite of safety-management tools known collectively as MineAlert.

This suite now includes Modular's fourth-generation CAS, which monitors and notifies operators of potential vehicle-to-vehicle collisions based on intelligent path-prediction algorithms. With over 100 collision scenarios modelled, this system is designed to increase operator situational awareness and safety, as well as help to reduce vehicle incidents and accidents.

Lucas Van Latum, director, product strategy at Modular Mining Systems, tells *Mining Magazine*: "[The latest version of] Modular's CAS, which will be commercially available later this year, focuses on vehicle-to-vehicle collision prevention through the use of a redundant, multi-layered sensing approach that utilises ranging sensors and GPS receivers.

"These work together to determine a vehicle's collision risk based on the travel speed, instantaneous direction, predicted path and other factors."
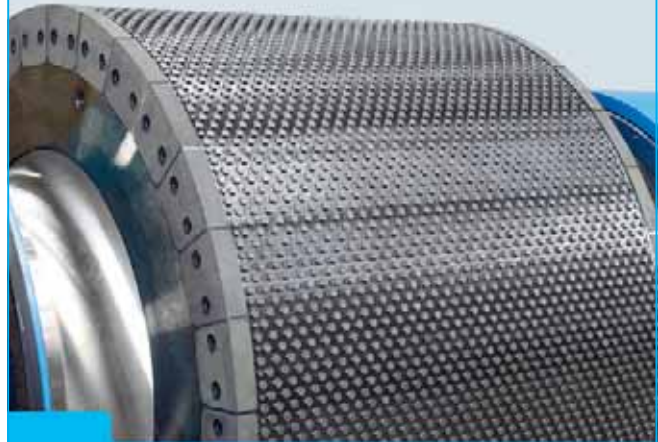
The system uses a high-speed, low-latency peer-to-peer safety-specific communications standard developed for automotive applications – dedicated short-range communications (DSRC) – to allow for timely warnings and informative messages to reach operators without delay. This peer-to-peer technology operates in environments with no wireless network infrastructure, allowing for full functionality everywhere for heavy and light vehicles equipped with the system.

Unlike some systems that focus solely on proximity, Modular's CAS differentiates between actual and ►

Hexagon Mining's HxM TrackingRadar is a 2-D object tracking radar that tracks the movement of multiple targets in the radar beam

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artificial collision threats by utilising an intelligent filtering system to virtually eliminate false alarms – alarms that alert the driver when no collision danger actually exists; for example, a normal manoeuvre such as passing another vehicle along separate lanes.

"These artificial alarms not only provide a constant source of distraction, but they also reduce the warning system's effectiveness by desensitising the operator to truly dangerous situations," says Van Latum.

"One of the major challenges of a CAS is the ability to predict the actual direction a driver is going – many systems on the market today use range and proximity sensors that alert operators when two vehicles are approaching each other, regardless of the risk of collision.

"When two haul trucks are passing each other on the haul route going in opposite directions in different lanes, there could appear to be a collision risk if proximity, speed and general direction are used alone for classifying the risk.

"With Modular's path-prediction capability, the system is able to accurately differentiate vehicles travelling in different lanes and also determine that their paths are not likely to intersect. The path prediction algorithm works with collision scenario recognition to provide a strong filtering mechanism that alerts operators only when a true risk exists."

Since Modular's system utilises radio communications and GPS, it functions without the need for line-of-sight. The DSRC radio uses frequency bands dedicated specifically for safety purposes, which are available (depending on local regulations) with a range of over 500m.

In addition, two levels of real-time alarms notify operators of impending vehicle-to-vehicle collisions via a dedicated display. If an operator doesn't take corrective action after the first notification, a more urgent, audible warning will sound.

Van Latum explains: "As a fully-functioning standalone application, Modular's CAS has no reliance or dependence on external applications or central servers.

"A dedicated in-vehicle CPU stores sensor data, which can be downloaded for use in analysis, reporting and training. When integrated with Modular's DISPATCH fleet-management system (FMS),

> "Artificial alarms not only provide a constant source of distraction, but they also reduce the warning system's effectiveness by desensitising the operator to truly dangerous situations"

data are transmitted directly to the DISPATCH central server for immediate and future use."

During its development, Modular's CAS underwent extensive testing at an active, open-pit copper mine in Arizona, US.

Van Latum says: "Those tests monitored interactions between mine vehicles to successfully determine that Modular's intelligent path prediction algorithms did indeed catch potential collision risks, while simultaneously differentiating between events that were merely proximity-related (with no risk of collision) to avoid a false alarm."

In addition, the system is currently being installed on a fleet of trucks at an iron-ore site in Brazil, where the company states it has already received praise for its robustness.

PRECO ELECTRONICS

Preco Electronics' safety suite for surface mining includes radar and camera/monitor active safety solutions. Detecting moving and stationary objects, Preco's technology is designed to help to mitigate blind-zone accidents, protecting lives and equipment.

Martell comments: "Built for the rugged mining environment, our systems detect objects through fog, snow, rain, dirt, mud, debris and other extreme elements and weather conditions."

Preco's safety solutions are installed on heavy equipment throughout the world, including North America, Africa, India, Indonesia and Australia.

Martell says: "After a site manager was fatally pinned between a large garbage bin and a building, one of our customers realised that the acci-

dent would have been prevented if the operator had been aware of objects in his blind spots. They tested our product in their most extreme environments. After installing PreView Radar on their fleet, they have seen a significant reduction in backing accidents."

SAFEMINE

Hexagon Mining's SAFEmine provides a range of solutions for traffic safety in surface mines.

This includes two levels of CAS protection – traffic awareness to indicate the presence of nearby vehicles (as this is situational awareness, there are no audible alarms); and collision avoidance based on vehicle path prediction, speed and vehicle type (with audible alarms only if on a collision path).

It also has vehicle-to-vehicle communications, providing real-time location tracking and alarming between interacting vehicles. No line-of-sight is required.

There are multiple technologies available, including GNSS, Tracking-Radar and cameras, which are integrated into one system and one display for the operator. These options can be selected according to the risks identified by the mine.

The GNSS-based vehicle proximity and path prediction is combined with radar for personnel detection and combined with cameras for visual check of blind areas.

HxM TrackingRadar is a 2-D object tracking radar that tracks the movement of multiple targets in the radar beam. This information is used to provide collision alarms only when the object being tracked is on a collision course with the vehicle.

Hexagon Mining also has the abil-

ity to integrate collision avoidance functions with its Jigsaw FMS. Ruff tells *MM*: "Heavy-equipment operators will have more combined safety and operational context on the FMS panel than before.

"For instance, the operator will know who triggers a CAS alarm, and what other vehicles are nearby before taking action. In the control room, any CAS incident can be reported in just one application, Jigsaw.

"The controller can take action over information received. Therefore, mines don't require an extra person to manage a new CAS."

CAS-FMS data report will be managed by Jview – users will have top 10 incident reports that can also be sent by email. Time is important in a mine, so the report system can be configured so that managers or users receive CAS-FMS report information once a day by email. Ruff says: "In addition, light vehicles with CAS devices can now be shown in the fleet-management control centre in real-time, so clients don't need to pay extra money to know the location of light vehicles."

The HxM FatigueMonitor is integrated with the CAS. Only one display is needed in the cab and it contains the eye-sensor, Fatigue-Monitoring display and CAS display. CAS information is also used by the FatigueMonitoring algorithms to determine the context of the situation, filter alarms and decrease nuisance fatigue alarms.

Ruff explains: "We have systems designed for specific vehicle interaction risks, such as ShovelCAS and SafetyCentre. ShovelCAS uses detection and alarming schemes designed for shovel operations. SafetyCentre was designed for the specific visibility challenges of haul trucks and integrates collision avoidance with camera technology."

After a successful trial at Barrick Gold Corp's Bald Mountain mine in Nevada, US (now owned by Kinross Gold) in 2015, Hexagon Mining's solutions were selected for a full-scale rollout at another undisclosed Barrick mine, which is scheduled for later this year.

Exxaro has implemented the SAFEmine CAS, SafetyCentre, TrackingRadar and FatigueMonitor at its Grootegeluk coal operation in South Africa, while Norsk Hydro's Paragominas mine in Brazil is rolling out CAS and FatigueMonitor.

SICK
Sick's MINESIC solutions have been developed with a human-centred design approach and a keen focus on human factors.

Cardinal says: "These solutions are developed to be an accepted aid to the operator and not an annoyance. These systems adopt operator behaviour recognition, automatic warning zone adjustment and context switching according to different operating manoeuvres to provide a seamless experience to operators."

Utilising the latest in laser-scanner technology and advanced filtering algorithms, the MINESIC CAS tracks and classifies objects into collision-relevant obstacles and only issues warnings to the operator when absolutely necessary, eliminating false alarms.

STRATA WORLDWIDE
Strata's technology, HazardAvert, is a near-field proximity-detection system that forms electromagnetic fields around machinery to detect people and other vehicles in close proximity and in blind-spots.

Mike Berube, CEO of Strata Worldwide, notes: "Machinery is fitted with generators that create the marker fields, and individuals wear a personal alarm device (PAD). Customers specify the size and shape of fields and they remain constant, but they can be changed at a later time if needed."

HazardAvert fields are completely unaffected by darkness, dust, fog, rain, snow, gravel, rock or other factors, and they do not require line-of-sight, so normal human visibility limitations and restrictions are eliminated. Its fields penetrate elements and substrates to remain stable and consistent.

In situations where people are not immediately aware of potential danger, or are unable to effectively react, HazardAvert can provide early warning to all parties and can be relayed into the machinery controls to manipulate functions such as slowing, stopping and completely disabling machinery.

For example, if a small vehicle is parked near or behind a large haul truck, the operators of both vehicles receive warning alerts and have the opportunity to respond.

Berube says: "HazardAvert sees what people can't, and reacts when people don't."

A potash company installed Strata's system on machinery at a surface operation in the US. The system has been installed on large machinery and light-duty vehicles, and there are numerous individual workers with PADs.

Mike Walling – US product manager for HazardAvert at Strata Worldwide, tells *MM*: "All PADs detect the marker fields on all of the equipment throughout the mine site and all equipped vehicles detect one another. On-site installation, training and site acceptance testing were completed within one week." ▾

Metal-to-metal contacts in the loading area are common between shovels and other equipment that must operate in close proximity
Photo: Strata Worldwide

"Hazard-Avert sees what people can't, and reacts when people don't"