Mine Health and Safety Council

MHSC

SIM130502 – PDS-Machine Interface Requirements

Milestone Report:

Milestone 1 – An investigation into PDS-machine interface related problems at the champion mines.

Research agency: Council for Scientific and Industrial Research

Project number: SIM 130502

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Contact: Deon Sabatta, dsabatta@csir.co.za

1 Table of Contents

2 Overall Project Summary

WHAT WAS PLANNED FOR THE MILESTONE?	WHAT WAS ACHIEVED?	*REASONS FOR DEVIATION*
Contact champion mines	Contact made with 3 of 4 champion mines	*Original contact was from Gold Fields before restructuring to Sibanye.*
Obtain information through questionnaire sent to champion mines	Questionnaire returned by 1 of 3 champion mines	
Identify problems or interface related risks at champion mines	No problems were identified	*No interface related issues were reported.*
Investigate machinery suppliers in use	Information obtained from some machinery suppliers	*Very difficult to obtain information from machinery suppliers.*
Investigate PDS systems in use	Information obtained from most PDS suppliers	

3 Executive Summary for Milestone

The goals of this milestone were to investigate the risks associated with PDS-machine interfaces, specifically related to problems caused by differing interface protocols between machinery and PDS suppliers. The identification of these problems was limited to the champion mines that were identified in the initial call for proposals.

After communicating with the champion mines, most reported fully functional PDS installations with no integration issues being experienced. One mine reported integration issues related to the installation of vehicle-to-person PDS systems onto rail-bound locomotives, although these issues were more related to the suitability of the PDS system for rail-bound use, rather than difficulties interfacing with the existing system. Following the absence of any notable integration issues present at the champion mines, we began contacting machine and PDS suppliers to obtain their experiences with the integration process.

The machinery and PDS suppliers provided many examples of fully integrated systems. Many of these however were simply driver warning systems, removing the need to interface directly to the machinery control systems. Each installation is handled on a case-by-case basis by the PDS suppliers, often with modification of their systems to allow integration with the target machinery. These findings have led us to believe that integration issues, while present, are not particularly hard to overcome may have already been largely resolved by the community in the time period between the initial proposal of the project and the delivery of this milestone (>1 year).

Despite the successful installation of PDS systems at many mines, there are two recommendations that can improve the integration process.

1. To improve mine management buy-in to negotiate with the machine suppliers to provide the necessary interface protocols for integration.
2. To investigate the possibility of standardisation of interface protocols to ease the integration process.

4 Overall Project Aims and Objectives

This project aims to address the risks associated with PDS-machine interfaces as experienced at several South African mining companies.

The research takes the form of a three phase study. The first phase is completed and the second phase is in progress.

The first phase comprised an analysis of existing risks related to the PDS-machinery interface in the champion mines and any measures that are currently in place to mitigate these risks. This was accomplished through visits to the champion mines to investigate the existing equipment configurations and how the interfaces between the PDS systems and the mining equipment have been managed.

The second phase will examine a selection of existing PDS and mining machinery suppliers, both local and international, to determine the existing protocols and interface methods. This phase may also include other related fields such as after-market teleoperation or remote control system providers to establish how they overcome the problems associated with interfacing with different suppliers.

The final phase will comprise a detailed analysis of the information gathered in the previous phases together with recommendations on reducing or mitigating the risks associated with PDS-machinery interfaces in South African mines.

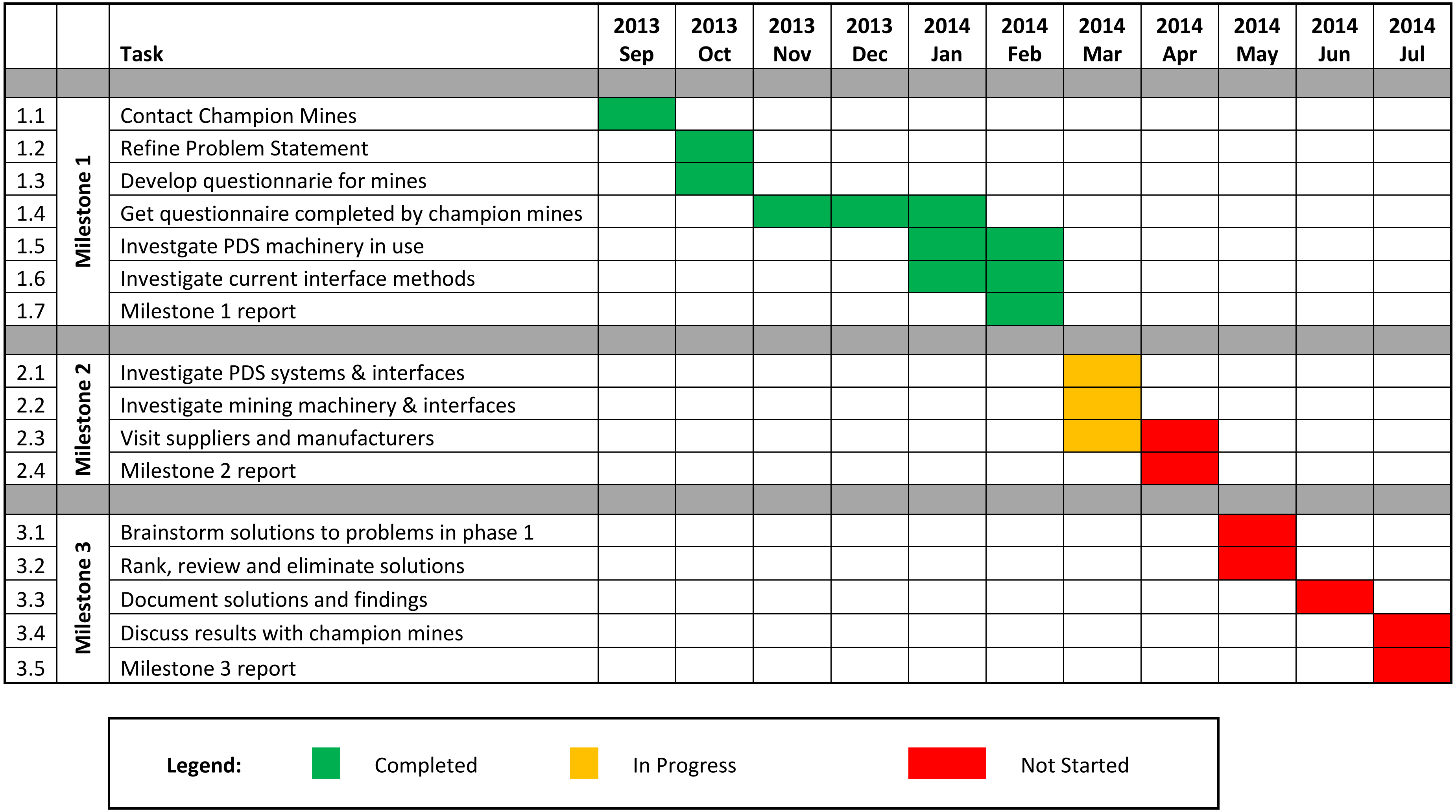
5 Project Schedule and Gantt Chart

The project schedule as laid out in the original proposal with amendments to the delivery dates as agreed is presented in the following table.

NO.	ENABLING OUTPUT	MILE -STONE START & END DATE (MM/YYYY)		COST per Milestone [R]
1	Report documenting existing equipment in use, as well as current risks, challenges and mitigation strategies.	09/2013	02/2014	309 410
2	Report documenting the analysis of leading suppliers of PDS systems and mining machinery, including their interface protocols.	02/2014	04/2014	326 817
3	Report summarising the findings of the project and suggesting future mitigation strategies for PDS-machinery interfaces	04/2014	07/2014	521 281

6 Gantt chart

PDS-Machine Interface Project Gantt Chart



7 Milestone Delivery

This section presents the results of the research undertaken for the first milestone. We begin by defining the problem and approach that was undertaken. Thereafter, I present the information that was gathered as part of the process and finally present my conclusions and recommendations.

7.1 Introduction

The first milestone of this project was initially envisaged to be a survey of existing interface problems as experienced by the various champion mines when implementing PDS systems on their sites. In practice, it was difficult to determine the exact extent and nature of the interface problems, also referred to as integrations risks, because the individuals at the champion mines did not admit to any problems existing.

7.1.1 Problem Definition

The original background and motivation for the research project as was included on the original call is as follows:

> *The Mining Charter expects companies to investigate the leading practices from the MOSH Learning Hub for adoption as relevant. The PDS leading practice has been promoted for adoption to address the transport and machinery safety risks. Transport and machinery risks have been classified as the second biggest contributor to industry fatalities. It is estimated that this practice can reduce transport and machinery accidents by 50%.*
>
> *The challenge with adopting this practice is that there are difficulties with the interface protocols of the current PDS systems, mobile machinery and track-bound control systems.*
> *PDS technology that is currently available in South Africa varies as far as interface protocol is concerned and likewise mobile machinery and track-bound equipment control systems vary.*
> *This challenge is limited to underground hardrock operations (whose PDS are battery operated) since trackless machines used in coal operations use electricity and therefore can interface much simpler.*
>
> *The introduction of PDS systems require or may require interaction with the control systems. There are potential risks for mines that use different PDS suppliers for different mining levels. Should the PDS accidentally end up at the wrong level, the PDS – machine interface might not function correctly. Another*

challenge is that non-standardised interaction constrains industry with respect to choice of systems /interchangeability.

From this call for proposals, I identified the following potential problems:

1. There is a need to implement PDS systems which has not been undertaken.
2. There are difficulties interfacing PDS systems with machines due to various non-standard interface protocols.
3. Underground hard-rock operations experience greater difficulties than coal mines in implementing PDS systems.
4. There is a problem with the compatibility of various PDS systems to one another (i.e. They use different interface protocols and/or different detection modalities).

7.1.2 Approach

While some problems were identified in the initial call for proposals, the exact cause and nature of the interface problems was not specifically outlined. For this reason, the first phase of the project focussed on soliciting additional information from the champion mines to further define the exact problems that were to be addressed. Following on from this information, a survey of available machines and systems would be undertaken, at which stage I would be in a position to make recommendations on how these problems could be addressed.

The remainder of this report deals with the process of trying to further solicit and identify the exact nature of the interface problems that the various champion mines experienced.

7.1.3 Outcomes desired by the Chamber of Mines

Following my project start up presentation to the Chamber of Mines, they requested a number of desired outcomes from the research. These included:

1. A list and description of mobile machinery and track-bound equipment control systems in underground hard-rock operations, their interface protocols, advantages and disadvantages.
2. A list and description of PDS systems in underground hard-rock operations, their interface protocols, advantages and disadvantages.
3. The feasibility of standardising protocols with interface risks and benefits thereof. This should be considered in light of the very dynamic technology advancement in the field.

4. A matrix of interfaceability between PDS systems and mobile machinery.

These outcomes closely match what was originally proposed, with the addition of the interfaceability matrix between the PDS systems and mobile machinery. Absent from these outcomes is the need to identify the existing interface problems which were purported to exist in the original problem statement.

7.2 Champion Mines

In the initial call for proposals, three champion mines were identified. These were African Rainbow Minerals (ARM), Glencore Xstrata and Gold Fields. We started by contacting each of these champion mines to solicit any information that may have been of use.

Following the restructuring of Gold Fields and the creation of Sibanye, the contact that was provided at Gold Fields was no longer able to provide any information on the project. At this stage, the Chamber of Mines was contacted and an additional contact at AngloGold Ashanti (AGA) was supplied.

To obtain detailed information as to potential integration issues experienced and build a comprehensive list of machines and PDS systems in use, a questionnaire was created and sent to each of the champion mines. Despite several requests, only AngloGold Ashanti provided a response to the questionnaire.

7.2.1 Summary of Findings

After making contact with the three champion mines and holding discussions with senior engineering people at the mines, no substantial interface protocol challenges or problems were identified, at least at management level. In one case, several integration problems were mentioned; however, these were more related to the immaturity of the PDS systems than to the actual PDS-machine interfaces.

In at least one case, the mine chose to implement driver/pedestrian warning systems only. This has a substantial effect on the complexity of the PDS system installation, as the only interface requirement is for the availability of power, and no direct machine interface to the machinery control system is required.

With regard to the use of different PDS systems on a single site, two champion mines provided examples. In the first case, machinery used by contractors on a site had different PDS systems to those used by the mine. In the second case, various types of machines required different PDS systems. As an example, at AngloGold Ashanti, a GPS-based system was used above ground while a magnetic field-based system was used on underground trackless machines. Naturally, these two systems would not be compatible; however their operating environments are also different enough that the two systems should not encounter each other in routine use.

The only notable integration problem that was reported was at AngloGold Ashanti, where they are experiencing difficulties integrating a PDS system onto underground rail-bound vehicles. On further investigation, their problem is more related to finding a suitable PDS technology for railbound systems rather than vehicle interface difficulties. This problem is currently being addressed as part of the SIM130501 project with the Mine Health and Safety Council.

7.2.2 Detailed Information per Mine

The following information was obtained from each of the mines that were contacted as part of the project.

7.2.2.1 Glencore Xstrata

The contact from Glencore Xstrata is Flip Kritzinger, General Manager of Health and Safety. Flip indicated that PDS systems have been installed at their South Witbank Operation. With regard to their choice as a champion mine, he mentioned that he did not recall asking for assistance in addressing any issues, but only stated that they had implemented a PDS system. Glencore Xstrata did not respond to the questionnaire for additional information.

7.2.2.2 African Rainbow Minerals

The contact from ARM is Nerine Botes, Executive for Sustainable Development. During our meeting with Nerine, she mentioned that to the best of her knowledge, ARM had not to date experienced any problems with the installation or integration of PDS systems to their equipment. That being said, the installation was only a driver warning system, so the only integration required was finding a suitable power source and mounting point. The integration of PDS systems to equipment at ARM is currently being performed by the OEM suppliers of the PDS systems.

ARM have installed vehicle-to-vehicle PDS systems at three mines, Modikwa (both North and South shafts), Two Rivers and Nkomati, and vehicle-to-person PDS systems at Two Rivers. The progress of the commissioning of PDS systems at these mines is provided in the following table.

Mine	V/V Systems (PDS Systems)	V/P Systems (Personnel Tags)
Modikwa North	110/110	0/1800
Modikwa South	97/97	0/1300
Two Rivers	181/181	3180/3180
Nkomati	18/18	0/340

ARM did not respond to the questionnaire for additional information.

7.2.2.3 AngloGold Ashanti

The contact from AngloGold Ashanti is At Greyling, Manager of Electrical, Mine and Field Services. AngloGold Ashanti currently have operational Hiprom PDS systems installed on surface track-bound vehicles and Schauenberg systems installed on all trackless vehicles. They are currently in the process of installing PDS systems to underground track-bound vehicles, but are experiencing some problems obtaining a suitable single PDS system for both vehicle-to-vehicle and vehicle-to-person detection.

All the problems listed as “integration issues” by the mine were related to the actual PDS system, and not to the integration or interfacing of the PDS system with the mining equipment. Examples of these problems included software issues, radio signal degradation, software firmware updates and changes in antenna design.

AngloGold Ashanti commenced installation of PDS systems to their equipment early in 2013 and currently have PDS systems installed on 100% of their trackless machines, but only 4% of their track bound machines.

Based on my discussions, it would appear that the problems related to the installation of PDS systems on hard-rock track-bound vehicles are more related to the availability of a suitable PDS system (see SIM130501 project) than to protocol or interface related issues.

AngloGold Ashanti reported the successful installation and commissioning of vehicle-to-vehicle and vehicle-to-person PDS systems on all 47 of their trackless machines at Mponeng. They also reported the installation and commissioning of PDS systems on 11 track-bound machines at Mponeng and 7 track-bound machines at Savuka; although these values represent only 4% of the total number of track-bound PDS systems required at all sites.

7.3 Machine Suppliers

Due to the lack of feedback from the champion mines, a number of common mining machinery suppliers were identified and contacted for information regarding the availability and nature of interface subsystems for integrating PDS systems.

The list of suppliers contacted were:

- Atlas Copco
- Barloworld / Caterpillar
- GHH Fahrzeuge
- Komatsu
- Manitou
- P&H Mining
- Sandvik
- Trident

7.3.1 Summary of Findings

The machinery suppliers and OEMs are in general not willing to disclose any information related to the operation and/or interfaces to any of their systems to third parties. This has been echoed by several PDS suppliers as the primary limiting factor to the easy integration of PDS systems onto mining machines. This is most likely as a result of the local agents being sales representatives for large international brands and therefore having very little sway in terms of technical details. The companies are also more likely to provide this information when there is a firm offer to purchase their machines. I believe the results of the enquiry would have proceeded along a radically different course were I interested in actually acquiring any machines from the suppliers.

Sandvik appear to be the exception in this case, working with several PDS suppliers to provide the necessary interfaces to limit the operating speed and to stop their vehicles. This has resulted in their vehicles appearing in several demonstration videos obtained from the PDS suppliers.

These findings highlight the importance of stakeholder buy-in on behalf of the mines to obtain interface information for the PDS suppliers. The PDS suppliers themselves do not buy the equipment and therefore have no power necessary to obtain the required information from the machine suppliers. This point was raised in several discussions with PDS suppliers, citing cooperation from the mines when negotiating with machinery suppliers as the single most important determining factor for the success of an installation.

Another complicating factor is the presence of old machines in the mines. These machines lack the modern control systems and interfaces and therefore present more of a challenge when integrating PDS systems.

7.3.2 Detailed Information per Supplier

As mentioned in the summary of findings, most machine suppliers were reluctant to provide any information on their products. The following two suppliers were the only ones to actually return calls and provide additional information.

7.3.2.1 Manitou

Manitou claim to have been involved in several projects involving the integration of PDS systems with their equipment – although very little additional information was provided. When commenting on the available protocols or machine interfaces, they mentioned that as the machines are built to order, customer requests for proprietary interface protocols are handled on a per case basis and it is therefore not possible to comment on the available protocols for any one machine in general.

7.3.2.2 Trident

Trident locomotives manufacture the mechanical subsystem of the locomotives only and procure external controllers and PDS systems. The two most common controller subsystems are provided by Battery Electric and A&R Engineering. Battery electric make provision for external inputs to stop the locomotive, and A&R engineering have a proprietary vehicle-to-vehicle PDS system called A&R LDIS (Locomotive Driver Information System). As this system is manufactured by the suppliers of the locomotive controllers, integration is carried out by the machine suppliers.

7.4 PDS Suppliers

This section covers information that was obtained from some PDS suppliers. These suppliers were chosen for their local presence, subsequent ease of access and prevalence in the industry. Following the lack of integration problems identified by the champion mines, the PDS suppliers were contacted in an attempt to elicit any interface problems that were experienced during installations of their systems. In general, the PDS suppliers were much more willing to provide information on their systems, installations and success stories.

7.4.1 Summary of Findings

Information obtained from the PDS suppliers indicate that hundreds of systems have been successfully installed, primarily in coal and trackless hard-rock installations. PDS systems for track-bound installations exist in the form of GPS- and camera-based systems for above ground installations, as well as, vehicle-to-vehicle systems for underground installations. There are a couple of vehicle-to-person PDS systems explicitly designed for underground track bound installations; however they do not have local distributors.

At present, every installation is handled as a unique case as no 3rd party PDS systems are inherently compatible with any machinery control systems. As a result, every installation requires some degree of customisation. This can complicate and prolong the installation process. One possible solution to address this would be the standardisation of interfaces across machines and PDS systems to simplify the installation process.

Important factors that were raised by multiple suppliers as indicators of the success of a PDS system installation are:

1. The importance of mine management buy-in and negotiation with machine suppliers to obtain the necessary interface points with the vehicles.
2. That older machines are the primary cause of problems when it comes to interfacing PDS systems with machines, as these machines lack the modern control systems that are typically required to interface to the PDS systems.

7.4.2 Detailed Information per Supplier

The following detailed information was obtained from the contacted suppliers.

7.4.2.1 Becker Mining Systems

Becker Mining Systems have been producing and supplying PDS technology to the mining industry for the past 18 years and are currently on their 4th generation of PDS systems. Early PDS systems were purely auditory/visual driver warning systems, but newer models are able to integrate with machinery control systems to slow down and stop vehicles.

Over their 18 years in business, they estimate to have sold around 5000 units worldwide together with over 50 000 personnel tags for vehicle-to-person PDS.

They have implemented stop and slow functionality onto a number of vehicles including regular consumer road vehicles (engine cut only), GHH Fahrzeuge machines at Glencore Xstrata and Sandvik machines. They have been working alongside Sandvik for approximately 18 months to develop the necessary interface protocols to stop and retard diesel vehicles, specifically through use of the CAN bus[1]. They have also been involved with several installations in Australia and the USA with various companies.

They are also suppliers for other PDS related technologies such as locomotive controllers, surface PDS systems utilising GPS and systems incorporating cameras to detect people.

When asked to comment on specific integration issues that have been experienced, they provided the following information:

1. Each type of machine requires a unique process for stopping the vehicle and a unique zone in which the machine should be disabled. For this reason, the company has developed as many as seven unique antennas to account for the various machines and configurations.
2. Standardisation across multiple machine suppliers and mineral commodities would go a long way to simplifying the installation process.
3. Many companies do not want the PDS system to interface directly with the vehicle, but rather just inform the driver of the presence of other vehicles or

[1] The CAN bus or Controller-Area-Network bus is a communications bus that was developed by the automotive industry, and has been incorporated in modern consumer vehicles and transport vehicles to manage communication between systems within the vehicle. Typical examples of such systems include technologies such as cruise control, ABS, dashboard information and entertainment systems.

people in the immediate area and leave the driver to make an intelligent decision.

7.4.2.2 Strata Systems

Strata Systems produce a magnetic field based PDS system that has been successfully commissioned in both coal and hard-rock trackless installations. They are currently working with AngloGold Ashanti to implement a vehicle-to-person system on their underground track-bound systems.

They have between 450 and 500 systems operating in coal mines and between 350 and 400 systems operating in hard-rock trackless installations within South Africa. They also have a large number of systems installed at various sites around the world, and have installed their systems on surface vehicles.

They have installed systems with stop and retard functionality on forklifts, tractors and a Sandvik LHD. Demonstration videos are available on request.

Installation of their systems in coal mines progressed much more successfully than the associated installation into hard rock mines. They attribute this predominately to the compliance and buy-in of the mining management and their assistance in obtaining the necessary interface details from the machinery suppliers.

Older diesel vehicles prove challenging as in many cases it is not adequate to simply cut power to the diesel engine because several other associated sub-systems that need to continue operating are also powered by the diesel engine. Consider for example hydraulic machines where the compressor is powered by a diesel engine. While cutting the engine will stop the vehicle, it will also disable any systems actively supporting loads and disable the driver’s steering and brake controls. For these reasons, it is important to disable the machine in a way that does not affect the driver’s ability to control the vehicle. In most cases, this is most easily achieved by working together with the machine suppliers.

The current means of interfacing with machines is through relays that are wired into the existing safety interlocks on machines.

7.4.2.3 Schauenburg

Schauenburg have approximately 300 systems currently in use, predominately in hard-rock trackless installations at AngloGold Ashanti and Impala Platinum. Most of these systems are driver warning systems only; however, they have installed systems which permit retard and stop functionality with Sandvik.

Integration with vehicles is performed either through relays that are wired into existing safety interlocks, or through the CAN bus interfaces when the machine suppliers provide the necessary information. Typically, the older the vehicles, the more integration issues are experienced during installation.

The primary problem identified by Schauenburg when dealing with the integration of PDS systems is the support of the mining machinery suppliers, especially for the interface protocols necessary to stop and/or retard the mining machines. This support is much easier to obtain if the initial request comes directly from the mining company.

7.5 Department of Mineral Resources Initiative

The Department of Mineral Resources is currently busy with an initiative to standardise interface protocols between machine suppliers and PDS manufacturers during the study period. Several PDS and machine suppliers that were contacted mentioned that they were attending a meeting on this topic. Unfortunately, I have been unable to establish contact with anyone at the DMR who is able to provide more information on this.

7.6 Conclusions

We undertook this milestone of the project with the intent of identifying PDS-machine interface related problems currently being experienced at the champion mines. When I failed to find significant problems at the champion mines, I started contacting mining machinery and PDS suppliers to obtain their views. What I found was records of thousands of operational PDS systems installed onto mining machinery both locally and abroad. That being said, each of these installations is customised and adapted to the specific case being handled, often by creating additional interface/add-on boards or modifying the default PDS systems to interface to the machines. These findings have led me to believe, that while integration related problems may exist, they are easily overcome on a case-by-case basis, and therefore do not present a significant hurdle in the installation of PDS systems at mines.

Despite these successes, there are several indicators of when a PDS system installation may require more effort to get operational. These are the presence of older machines, lack of buy-in from machine suppliers and not having a suitable PDS system for certain types of machines.

We believe that the problem of older diesel machines will resolve itself in due course due to the World Health Organisation's classification of diesel particulate matter as a carcinogen in 2012. This will require that these machines eventually be replaced.

Non-cooperation from machine suppliers is most easily resolved by targeting their primary source of income. As PDS suppliers are not customers, the machine suppliers are in general reluctant to interact with them. Management buy-in on behalf of the mines will result in the request for interface information coming directly from the machine supplier's customer, where customer relationships and after-sales service are more likely to influence the interaction. In the initial call for proposals, it was mentioned that the interface related challenges are limited to underground hard-rock installations. One PDS supplier attributed this discrepancy to the involvement of management at the coal mines in attaining the necessary information from the machine suppliers.

The last issue to investigate is the availability of suitable PDS systems for the task at hand. Every PDS system was designed with a certain application in mind. Attempting to use this PDS system for a different application will have varying degrees of success. A primary example of this is PDS systems for underground rail-bound applications. One case was cited by AngloGold Ashanti where the 30m range of the trackless PDS system is not suitable to cover the locomotive as the length of the locomotive is 35m. Problems like this should be addressed by finding suitable PDS systems for the task at hand.

According to information from the Chamber of Mines, this project was the result of work being undertaken at AngloGold Ashanti. Their PDS commissioning started at the beginning of 2013, and this project was originally proposed at the MHSC early in 2013. During the last year, a large amount of progress in integrating PDS systems has been observed at AngloGold Ashanti. It is therefore possible, that many of the problems that existed when originally proposing this project have been independently solved by either the mines or the PDS suppliers.

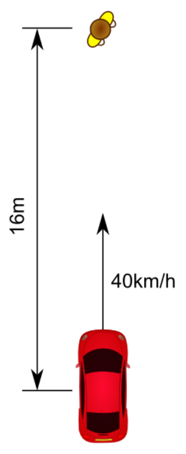
7.6.1 Importance of Driver Input

Many mines have chosen to implement driver warning systems only. This greatly simplifies the installation and integration of PDS systems to mining machines as the only requirement is mounting points and power, and a direct interface to the machinery control system is not necessary.

In this section, I attempt to answer the question of which is better, direct intervention by stopping the vehicle, or simply informing the driver of the presence of a potential obstacle. Obviously, the latter requires that the driver is paying sufficient attention to the environment and cognitively recognizes the presence of nearby obstacles.

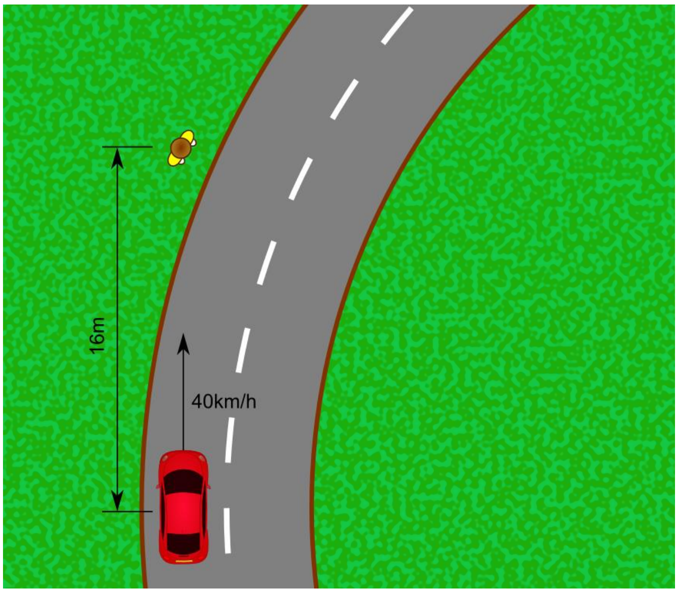
One solution to this problem is the A&R LDIS system. This system notifies the driver of the presence of another vehicle and requires the driver to acknowledge this notification. If the driver acknowledges this signal, the vehicle continues under driver control; however, if the driver does not acknowledge the signal in a sufficient time, power to the vehicle is removed and the vehicle is brought to a stop.

To emphasise the importance of driver input on the collision avoidance process, consider the configuration shown in the figure below. In this figure, a vehicle is travelling at 40km/h, with a pedestrian 16m directly ahead of the vehicle. In this situation, the vehicle would collide with the pedestrian in less than 1.5 seconds. At this point, the stopping distance is actually insufficient for most vehicles, meaning that the collision avoidance system should have already started to take action.



Now consider the case shown in the following figure. The speed and location of both the pedestrian and the vehicle have remained unchanged; however, this situation happens hundreds of times each day around the world with very few fatalities.

This example demonstrates the importance of driver input and cognitive processes (which cannot be observed/predicted) on the collision avoidance system. If we had to stop cars every time they could collide with something, we would never be able to drive. A similar example arises if we locate the pedestrian in the road far enough along the curve so that the car would miss him if it continued straight.



While this example is not always the case, it does raise an important consideration to be taken into account when interfacing collision avoidance systems with equipment.

7.6.2 Summary of Conclusions

Based on the information I have obtained through discussions with the various stakeholders involved, I have to draw conclusions from the following:

1. The project was commissioned at a time when PDS-machine interface problems existed, but these have since been resolved by the community.
2. PDS-machine interface related problems exist because the machinery suppliers will not supply the necessary interface protocols to allow the PDS systems to interface with the machines. This problem can generally be overcome with the assistance of the mining house driving the integration need with the machinery suppliers.

3. PDS-machine interface related problems exist because the machinery currently in use at the mine is too old and can therefore not interface to the new PDS technology.
4. Suitable PDS systems do not exist for the vehicle (generally limited to hard-rock track-bound vehicles) and as a result, integration problems arise when trying to use systems designed for other vehicle types.
5. PDS-machine interface problems may be cited as an excuse to delay or prevent the installation of PDS systems on a site.

7.7 Recommendations

Based on the discussions that I have had with various stakeholders in the process, my primary recommendation to simplify the integration of PDS systems with mining machinery would be the standardisation of interface protocols between machines and PDS systems together with the legislated implementation of minimum requirements by machine and PDS suppliers. These minimum requirements could be slowly evolved to ensure minimum impact on acquiring new equipment while allowing improved PDS equipment to have better communications with the newer mining machinery. While these recommendations would not solve the integration problem in existing installations, it will ease the integration problems in the future. I propose that this process be handled by developing a South African National Standard for the interface between machinery and PDS systems.

Regarding this project, based on the outcomes so far, it will not be possible to continue with the project in its current form. The initial project proposal offered as a third milestone, a report detailing solutions to the problems identified in this report. As no interface related problems have been identified in any of the champion mines, the final milestone cannot be delivered as stated. There are however some meaningful outputs that may be generated, that were initially related to the outcomes desired by the Chamber of Mines.

My recommendations regarding the continuation of this project are therefore as follows.

1. **Interfaceability Matrix:** Based on the extensive nature of the adaptations that are made to both PDS systems and machines to ensure that they interface with one another correctly, documenting this matrix does not make much sense. Instead, I would like to propose a matrix of existing interfaces, that is, a matrix

showing which PDS systems have been successfully integrated on which machines.

2. **Standardisation:** It is still possible to investigate the possibility of standardising the interface protocols between the machines and PDS systems. Although this pre-feasibility study may already be being undertaken by the DMR. Before we continue with the pre-feasibility study into the possibility of standardising interface protocols, I would like to be placed in contact with the leader of the initiative at the DMR to determine to what extent this has already been done.
3. **Discontinue:** The final option is to halt the project at its present stage.

8 Next Milestone

Planned work for the next milestone involved contacting machine and PDS system suppliers to elicit the interface protocols and compatibility. A large portion of this work was already undertaken during the current milestone in an attempt to identify PDS-machine interface and integration problems.

Many machine and PDS suppliers customise their interfaces to work with each other. Typically, the machine suppliers may provide some changes in interface protocols to accommodate the mines wishes, but by far the greatest adaptation happens of behalf of the PDS suppliers. In some cases, the PDS suppliers develop custom interface boards to match the interface and power requirements for a particular set of machines at an installation. The PDS system interface protocols therefore differ somewhat between various installations. In a similar vein, machine suppliers can provide various interfaces at the request of the clients. As a result, identifying and listing interface protocols will have limited benefit.

Following on from the desired outcomes requested by the Chamber of Mines, my recommendation moving forward is to conduct a pre-feasibility study into the possibility of standardising on a fixed interface protocol, and in the interim, to compile a list of working system pairs (i.e. mining equipment to PDS system), such that the mining community can have an indication of which systems have already been interfaced with which machines.