Proximity Detection Systems in Underground Mines

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Abstract:
Proximity Detection or Collision Avoidance has been a key focus of the Queensland mining industry and authorities over the past three years.

The paper discusses the technology and experience in both hard rock and coal mines to provide a system that can deliver an additional level of control to the risks associated with people-vehicle interactions underground.

The presentation will detail the initial implementation of Proximity Detection Systems in the hard rock mining environment. This hard rock proximity system is based on two zones of detection which are required for large and relatively high speed vehicles. Information will include:

- The principles of the underlying technology
- Installation learnings and effectiveness
- Change management methodology and issues

Then an overview of a Proximity System specifically developed for application around continuous miners and shuttle cars in coal mines will be presented, covering:

- The technical challenge of providing precise control zones in the confined area around a continuous miner.
- The principles of the underlying technology, focussing on the alliance between Mine Site Technologies and Frederick Mining Controls to accelerate time to market
- An installations and trials.
- Implementation plans.

Finally, the most recent work on a Longwall Tracking System will be discussed, as its objectives are closely related to Proximity Detection Systems.

Introduction
Considerable evidence has been presented in the form of statistics by others, including by Queensland DEEDI during last years series of Proximity Workshops to clearly demonstrate that people-vehicle and vehicle-vehicle collisions are a major factor in the many fatalities in the mining sector in Australia. These statistics are similar in other mining countries, such as the USA and South Africa.

Hence the justification for an extra level of risk control around vehicles is well acknowledged. To this end Mine Site Technologies (MST) has been working with several industry partners over the last 5 years to develop a Proximity Detection System (PDS). Key partners include Australian Coal Association Research Program (ACARP), Xstrata Zinc and Xstrata Coal.

Sometimes referred to as Collision Avoidance Systems (CAS), most industry progress has been made in the surface environment, particularly for heavy vehicle-light vehicle interactions. This led to MST's decision to focus on their core market in underground mining where no proven or widely deployed system existed.

The development has been in two stages, firstly for hard rock mines and most recently for underground coal mines.

Hard Rock Mines
The basic concept is to use active Tags worn by miners underground to be detected by vehicle mounted Readers. The Reader is our existing Vehicle Intelligence Platform (VIP) Wi-Fi enabled data logger module. This VIP module is interfaced to a Display Unit to alert the driver of a person encroaching within the vehicles vicinity. The Display Unit will also provide the interface between the operator and the system and a means to acknowledge Tags and other necessary controls, such as alert outputs, etc.

Outer Zone – 60 to 120 m:
- Gives a first warning to operator that there is someone around
- Detection Range is roughly adjustable from 60-120m
- Importantly, it can detect personnel around corners and blind-spots

Inner Zone – 5 to 15 m:
- Uses a Very Low Frequency (VLF) magnetic field to give an accurately-shaped detection zone around the vehicle
- Detection Range adjustable from 5-15m with adjustable in 1m increments
- Triggers a higher-level alarm

These two levels of warning are shown in the diagram below:

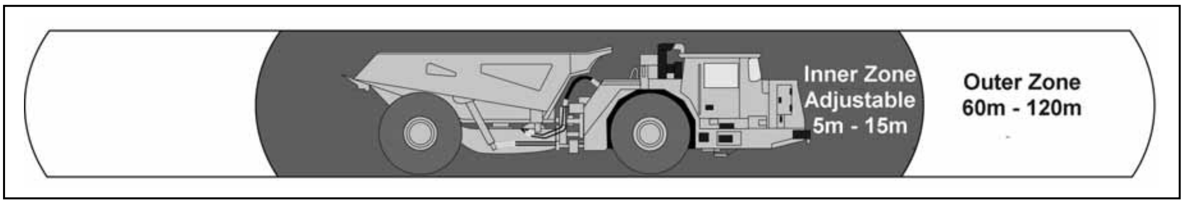

Figure 1 - Proximity Detection System is based on two warning zones

The first installed system is at Xstrata Zinc's George Fisher Mine. This involved a staged approach of adapting the technology tested on outbye vehicles in coal mines to the hard rock mining environment.

The project team consisted of a broad range of skills, including:
- Xstrata loader operators
- Xstrata electrical and maintenance engineers
- Xstrata Mine management
- MST electronic and software engineers, communication technicians and project manager.

Coal Mines

The on-vehicle equipment used in the hard rock PDS were always going to present a challenge for coal mine certification. In addition, the complex situation and control needed around the mining face with continuous miners and shuttle cars required additional technology development.

Before developing this additional technology MST did a review of other PDS and CAS technologies to determine if a technology existed that could be directly applied or adapted to the coal requirements. This extensive investigation has led to an alliance with Frederick Mining Controls out of the United States for integrating their HazardAvert® System into MST's overall Proximity Detection System

The Need for a Proximity Detection System:

Using US statistics, since the introduction of remote controls in the mid-1980s, the United States mining industry has experienced 31 crushing or pinning type fatal accidents associated with the operation of remote control CM's (see Figure 2). Remote controls offered increased safety and health benefits to continuous mining machine operators by removing them from the noise and dust exposure of on-board operation, but subjected the operator to new crushing and pinning hazards.

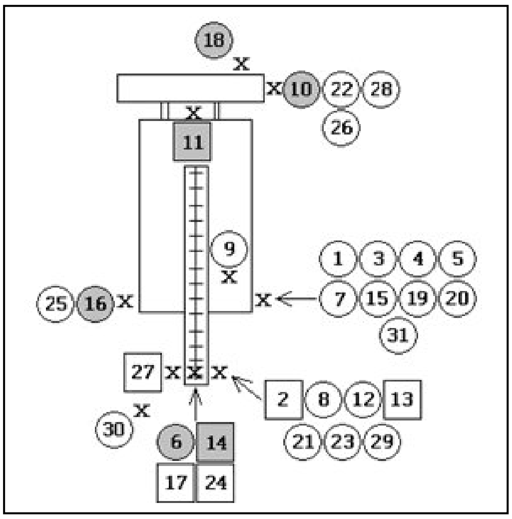

Figure 2 - Crushing or Pining Fatal Accidents – US Coal

In Figure 2 the circles represent operators, the squares represent helpers and the greyed areas indicate fatalities during maintenance operations.

"MSHA recently conducted a review of all mining-related fatal accidents from the last five years. It was determined that approximately 20% of all mining-related deaths could be prevented through the use of proximity detection." (http://www.msha.gov/accident_prevention/newtechnologies/proximitydectection/proximity%20detection%20paper%20(020209).pdf)

NIOSH has complied statistics for "Struck by Accidents" between 2004 and 2008 for underground coal. The data indicates many partial and permanent disabilities.

In Australia 2009 statistics released by the Queensland Department of Employment, Economic Development and Innovation (DEEDI) revealed that 35% of fatalities within Queensland mines involved vehicle interaction. A sampling of incidents in Australia is highlighted in the Mines Inspectorate Safety Alert 237, 18 December 2009.

HazardAvert is an adaptation of a PDS which was originally developed by NIOSH-PRL personnel in the US to warn underground coal miners whenever they get too close to continuous mining machines.

Since its creation, HazardAvert has not only been applied to CM's but also to Shuttle Cars, Load-Haul-Dumps, Haul-Trucks, Roof Bolters, Drag-Lines, Feeder-Breakers, Light Duty Vehicles, Fork Lifts, and other machinery.

Fundamentally, the HazardAvert system consists of a low-frequency signal marker device (Generator), a Personal Alert Device (PAD), and a Vehicle Alert Device (VAD). The Generator is used to mark the area considered dangerous around a machine. In many cases this encompasses the whole machine. A PAD is worn by workers-on-foot to alert them and a vehicle operator when they enter an area marked by a Generator. A VAD resides on a vehicle and alerts vehicle operators that another vehicle is in a dangerous area around the machine which they are operating.

The Most Important Requirement for an Effective PDS:
Areas around machinery where injuries have occurred need to be highlighted and marked in some way so that the workers and the vehicle operators are made aware of the danger. The danger zone marker must be robust and should not change, even when in open space or close to coal pillars and other equipment. Marker zone changes would reduce confidence which is not conducive to an effective safety system.

A marker signal in effect is limited to low frequency signals. The frequency chosen must be low enough that it does not propagate. Signals above 100 kHz or so, start to attach to just about any piece of conductive material and can propagate for miles. Determining the central focus of a danger marker would be extremely challenging at signals greater than 100 kHz. Low frequency signals can penetrate just about anything, including; coal, rock, dust, water sprays, metalliferous ore, as well as metal. This fact obviously makes low frequencies an excellent marker choice. The frequency of the marker however must be high enough so that it is out of range of the high energy, low frequency electromagnetic noise ever present in mines. The levels of the electromagnetic noise generated can overwhelm the best designed electronic system in close proximity to the source. Fortunately the magnitude of the electromagnetic noise decreases rapidly at short distances from the source. After many measurements in mines near various machines (using a spectrum analyzer) 30 kHz was found to be about the high end of expected electromagnetic noise near heavy machinery. Hence, it follows that the best choice for a marker signal would be at the sweet spot between 30 kHz and 100 kHz.

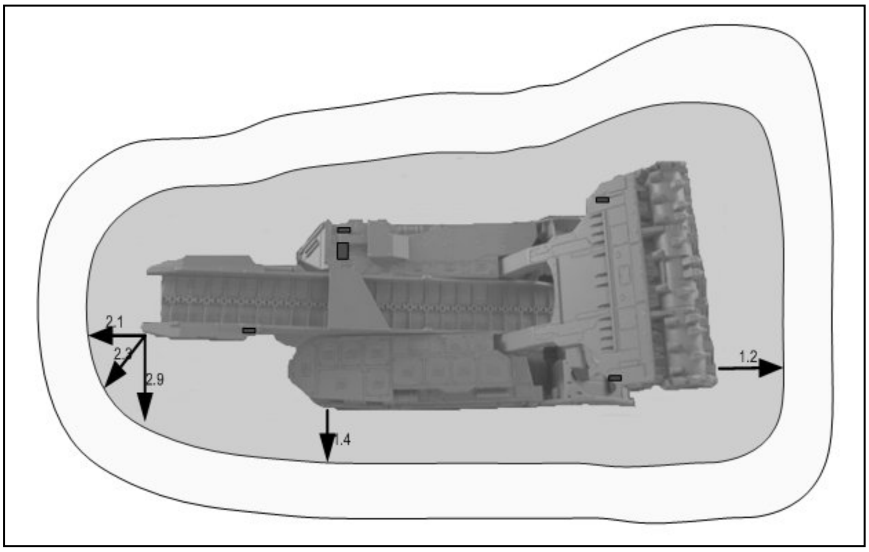

Figure 3 – A number of stable detection fields around a c/miner form the basis of the HazardAvert System

HazardAvert® System Components:
The basic system components of the HazardAvert system are a Generator, a Personnel Alert Device (PAD), and a Vehicle Alert Device (VAD). Other peripheral devices are added depending on the environment in which the system will be used and the type of vehicle to which it is attached. A select group of these components will be described.

A Generator consists of microprocessors, an electromagnetic marker circuit, a warning module, a wireless data link, and can contain a VAD. The Generator is contained in a mine worthy rugged enclosure. There are at least two packaging arrangements for the generator; one an FLP housing, and the second non-FLP housing for most other applications. The Generator marker signal frequency is 73 kHz, which is at the sweet spot for marker signals. The size of the HazardAvert marker field is based on the amount of energy put into magnetic marker field. HazardAvert can project a marker field up to 30 metres from its centre.

The size of the field can be adjusted to the requirements of the application. Additionally, the size of the field can be dynamically adjusted if accurate vehicle speed information can be acquired. This lends its use to mine operations where many vehicles work in close proximity to one another.

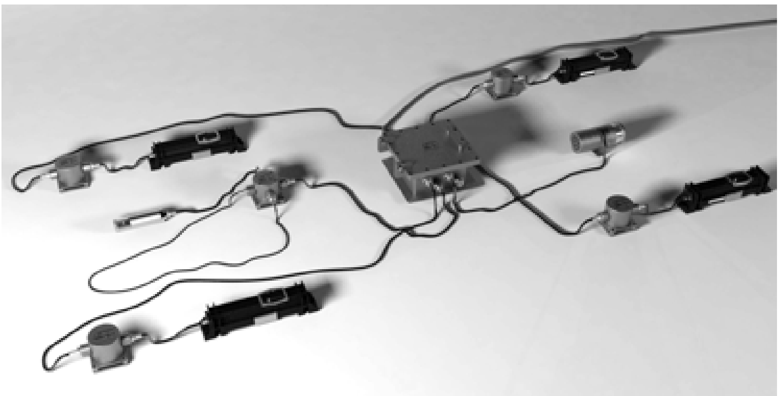

Figure 4 – HazardAvert on-machine components

Also contained in the Generator is a wireless data link which provides communications with PAD's and other devices. The system warning module is placed within the operators viewing range in the vehicles cab. In many cases, a single Generator can provide the protection needed around a vehicle. Larger vehicles however can be accommodated using two or more Generators.

A PAD is worn by a worker on foot. It is a highly accurate multi-axis magnetic field measurement device with a wireless data link. The magnitude of the Generators magnetic field as measured by the PAD determines the distance to the Generator. The PAD includes a warning module which can be attached to the brim of a hard hat. The PAD is calibrated at the factory to provide a Warning Alert at one distance from a Generator and a Danger Alert at another distance from a Generator. The alerts provided are audible and visual and are programmed to suit the needs of the application. For Australia PAD's are currently being integrated into the ICCL cap lamp.

A VAD is a PAD integrated into the housing of a Generator. Its purpose is to detect when another vehicle, which contains a Generator, is within its Warning/Danger zone. Subsequently, the operators of both vehicles will be alerted to the other vehicles presence.

HazardAvert Installations:

A number of trials and demonstrations of the HazardAvert System have been undertaken in Australia, one of the most recent at Anglo Coal's Grasstrees Coal Mine. A longer term trial is also on-going in a hard rock mine, at BHPB's Cannington Mine. However, longer term trials and full installations at coal mines have not started in Australia, due to certification still pending. With that in mind, a brief description of the most extensive HazardAvert deployment to date, at Sasol coal mines in South Africa, will be given.

PDS activity in South Africa began with Sasol's ZERO harm mining strategy. A company team was assembled to investigate the risks with workers in proximity of mining equipment and to determine what solutions were available to address the risks. The team created a list of basic performance requirements for the system. The system had to:

- work on all underground machines,
- warn all miners and operators of the dangers
- slow down and then stop the machine
- work with multiple machines with multiple people
- have every machine respond to every miner
- individually warn every miner
- indicate to the operator the highest priority warning/danger
- be active with two-way verification
- be inherently safe
- provide robust marked zones.

HazardAvert was further developed to meet all the requirements. Of the vendors reviewed, the HazardAvert system was chosen for trial. The trial processes followed included: a full risk assessment, training, a phased approach to implementation, regular feedback sessions, a support team on all production shifts, and spare equipment held in the sections. The trial was conducted at Sasol's Twistdraai Mine and was concluded in January of 2009,

The Trial Findings were:

- System very reliable
- Equipment damage negligent
- System consistency very good
- No false indications
- Operator feedback very good
- Data collected very useful to address operational concerns
- Interlocks worked very well
- Machine coverage very good
- Improved overall safety awareness dramatically

(see http://www.sacollierymanagers.org.za/Publications Proximity Detection System. Jaco Duvenhage 21 May 2009)

The success of the Sasol trial resulted in a complete mine roll-out strategy, where approximately 65 working sections are fitted with the HazardAvert System.

HazardAvert is now on a few hundred underground machines including CMs, shuttle cars, load-haul-dump vehicles, and rotary breakers.

Proximity Detection and HazardAvert Activity in Australia

Mine Site Technologies and Frederick Mining Controls have formed an alliance to integrate the HazardAvert System into MST's Proximity Detection System. Though particularly relevant for coal mine use, this integration also allows another option for underground hard rock mines where confined area machine control is required.

The status of the activities in introducing the HazardAvert technology include:

- Continuing work with BHPB Cannington on extending beyond the initial trials into a longer term deployment on all vehicles.
- Integration of the PAD into the Integrated Communications Cap lamp (ICCL) to ensure the PAD module is always with a miner underground and part of their PPE.
- I.S. Certification of the PAD/ICCL unit.
- Certification of the flameproof components of the on-vehicle devices (VADs, Generators, and Controller).
- Integration of MST's existing Wi-Fi based proximity system with HazardAvert. In particular incorporating the "Outer Zone" detection system with the HazardAvert "Inner Zone" detection capability.
- Integration of MST's Vehicle Intelligence Platform (VIP). This will allow real-time reporting of proximity events and alarms via a Wi-Fi communication link with a mine's digital network, where this digital backbone is installed.
- A Functional Safety Assessment to determine and confirm the Safety Integrity Levels (SIL) and Functional Safety requirements for such the system, particularly as the system does have the capability to stop or slow vehicles where required.

Longwall Tracking

Of interest to the coal miners is a current project to provide tracking of personnel moving along a Longwall face. The need for such a system is being driven the developments in automation of longwalls.

The need to know where people are or, more precisely, that they are in a designated safe location for the remote or automatic operation of shields and face alignment pushes.

MST is working with a longwall OEM for the delivery of a longwall tracking system for Narrabri North's longwall. The basic principle is monitoring a person's location as they move along the face from support to support. This is done by detecting a RFID Tag worn by each miner (integrated into their ICCL cap lamp). This RFID Tag is already used for general tracking of the person as they move from surface to underground and through the mine.

For Longwall Tracking a special detection field generator or exciter is installed on each support along the face. This field is very similar to the field used as the "Inner Zone" detection field in the general hard rock Proximity Detection System. Figure 5 below shows the principle of the detection fields along the face that monitor the movement of people to the nearest roof support.

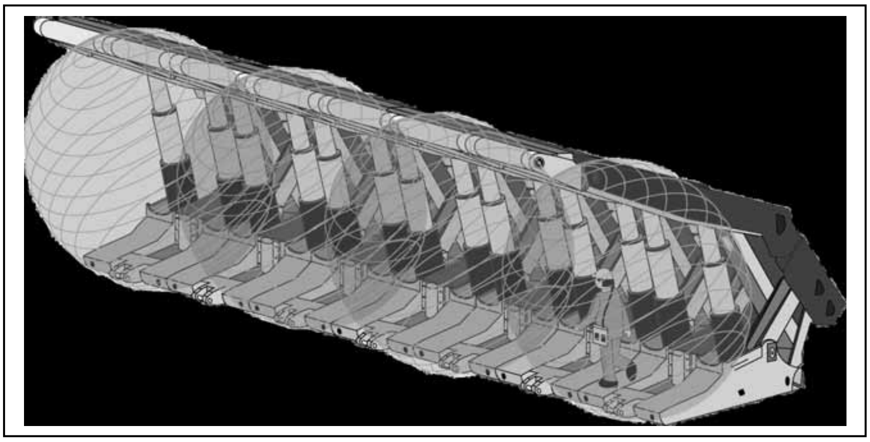

Figure 5 – Longwall Tracking

However in the longwall application we use it to raise an alert when a person leaves the field, not when they enter it as in the case of proximity detection. In the Narrabri North configuration, the safe zone is between the supports legs and the rear of the shield (see Figure 6 below).

Figure 6 – Longwall Safe Zone

Conclusions

The development and deployment of a Proximity Detection System has been seen to offer additional levels of control for people-vehicle interactions underground. The benefits of such systems need to be carefully introduced into a mine's current systems and procedures. In particularly their initial introduction should focus on their use as an adjunct to, and not a replacement of, existing procedures. This will ensure their benefits are realized and not compromised by individual complacency and/or de-sensitisation.

Additional References:

Schiffbauer WH, Mowrey GL [2001]. An environmentally robust proximity warning system for hazardous areas. In: Instrumentation, Systems and Automation Society (ISA) Emerging Technologies Conference. (Houston, TX, Sept 2001), Paper No. 2091, 10 pp.