

**Case study**

# Avoiding collisions in underground mines

Robin Burgess-Limerick

*Minerals Industry Safety and Health Centre, The University of Queensland, Australia***Abstract**

**Background:** Collisions between vehicles, and between people and equipment, are a high risk in underground mines, and particularly coal mines. The consequences include serious injury and fatalities. The prevention of collisions has recently been a focus of attention by regulators in NSW and Queensland; and particularly the promotion of technological solutions for alerting equipment operators to the proximity of other vehicles, equipment, or people. **Aims:** This paper examines reports describing fatal underground collisions occurring in the USA to determine the likely benefit of a range of control measures. **Methods:** All fatalities involving collisions in underground coal mines in the USA since 2000 were identified. A series of mini-case studies are presented, adapted from the publicly available reports of these fatalities. **Results and Conclusions:** The case studies illustrate that restricted visibility is implicated as a causal factor in many fatalities, suggesting that control measures such as the provision of video cameras, and proximity detection linked to warning tones may be effective barriers in some situations. A significant number of fatalities were also noted in which the person operating the equipment was killed, or where the operator of the equipment was aware of the location of the person who was killed. In these situations, provision of video cameras, or proximity detection linked to a warning tone alone, may not be sufficient. The role that directional control-response incompatibility may play in some situations was also noted.

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**Background**

Collisions between vehicles, and between people and equipment, have been identified as a relatively prevalent hazard in underground mines with potential consequences including serious injury or fatality [1-3]. The probability of collisions is relatively high because of the restricted working environment, restricted visibility from vehicles, and in some situations, by the use of mining methods which involve close interactions between pedestrians and equipment.

It has been suggested that a causal factor associated with underground collisions is restricted operator visibility inherent in the design of underground vehicles. This issue has been the subject of research attention which has confirmed its importance [4,5]. One response is to provide video cameras to augment the operator's vision. Another has been to propose the implementation of proximity detection technologies which compensate for the operator's restricted visibility, and provide a warning that another vehicle or pedestrian is in the vicinity. The implementation of this control measure by underground mines has been a recent focus of attention of regulators in Australia and the USA (e.g., [http://www.msha.gov/Accident\\_Prevention/NewTechnologies/ProximityDetection/ProximitydetectionSingleSource.asp](http://www.msha.gov/Accident_Prevention/NewTechnologies/ProximityDetection/ProximitydetectionSingleSource.asp); <http://www.dpi.nsw.gov.au/minerals/safety/publications/seminar-presentations/2011-proximity-detection-workshop>). The implementation of proximity detection devices which "detect the presence of pedestrians in and around mobile equipment" was given further weight through a

recommendation arising from a recent Queensland coronial inquiry [6].

The aim of this paper is to undertake an examination of public domain reports describing fatal collisions occurring in underground coal mines in the USA over the last 11 years to assess the potential role of proximity detection and other potential control measures in preventing collisions.

**Method**

The US Mine Safety and Health Administration (MSHA) makes detailed accident reports available for all mining fatalities (<http://www.msha.gov/fatals/fab.htm>). All fatalities involving collisions with underground coal mining equipment since 2000 were identified, and the corresponding reports downloaded for subsequent analysis. The reports were assessed to determine whether restricted operator visibility was likely a causal factor in the fatality, and examples selected for discussion.

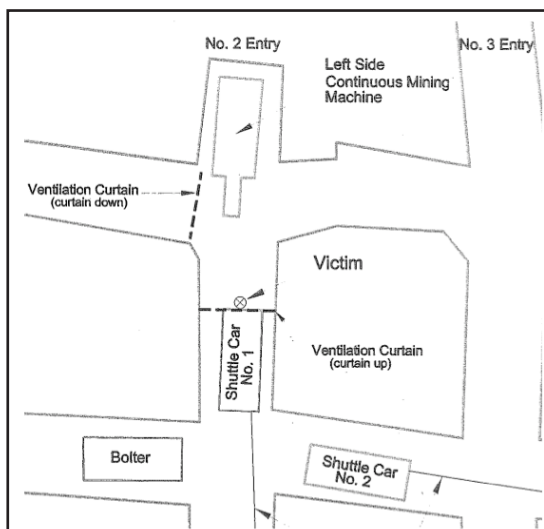
**Results and Discussion**

Forty-one fatalities resulting from underground coal mining equipment collisions were identified. All were single fatalities. The equipment most commonly involved were continuous miner (15), haulage e.g. shuttle car (10), and scoop / LHD (5). Six examples have been selected to provide an illustration of the range of typical scenarios in which the fatalities occurred.

### Case Study 1.

On July 1, 2010, an electrician was killed when he was run over by a shuttle car. Prior to the accident, the victim was walking toward the continuous mining machine operating in the No. 2 Face. (see Figure 1 for a schematic representation of the situation). The continuous miner operator next saw the victim beneath and being dragged by the left side, standard shuttle car as it was leaving the continuous mining machine after being loaded with coal.

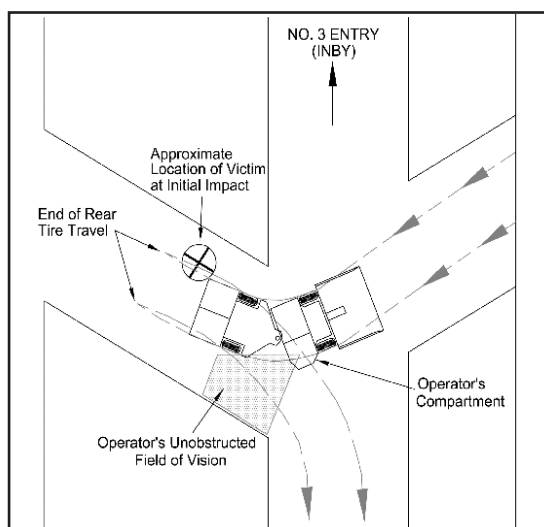
A key feature of this situation is that the shuttle car cab is located at the outbye end of the shuttle car (bottom left corner of the car illustrated in Figure 1), and the operator's view towards the continuous miner is greatly obscured by the length of the vehicle. This restricted visibility is very likely to have been a causal factor in the fatality.



**Figure 1.** Fatality of July 1, 2010 in which an unloaded shuttle car traveling inbye (towards the continuous mining machine) collided with a pedestrian.

### Case Study 2.

On June 20, 2003, a pedestrian was fatally injured when he was inadvertently run over by a battery-powered rubber-tire scoop (Figure 2).



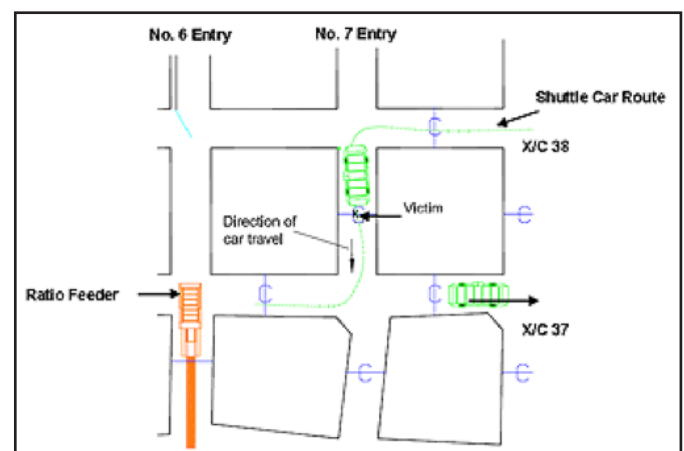
**Figure 2.** Fatality occurring June 20, 2003, in which a scoop collided with a pedestrian.

The MSHA investigation revealed that the lights provided for the scoop had been relocated, only two of the four lights provided were operative, and there were no reflectors on the front and rear of the scoop. The scoop operators' field of vision was through a small opening between the canopy and the top of the scoop frame. The investigation clearly implicated the severely restricted visibility of the operator as a causal factor.

In both case study 1 and 2, the operator's restricted visibility may have been overcome to some extent by the provision of video cameras, and this is becoming a relatively common addition to large underground coal mining vehicles [7].

### Case Study 3.

On October 27, 2010, a continuous mining machine helper was killed when he was struck by a loaded shuttle car. The victim was repairing a ventilation curtain (see Figure 3).



**Figure 3.** Fatality of October 27, 2010 in which a loaded shuttle car traveling outbye (towards the ratio breaker) collided with a pedestrian repairing a ventilation curtain.

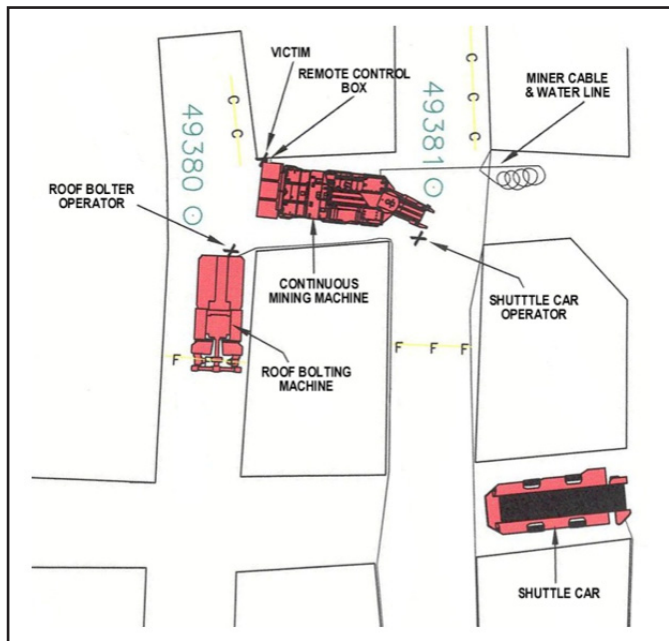
In this case, although the shuttle car driver's view in the direction of travel was relatively unobscured (the cab being located at the end of the vehicle closest to the victim), the victim's location was obscured by a ventilation curtain which he was repairing. Restricted visibility was a causal factor, although not a consequence of the vehicle design, and the provision of a video camera would not likely have prevented the fatality.

Case studies 1-3 all had the common characteristic that the equipment operator was unaware of the location of the person who was killed, and visibility of the victim was reduced by either the equipment design, or an aspect of the mine environment. Whilst many other factors were also implicated, and other control measures could be suggested, in each case it is reasonable to suggest that proximity detection linked to an alarm may have prevented these fatalities. An important caveat here is that this is that the design of the proximity detection human interface is critical to ensuring the warning is identified, understood, and appropriate action taken in time to avoid the collision. If the warning provided by the proximity detection system is not identified, understood, and acted upon appropriately in sufficient time, then a proximity detection control measure may not have prevented the fatalities identified. Cooke [8] investigated a "near miss" in a

Queensland underground gold mine in which a loader fitted with proximity detection collided with a light vehicle. The investigation identified that the incident occurred in part as a consequence of poor interface design; demonstrating that this is a non-trivial concern.

#### Case Study 4.

On April 3, 2004, a continuous mining machine operator with 29 years of mining experience was killed while tramping the continuous mining machine in high speed through the No. 3 left crosscut. The operator was pinned between the cutting head of the continuous mining machine and the coal rib (Figure 4).



**Figure 4.** Fatality occurring April 3, 2004, in which a continuous miner operator was crushed between the continuous miner head and rib whilst tramping the miner forwards.

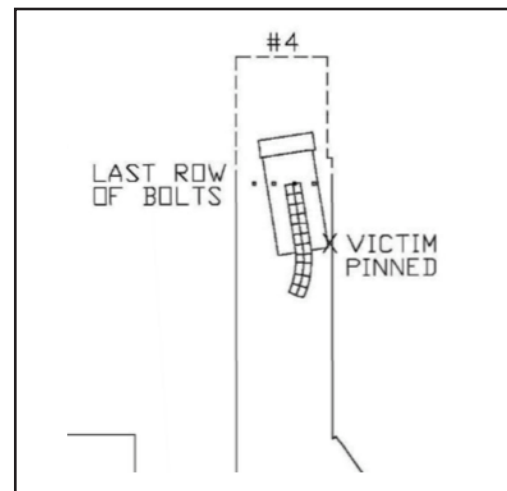
The continuous mining machine operator was controlling the equipment via a remote control whilst walking backwards, ahead of the machine. The tracked machine is steered using left and right track controls located on the left and right of the remote control. The remote control is usually operated from the behind the conveyer of the mining machine looking towards the cutting head, and in this normal situation, moving the right control forwards, and the left control in reverse causes the equipment to rotate to left. However, the directional control-response relationship is reverse in the situation encountered in this case. It is likely that this issue was implicated in the fatality. Regardless of this however, restricted visibility was not implicated.

#### Case Study 5.

On June 24, 2010, a miner with twelve years mining experience was crushed between the continuous mining machine he was operating and the coal rib (Figure 5).

The victim was tramping the mining machine by remote control along the right rib line to clean up the loose coal

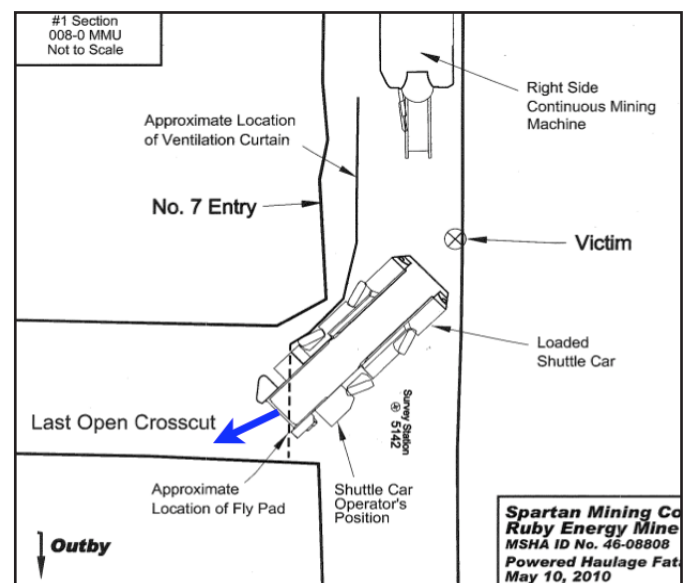
on the mine floor. While he was turning the front of the mining machine to the left, he became caught between the mining machine and the coal rib. In this case the directional compatibility of the controls was not implicated, but rather the operator's mental model of the effect of the controls, and neglecting to anticipate the distance that rear of the miner would move laterally towards him as the front moved left. Again, restricted operator visibility was not implicated.



**Figure 5.** Fatality occurring June 24, 2010 when a continuous mining machine operator was crushed between the rear of the continuous miner and the rib.

#### Case study 6.

On May 10, 2010, an experienced continuous mining machine operator received fatal crushing injuries. As a loaded shuttle car turned into the last open crosscut from the No. 7 Entry, the victim was positioned in the outside turn radius of the shuttle car and was crushed between the shuttle car and the coal rib (Figure 6).



**Figure 6.** Fatality occurring May 10, 2010 when a continuous mining machine operator was crushed by a turned shuttle car.

To achieve the desired payload and maneuverability, shuttle cars are very long vehicles with four wheel steering, with

the wheels located close to the centre of the vehicle. The consequence is that when the vehicle turns, the extremities move a long way laterally, and with considerable speed. In this case, immediately prior to driving the shuttle car away from the continuous mining machine and turning right, the shuttle car driver's cab was adjacent to the position of the victim, and the operator was aware of the victim's location.

The latter 3 cases presented all had the common characteristic that the equipment operator was the one killed, or he was aware of the location of the person who was killed immediately prior to the accident. In these situations it can be argued that the implementation of proximity detection linked to a warning alone may not have been a sufficient barrier, regardless of the effectiveness of the interface.

The circumstances of the last case study presented are strikingly similar to the fatality which occurred in Queensland in April 2007, the investigation of which led to the coronial recommendation for the implementation of proximity detection. A feature of the witness accounts is that the continuous mining machine operator, Mr Blee, had spoken to the shuttle car driver instructing him to take the car out of heading moments before the car was driven away and Mr Blee was killed. Clearly the shuttle car driver was aware of the position of the victim, and a warning provided by proximity detection may not have been a sufficient control barrier.

Indeed, the analysis of the 41 collision related fatalities occurring in underground coal mines in the USA revealed that in 23 cases (56%), either the operator of the equipment was the victim (usually a continuous mining machine operator), or the equipment operator was aware of the position of the victim immediately prior to the accident occurring. Consequently, it may be argued that the implementation of technology which merely detects the presence of pedestrians in and around mobile equipment may be an inadequate control measure unless the detection is interlocked with equipment control to slow and stop moving equipment in the presence of pedestrians, and prevent stationary equipment from commencing movement in close proximity to pedestrians.

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