Trade & Investment
Mine Safety

GUIDELINES

MDG 2007

Guideline for the selection and implementation of collision management systems for mining

~~July~~ December 2013

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July 2013

Acknowledgements

The constructive evaluation and input provided by the Mining Equipment/Personnel Interaction Advisory Group (MEPIAG) Working Group Members is gratefully acknowledged in the development of this guideline. We wish to thank the Coal Safety Advisory Committee for its most welcome support of this publication.

Disclaimer

The compilation of information contained in this document relies upon material and data derived from a number of third party sources and is intended as a guide only in devising risk and safety management systems for the working of mines and is not designed to replace or be used instead of an appropriately designed safety management plan for each individual mine. Users should rely on their own advice, skills and experience in applying risk and safety management systems in individual workplaces.

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Foreword

The working group was formed at the completion of work that was done by the Remote controlled Equipment advisor group which was originally charged with reviewing MDG 5002 *Guidelines For The Use Of Remote Controlled Mining Equipment* that was developed following a review into mine safety commissioned by the then NSW Minister for Mineral Resources, the Hon Bob Martin MP, in November 1996. The original guideline was developed by Task Group One and was first published in February 1998.

During 2002, the Remote Control Equipment Advisory Group (RCEAG) was formed with representatives from underground coal operators, unions, equipment suppliers, NSW Mine Safety and the Department of Natural Resources and Mines QLD. The scope and purpose of the RCEAG was to develop industry guidelines associated with the use of remote control equipment used in mining.

In 2011 the working group was reformed and retitled to Mining Equipment, Personnel Interaction Advisory Group (MEPIAG) to develop guidance material associated with interaction of people, infrastructure and equipment. The group consists of representatives from underground coal operators, unions, equipment suppliers, NSW Mine Safety and the Department of Natural Resources and Mines QLD.

Acknowledgement is given by the working group to AngloAmerican and Glencore Xstrata for allowing use of material to allow development of this publication.

As technology advances and is used in mines the risk profile changes. It is not the intention of the working group to stifle or restrict technology advancement, but to assist with maintaining ALARP for the industry and assisting operator and designers of plant to establish common ground.

Functions of MEPIAG

The scope of the MEPIAG is to advise industry on:

- The management of interaction risks to personnel, infrastructure and equipment during mining operations.
- The implementation of proximity detection/collision management systems to minimise risks to personnel, infrastructure plant and equipment.
- Act as a forum for mining operators, employee bodies, equipment suppliers and regulators to work together to improve safety in this dynamic environment.
- The group will focus on all types of mining (underground, surface, coal, metalliferous and extractive).

Core activities for MEPIAG

The group will undertake the following activities:

- Participate in the review of legislation, standards and guidelines
- Monitor the implementation of proximity detection systems and new technology in this area
- Review any significant incidents relating to collisions and near misses reported to a regulatory authority as required
- Develop guidance material relevant to the scope
- Effectively communicate its activities to industry
- Advise regulatory authorities as required

MDG 2007, *Guideline for the selection and implementation of collision management systems for mining* was developed by an industry working group coordinated by the MEPIAG sub-committee. The working group consisting of representatives from a number of mines in NSW, equipment suppliers/maintainers, unions, NSW Trade & Investment and Department Natural Resources and Mines Qld. Their constructive evaluation and input into the development of this guideline is gratefully acknowledged. This is a 'Published Guideline'. Further information on the status of a Published Guideline in the range of WHS instruments is available through NSW Trade & Investment – Mine Safety, Legislation. The range of instruments includes:

- Acts of Parliament
- Regulations made under the Acts
- Conditions of exemption or approval
- Standards (AS/NZS, ISO, IEC).
- Approved industry Codes of Practice (under the WH&S Act).
- Applied guidelines.
- Published guidelines.
- Guidance Notes.
- Technical Reference documents.
- Safety Alerts.

The MDG 2007, *Guideline for the selection and implementation of collision management systems for mining*, was distributed to industry for consultation and comment through a representative working group, the Coal Safety Advisory Committee and the Mining Equipment Personnel Interaction Advisory Group.

NSW Trade & Investment Mine Safety Operations has a review time set for each guideline that it publishes. This can be brought forward if required. Input and comment from industry representatives will be much appreciated. The feedback sheet (separate Word document) can be used to provide input and comment.

Rob Regan
Chief Inspector of Mines

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1.1 Title

This MDG 2007 the *Guideline for the selection and implementation of collision management systems in mining* has been developed for use by coal mines, metalliferous mines and quarries (referred to in this guideline as mines).

Purpose and scope

The purpose of this guideline is to provide information to assist in applying an appropriate methodology to define, select and implement a collision management system suitable for the mine and may be used to review the system in operation.

The scope of this guideline is limited to providing guidance for an operator to select and implement a suitable system for their operation as well as providing consistency across the mining industry.

~~The scope of this guideline is limited to providing guidance for an operator to select a suitable system for their operation as well as providing consistency across the mining industry.~~

This guideline applies to equipment used in mines that interact with people, other equipment and infrastructure.

~~This guideline applies to Equipment Under Control (EUC) used in mines that interact with people, other equipment and infrastructure.~~

It is important to note that:

1. Adherence to guidelines does not itself assure compliance with the general duty of care.
2. ~~Mine operators deviating from guidelines should document a risk assessment supporting the alternative arrangements and demonstrate that there is no increase in safety risk.~~
3. These guidelines have been developed by an industry working group with representation from all stakeholders. The working group has deliberated over ideas and suggestions and recognises that some operators could have other ideologies.
4. This guideline defines a minimum recommended approach to the selection of a suitable collision management system for a mine. Mines are encouraged to look at their application and provide a system that is suitable for the mine.

   ~~*Note: Collision Management System is the collective name for the preventative and mitigating controls that reduce the frequency of collision situations and the level of risk to as low as reasonably practicable/achievable (ALARP).*~~

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1.2 Definitions

The following definitions apply to this technology:

ALARA — **As Low as Reasonably Achievable**

ALARP — **As Low as Reasonably Practicable**

The level of risk between tolerable and intolerable levels that can be achieved without expenditure of a disproportionate cost in relation to the benefit gained.

Behaviour Zones — Behaviour zones are dynamically sized zones based on the current situation of the plant. These behaviour zones are defined independently of the detection zones; whilst still considering the abilities / limitations of the sensing technologies.

CAS — **Collision Avoidance System**
The combination of technologies (i.e. SAT, PAT, PDT & CAT) to form a system.

CAT — **Collision Avoidance Technology**
Technology or device/s that actively scans for other vehicles or personnel and takes automatic action to render the equipment to a safe state (e.g reversing radar with brake control).

CAT Zone — The CAT zone is the area in which CAT is primarily required to operate. PDT and PAT may overlap this zone. CAT zones are identified in these series of documents with red colouring.

Collision Management System is the collective name for the preventative and mitigating controls that reduce the frequency of collision situations and the level of risk to as low as reasonably practicable/achievable (ALARP).

CWA — **Controlled Work Area**
An area, defined by a site-specific risk assessment, where trained people can enter to work and operate the machine. This is type of control is considered to be low on the hierarchy of controls. A collision awareness system will elevate the controls within the hierarchy of controls (Figure 1).

Detection Zones — Detection zones are defined as the range of the sensing technology. For example, an electromagnetic field zone may only cover a few metres from the machine; whilst a UHF signal may cover up to 100 metres. It is of very high importance that the mine have an understanding of the abilities and limitations of each sensor type being used to determine proximity. A detection zone should be identified for each sensing technology used.

E/E/PES — (AS61508 Term) - **Electrical/Electronic/Programmable Electronic System** for control, protection or monitoring based on one or more electrical/electronic programmable electronic devices, including all elements of the system such as power supplies, sensors and other input devices, data highways and other communication paths, and actuators and other output devices.

EQ — Acronym – **EQ**uipment – one of the key system elements (after Nertney et al) related to achieving safe production.

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EUC	**Equipment Under Control** (AS61508 term). Equipment, machinery, apparatus or plant used for manufacturing, process, transportation, medical or other activities.
Functional safety	Part of the overall safety relating to the EUC and the EUC control system that depends on the correct functioning of the E/E/PE safety related systems, other technology safety related systems and external risk reduction facilities. (AS61508 Term)
Interaction	Defines as an intentional or unintentional close encounter between two or more objects. This may be • equipment to personnel • equipment to equipment • equipment to infrastructure

Mine	Refers to the following types of operations: • Underground coal mine • Surface coal mine • Underground metalliferous mine • Surface metalliferous mine • Extractive operations (quarries)
Mobile equipment	Includes all equipment that can move under its own power on wheels, crawler tracks or on rails.
Moveable plant	Plant that is mounted on skid plates and is normally stationary but, it can move under its own power using a walking mechanism, external hydraulic supply or by cable winch. (e.g dragline, longwall roof support).
OEM	**Original Equipment Manufacturer**. The OEM referred to in this MDG might refer to the manufacturer of the host mobile machine or the manufacturer of the collision management system that may be two or more separate parties. It is expected that where more than one OEM is involved, that all OEMs will interact and clearly document roles, responsibilities and boundaries for each party to achieve a safe outcome.
PAT	**Proximity Awareness Technology** Technologies that aid personnel to identify they are converging to another vehicle, person or infrastructure (e.g. reversing mirrors, flashing lights, reversing sirens).
PAT Zone	The PAT zone is the area in which PAT is primarily required to operate. PAT zones are identified in these series of documents with yellow colouring.
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).
PDT Zone	The PDT zone is the area in which PDT is primarily required to operate. PAT zones might overlap this zone. PDT zones are identified in these series of documents with orange colouring.
PE	Acronym – **PE**ople - one of the key system elements (after Nertney et al) related to achieving safe production.
Qualified functional safety practitioner	A person registered on the National Professional Engineers Register, with experience ~~with~~ and registration in functional safety and risk management or a person certified under an internationally recognised scheme recognised for functional safety practitioners or a person with knowledge and experience of functional safety and knowledge and experience in conducting risk assessment involving functional safety.
Safety Function	(AS61508 term) - Function to be implemented by ~~an E/E/PE safety relateda~~ a safety related control system, other technology related system or external risk reduction facilities, which is intended to achieve or maintain a safe state for the EUC, in respect of a hazardous event.

Safety requirement specifications	Specification containing all the requirements of the safety functions that has to be performed by the safety related systems. (AS61508)

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).

SCADA — **Supervisory control and data acquisition.**
It refers to industrial computer systems that monitor and control industrial, infrastructure, or facility-based processes.

SIL — **Safety Integrity Level**. (AS61508 term)
Discrete level (one out of a possible four) for specifying the safety integrity requirements of the safety functions to be allocated to the E/E/PE safety-related systems, where safety integrity level 4 has the highest level and safety integrity level 1 has the lowest.

SOP — **Standard Operating Procedure**

Stationary plant — Plant that cannot move under its own power and may be either fixed or relocatable from time to time using other equipment (e.g. portable lighting tower, generator set, pit pump, DCB).

void (No-Go) — In some instances, mobile equipment and personnel might be prohibited from entering areas that might include

- unstable ground
- open stopes
- highwalls
- out-of-bounds areas around machines
- blast zones
- other off limit areas

worker — A worker is anyone who carries out work for a PCBU, such as:

- an employee
- a contractor or sub contractrtor
- an employee of a sub contractor
- an employee of a labour hire company
- an apprentice or trainee
- a student gaing work experience
- an outworker
- a volunteer

You may also be a PCBU and a worker if you carry out work for another PCBU

~~This includes people working on site and includes: management, maintainers, equipment operators, supervisors, contractors, suppliers, consultants and authorised officers.~~

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SECTION 2 - Introduction

2.1 Context

Industry has developed this publication based on the number of fatalities, serious bodily injuries and near misses that have occurred globally in the mining industry.

This guideline is intended to assist operators in the decision-making process of selecting a collision management system.

It is important that the user of this publication notes;

a) The decision process needs to consider interactions between;

- equipment to personnel
- equipment to equipment and
- equipment to infrastructure

Note: Throughout this publication the three interactions listed above are referred to as interactions.

b) The collision management system needs to provide additional layers of protection to reduce the risk of collision interaction where other types of controls are not effective or impractical to apply. It is not intended that the~~se~~ systems replaces existing administrative controls (e.g. induction, training etc) but will be elevated within the hierarchy of controls ~~to engineering as a minimum~~ (refer to Figure 1) to ensure that the risks associated with interactions are as low as reasonably practicable.

c) The collision management system needs to consider the use of functional safety standards in relation to safeguards through the design, implementation and operation with appropriate safety integrity. (e.g.. where the system has been designed and manufactured based on SIL assessment principles but has not had formal SIL rating applied the full documented evidence needs to be made available to equipment operators).~~The collision management system needs to consider the use of safeguards throughout the design, implementation and operation with appropriate safety integrity. (e.g. the system might have been designed and manufactured based on SIL assessment principles but might not have had a formal SIL rating applied. Full documented evidence needs to be made available to equipment operators).~~ For integrated systems, the following information shall be provided to the machine operator:

- Assurance of what functional safety standard has been used.
- Identification of safety critical systems and components of those systems.
- Documentation of what tasks need to be undertaken to maintain system integrity across the lifecycle of the system.

For non-integrated systems the commissioner of that system is solely responsible for the system functional safety performance."

d) The working group highly recommends that a functional safety approach in the application of collision management systems is applied throughout the equipment's life cycle. This approach will provide a safety assessment of all aspects of the system including integration of multiple sub systems to form the overall system.

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Where safety critical aspects of a third party~~the~~ system have been identified during the machine risk assessment "~~definition of function safety~~", a suitably qualified functional safety practitioner should be engaged to assist in the assessment of the design.

Third party collision management systems may impair the existing safety functions on the host equipment. The OEM should be consulted to determine the impact to these safety functions, if any, and their significance.

~~It should be noted that installing an aftermarket PAT, PDT or CAT might impair the safety function of the host machine. The OEM's during the design of integration of systems. Contact should be made with the host machine's (mobile or movable) OEM to confirm that there is no impact on the functional safety of the machine~~

e) Risk management practices that are used are consistent with the methods already in use at the mine or that these practices be improved to cater for analyses of ~~proximity detection equipment~~collision managmenet system.

f) MEPIAG understands that technology is continually emerging and users need to be aware of the changes and advances in technology.

1. Eliminate the hazard
2. Substitute/minimise
3. Isolation from people
4. Engineering control
   - Redesign
   - Enclose
5. Administrative controls
   - Safe Work Procedures
   - Training
   - Warning devices
6. Personnel Protective Equipment

   (last line of defence).

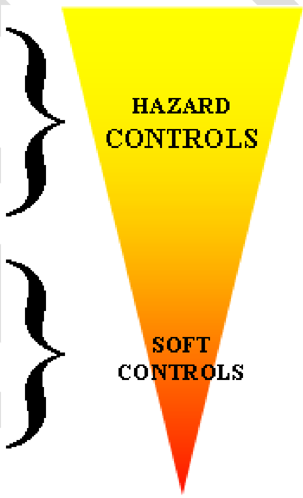

Figure 1 – Hierarchy of controls

2.2 Intent of collision management system

The intent of the collision management system is to reduce overall operating risk by:

a. recording all interactions and events for analysis so that the mine can use the captured data to analyse the effectiveness of the system. This analysis allows the management of excessive alarming during the implementation and operation of the system (applies to PDT and CAT only)

b. providinge additional information to personnel on the proximity of equipment, infrastructure and personnel in the surrounding area (applies to PAT / PDT / CAT)

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c. alerting people to interactions that might be unsafe to allow them to take corrective action (applies to PDT and CAT only)

d. intervention and take a form of control to prevent an unsafe event through appropriate risk management practices in the event of a dangerous interaction to prevent an unsafe event provided that the control can be applied safely and the overall risk is reduced through appropriate risk management practices (applies to CAT only).

The intent of the collision management system is to:

a) record all interactions and events for analysis so that the mine can use the captured data to analyse the effectiveness of the system. This analysis allows the management of excessive alarming during the implementation and operation of the system.

b) provide additional information to personnel on the proximity of equipment, infrastructure and personnel in the surrounding area.

c) alert people to interactions that might be unsafe to allow them to take corrective action.

d) intervene and take a form of control through appropriate risk management practices in the event of a dangerous interaction to prevent an unsafe event.

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2.3 Purpose

This document describes a methodology for defining a collision management system for a mine or mines.

It also provides guidance to assist mines to incorporate appropriate functional safety requirements into the scope of works to ensure that the system functions correctly and reliably throughout its life cycle. Consideration of integration into pre-existing systems needs to be assessed by each mine based on the type of plant/equipment that is being proposed.

2.4 Legislation, standards and publications

2.4.1 Legislation

a) *Work Health and Safety Act 2011*

b) *Work Health and Safety Regulation 2011*

c) *Coal Mine Health and Safety Act 2002* (*CMHS Act 2002*)

d) *Coal Mine Health and Safety Regulation 2006* (*CMHS Regulation 2006*)

e) *Coal Mining Safety and Health Act 1999 (QLD)*

f) *Coal Mining Safety and Health Regulation 2001(QLD)*

g) *Mining and Quarrying Safety and Health Act 1999 (QLD)*

h) *Mining and Quarrying Safety and Health Regulations 2001 (QLD)*

Note: Details of the legislation can be found at www.legislation.nsw.gov.au and www.legislation.qld.gov.au

2.4.2 Australian and ISO Standards

a) *AS/NZS 4024 Safety of Machinery.*

b) *AS/NZS 4240 Series Remote Control Systems for Mining Equipment.*

c) *AS/NZS 4360 Risk Management.*

d) *AS/NZS 4871.1 Electrical Equipment For Coal Mines For Use Underground General Requirements.*

e) *AS/NZS/ISO 31000:2009 Risk Management*

f) *AS61508 Series, "Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems".*

g) *AS62061 Safety of Machinery – Functional safety of safety related electrical, electronic and programmable electronic control systems.*

h) *ISO 5006 Earth-moving machinery – Operators field of view – Test method and performance criteria.*

i) *ISO 12100 Safety of Machinery – General principles for design – Risk assessment and risk reduction.*

j) *ISO 13766 Earth-moving machinery – Electromagnetic compatibility.*

k) *ISO 13849-1 Safety of machinery – Safety related parts of control systems – Part 1: General principles for design.*

l) *ISO 15998 Earth-moving machinery – Machine-control systems (MCS) using electronic components – Performance criteria and tests for functional safety.*

2.4.3 NSW Trade & Investment– Mine Safety publications

a) *MDG 15 Guideline for Mobile and Transportable Equipment in Mines.*

b) *MDG 1010 Risk Management Handbook.*

c) *MDG 1014 Guide to Reviewing a Risk - Assessment of Mine Equipment and Operations.*

d) *MDG 5001 Guidelines for the Design of Remote Control Systems for Mining Equipment.*

e) *MDG 5004 Study of Risky Positioning Behavior of Operators of Remote Control Mining Equipment.*

f) *Minerals Industry Safety Handbook – July 2002.*

g) *Mine Safety Management Plan Workbook.*

SECTION 3 - Process for establishing collision management systems

This section provides guidance material for a mine to establish a collision management system suited to the operation. Integrated throughout the process are varying risks that need to be assessed and controlled. The goal of any system is to strive for zero harm (Refer to Figure 2).

Systems identified in Figure 3 should, where appropriate, be developed and expanded in consultation with workers.

Notes:

1. *Risk assessment referred to throughout this document generally refers to the assessments completed by the mine to understand the basis and requirements of their intended system.*
2. *In consultation with designers, manufacturers and installers the mine should participate in completion of risk assessments at the various life cycle phases of the host machine and collision management system to ensure that the level of risk is ALARP.*
3. *During the design of their system, –OEMS are still required to assess their system for appropriate safety integrity and functionality.*
4. *At a mine, different mining applications should be individually assessed as the risks can vary, which affects the functionality of the system.*

3.1 Risk management

3.1.1 General

Collision management systems have been introduced to primarily improve safety and reduce unsafe interactions. The system design should support/complement existing controls and not replace these controls. Equipment under control can expose workers to risks such as being run over, out of control equipment, impact from other equipment and ergonomic factors resulting in injury or death. This recognition of introducing different hazards and increasing the risk from traditional hazards requires a systematic risk-based approach to adequately manage the changes.

Management systems for the use of EUC should be integrated into the Mine Safety Management Plan (MSMP) and be based on a risk management approach to safety. Users of this guideline should refer to AS/NZS ISO 31000 *risk management – principles and guidelines* for more information.

This guideline should be considered when developing hazard controls and safe work systems for collision management systems.

Procedures for monitoring and evaluating the entire mining process and environment should be developed as an initial part of developing safe work systems and procedures. That is, no system/procedure is complete without an established monitoring, evaluation, audit and review process.

A risk management approach involving a cross section of the workers at the mine should determine safe working systems for the use of mining equipment. All hazards associated with the use of mining equipment should be identified, assessed and eliminated or adequately controlled using the hierarchy of controls (Figure 1).

3.1.2 Risk assessment

The primary objectives of a risk-based analysis are to:

1. Identify and prioritise any additional hazards that issues that could arise during the life cycle of a collision management system deployment.
2. Confirm there were no omissions or oversights in the recommended controls put forward by the various members of the risk assessment team.
3. Provide material that will suit a guidance document/starter kit for organisations considering proximity detection – issues to consider and design parameters.
4. Provide guidance material on integrating a proximity detection system into an operating mine.

Many operations are exploring the potential of introducing proximity detection. The benefits of avoiding predictable human errors in respect to positioning around machinery by warning personnel or slowing/stopping machinery movements can provide an engineered solution to a hazard (or unwanted event). A number of studies have been completed in this area, including MDG 5004, "A Study of the Risky Positioning Behaviour of Operators of Remote Control Mining Equipment" (see MDG 5004, "*A Study of the Risky Positioning Behaviour of Operators of Remote Control Mining Equipment*") by warning personnel or slowing/stopping machinery movements can provide an engineered solution to a pervasive threat.

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An independent facilitator guided the working group through a risk analysis process. It is important to consider that the outcomes of this risk analysis are:

- Process driven and challenge current thinking and may not necessarily appear appropriate or reflect "pre-conceived" ideas; and
- The result of the team review of the topic and not the results of any one individual or organisation.

It is essential to constantly challenge the underlying assumptions, current and recommended controls of any risk assessment – it is a "living process" and not a one-off exercise.

Appendix 5 lists the outcomes from a MEPIAG risk assessment.

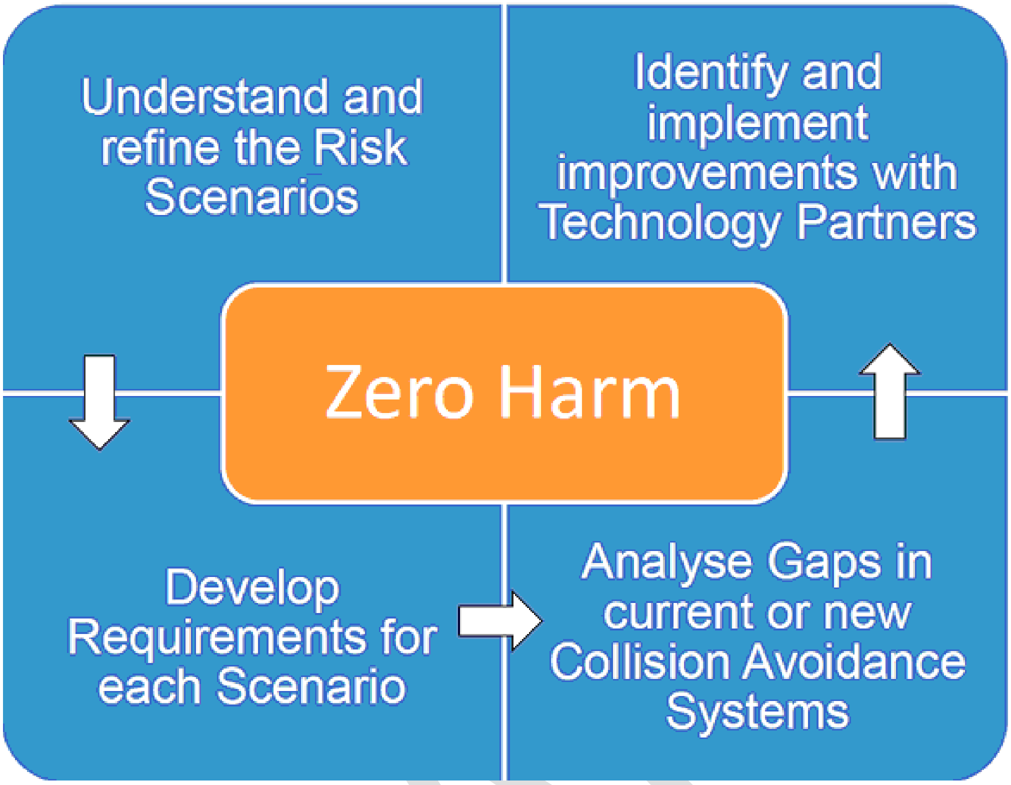

Figure 2 – Road to zero harm

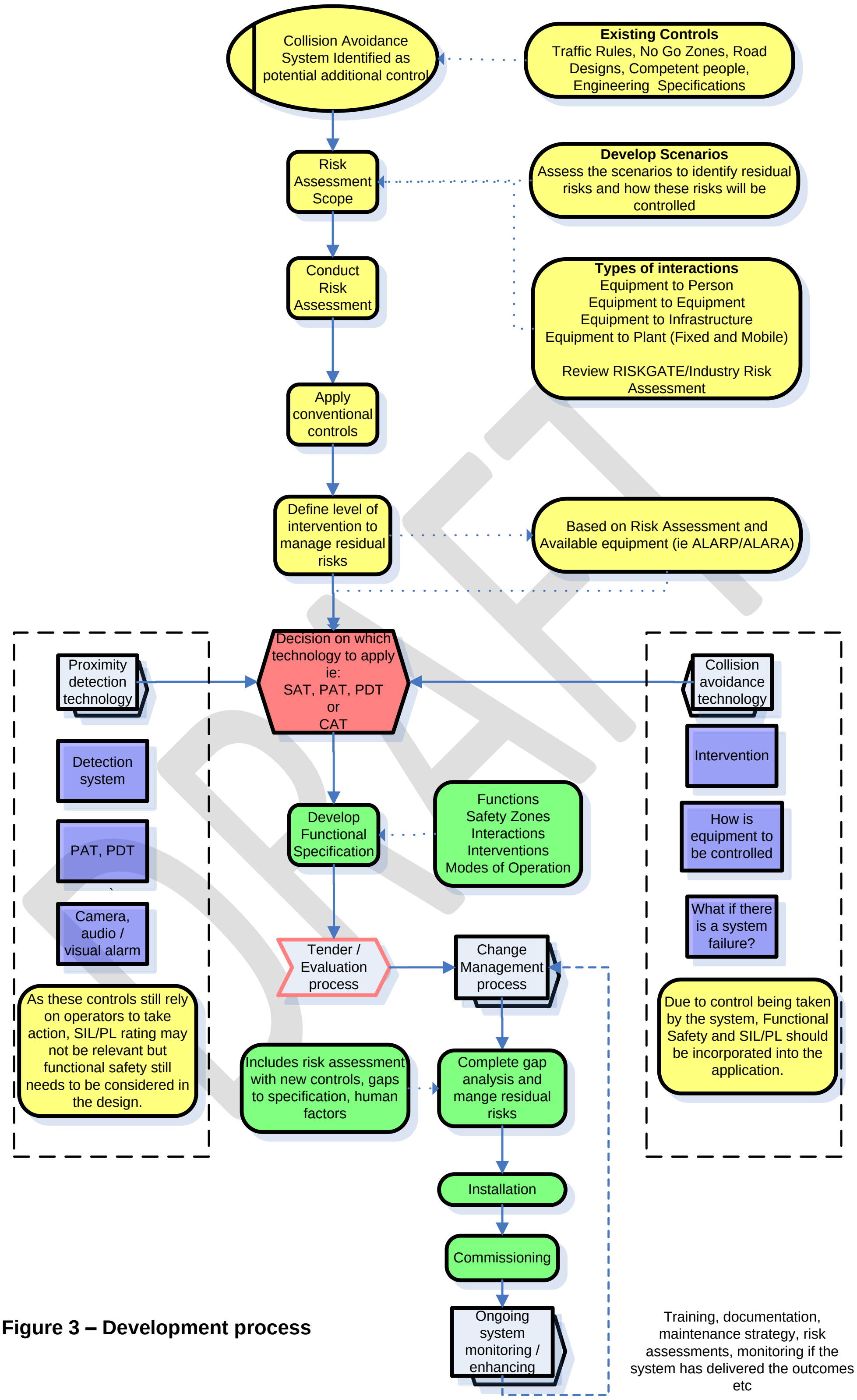

Figure 3 – Development process

3.2 Define level of intervention

Available systems have varying levels of intervention. Through a risk management approach, the mine operator should conduct a risk assessment considering the frequency of exposure and serious potential collision outcome to identify the balance required between CAT and PD~~A~~T that should be applied. The two main levels are:

1. Proximity ~~Awareness~~ Detection (operator made aware of a situation – Soft Control (Figure 1) and
2. Collision Avoidance (machine intervenes to prevent impact – Hard Control (Figure 1).

In the design, the system might require a combination of technologies to achieve a complete collision management system.

1. A PAT system is used to prevent potentially dangerous interactions from occurring by providing additional information to personnel on the status of equipment and personnel in the surrounding area.
2. A PDT system is used in the event of a potentially dangerous interaction to automatically generate alarms that instruct personnel to take corrective action to avoid a collision.
3. A CAT system is used in the event of a potentially dangerous interaction to automatically take appropriate control of equipment to avoid an adverse outcome based on the outcomes of the mine's risk assessment.

~~It is considered that~~Often, the highest risk interaction category is equipment to people. To best manage this area of risks, implementing the hierarchy of controls should, if possible, be at the engineering level or higher (refer to Figure 1).

A detailed risk assessment associated with the full life cycle of the collision management system should be undertaken to evaluate and manage new potential risks to people, plant, equipment and infrastructure at the mine.

~~A detailed risk assessment associated with the full life cycle of the collision management system should be undertaken to not introduce new risks to people, plant, equipment and infrastructure at the mine.~~

3.3 Areas of interaction

It is considered that three areas of interaction exist that should be considered during the design of a system (refer to Table 1).

1. Equipment to people.
2. Equipment to equipment.
3. Equipment to infrastructure (e.g. overhead powerlines, buildings, process plant, other types of plant etc).

	~~People~~	~~Equipment~~	~~Infrastructure~~
~~People~~		✓	
~~Equipment~~	✓	✓	✓

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~~**Table 1 – Interaction considerations**~~

3.4 Defining the function of the system

In considering the three areas of interaction, the operator should clearly define what functionality the system should provide to workers at the mine to reduce risk to as low as reasonably practicable (ALARP).

Where appropriate, the mine should ensure that designers identify safety critical components of the system so that the mine can determine a quantifiable level of risk to workers.

Safety critical functions should be identified by the designer and end user while defining the functionality of the system. The required Safety Integrity Level (SIL) or Performance Level (PL) should then be determined by the end user based on their specific operation.

Where interfacing of a system with existing systems is to occur, then the entire system, including the interface, should be considered during the functional safety assessment.

In the event that SIL/PL is unable to be assigned, other risk mitigation methods need to be specified.

~~Safety critical functions should be identified while defining the functionality of the system. An appropriate Safety Integrity Level (SIL) or Performance Level (PL) needs to be assigned. In the event that a SIL/PL has not been assigned, other risk mitigation methods need to be incorporated into the system. Where interfacing of a system with existing systems is to occur, then the entire system, including the interface, should be considered during the functional safety assessment.~~

> ***Note:*** *Technical guidance for the design of proximity detection systems should come from one of the functional safety standards listed in section 2.4.2.*

The mine should give consideration to how hire plant and equipment fitted with a collision management system can be/will be integrated into the mines system/s. (e.g. contractor plant and equipment, hire equipment).

3.5 Defining the safety zones

It is important to distinguish between detection zone minimum requirements (the actual sensing technology); and the changing, dynamic behaviour that needs to occur upon detection in different situations.

There are three specific behaviour zones defined in this guideline:

- Stop zone – the object is within critical range of the plant given the current operational situation.
- Alarm zone – the object is within an alarm range of the plant given the current operational situation.
- Alert zone – the object is within an alert range

The relationship of these zones is shown in Appendix 1 and 2.

Whilst defining safety zones, the following factors should be consider:-

1. Speed and direction of travel of EUC.
2. Location of workers.
3. Operating conditions.

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4. Operating environment.
5. Location of EUC operators.
6. Visibility from EUC position.
7. Operation of machine (e.g. remote control, onboard, tele-remote, autonomous).
8. "Demand load" on the system. (That is the likely frequency of potential interactions – so that an area such as a working production area would have a higher level of technology applied due to the increased interactions than in a working area that is less frequented or remote where the area is infrequently populated.) This should also be considered during the functional safety analysis ~~or functional safety determination~~.
9. Latency of system should be considered as the response time and ability to handle detection of multiple hazards by the CATs as well as the response time of the EUC, such as delays resulting from hydraulic system flow rates, brake wear, tyre size etc needs consideration.
10. During the defining of the detection/protection zones, consideration should be given to the dynamic shape of zones under all operational scenarios. As an example, the zone around an articulating type machine (loader, continuous miner, excavator) might need to adjust with the machine size, lateral movement, articulation or the swing radius.

3.6 Developing scope for system

The operator should develop a scope of work for the supply of system/s as defined by the mine. The scope should include items that the operator considers are mandatory and those that are optional. In developing the scope, consideration should be given to future technological advances and integration into other mine systems.

In developing the scope, the following information should ~~is to~~ be included;

1. Level or levels of intervention.
2. How functional safety is to be treated ~~determined~~ and maintained through the equipment's lifecycle.
3. Identification of safety critical functions.
4. Site specific requirements.
5. Ability to interface with other systems.
6. Limitations associated with operating conditions.
7. Testing and commissioning and verification requirements.
8. Certification documentation (where applicable).
9. Ability to accept future technology (future proofing).
10. Ability to record and log events for retrieval.
11. Maximum scan time and reaction time of system or output events.
12. Notification from the supplier/s of
    a. residual risk and/or,
    b. limitations associated with the supplied system/s or any of its components,

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c. ability to over-ride system/s in the event of a system/component failure to make the equipment safe.

d. system 'self-test' functions.

e. system safety zone range, accuracy and polar coverage.

3.7 Override for emergency recovery

A collision avoidance system might have provision to be overridden in the event of an emergency for recovery of the machine. Override shall allow the machine to be operated with limited functionality to allow recovery from areas of risk to personnel, e.g. unsupported areas, impact zones.

The mine should identify potential emergency recovery scenarios by applying team bases and/or desktop risk management practices and specify any conditions that could require the collision avoidance system to be overridden conditions.

It will be necessary to implement rigorous controls for the use of override facilities. The manufacturer/supplier of the equipment should provide recommendations on the administrative controls based on the equipment risk assessment. These recommendations should then be evaluated by the end user in relation to their specific operating conditions..

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3.8 Change management

Change management is generally well established in the mining industry. The mines/ corporate philosophy surrounding change management should be applied to achieve safe outcomes.

3.9 Installation

Installation of a collision management system is detailed in the mines risk assessment. It is recognised that more than one supplier could be utilised or more than one installer engaged. All activities associated with the installation should include:

1. Risk assessments (including interaction between work parties where required).
2. Full operation, maintenance and service documentation from supplier/s. These documents should become part of the mine's safety file.
3. Activities completed as prescribed in the supplier's documentation (typically including consideration of residual risk and procedure development).
4. A requirement to take into consideration the exposure of the system components to physical damage.
5. Mounting locations should consider:
    a. the effects of loss of signal integrity due to other physical constraints associated with the mounting location.
    b. effects on the operator through reduction in visibility associated with components of the system irrespective of mounting location.
    c. access to the components for cleaning, adjustment, maintenance etc.
6. The effect on the zones associated with components that are mounted on moveable structures (e.g. continuous miner boom (tail), dragline swing radius)
7. Design in consultation with the mine should determine the number of transmitters/sensing devices that should be mounted to provide adequate coverage.

8. Full commissioning test should be completed and documented. This should include:
    a. documented test plan specific for the equipment/installation.
    b. validation that the mine's requirements have been met.
    c. confirmation that RF signals do no affect other aspects of the operation, including controlling of machines.
9. For aftermarket systems, an assessment should be made on the impact the system will have on existing machine systems. This includes EMC and the effect on the functional safety of control systems of the base machine.

3.10 Training

By incorporating collision management systems into EUC, the equipment operator/s and management are to be trained in the systems operations. The training plan should include:

- a training plan for the collision management system to be developed and maintained.
- a process to ensure operators, supervisors and maintenance personnel are trained and competent to perform the tasks required of them in both normal and failed situations.
- a documented and competency-based training assessment process with a practical and theoretical component.
- a reassessment program.
- records on each personnel file.
- a way to ensure that the system is effective and fully operational.

3.11 Commissioning

Before any equipment is forwarded to the mine, the mine should establish that:-

- one person is appointed as the commissioning engineer. This may be an OEM or representative from the mine.
- factory acceptance testing was completed.
- the equipment is fit for the intended purpose.
- the systems meets the mandatory requirements in line with the mine's scope.

In situ commissioning should verify through documented processes that equipment operates as designed in its intended operating environment.

The process for commissioning needs to be developed based on the life cycle management process applicable to the equipment.

> ***Note:*** *Where the OEMs are in dispute, the mine should take the lead to commission the system with input from all OEMs. The process should be fully integrated into one commissioning process to ensure full functionality of the system/s to provide a safe outcome.*

3.12 Maintenance

A maintenance system to ensure that the system and its components are operable and are within tolerance should be developed and implemented at the mine. The maintenance program needs to include items that will render the equipment un-usable due to the failure of a component associated with the system or a complete system malfunction. Where a CAT system has been incorporated into the EUC, the maintenance should extend to all peripheral items or systems to ensure that all aspects of the entire collision management system are fully functional (e.g. braking system).

3.13 System health monitoring and system failure procedure

The operating condition of the collision management system should be monitored on a regular basis to ensure that the system is fully functional. Ideally the collision management system should contain automatic health monitoring/diagnostics and report to the operator via an alarm when there is a failure. In the event of a system failure, the system should fail to a 'safe-state'.

The mine via risk assessment should define what components of the collision management system are classified as 'safety related ~~critical~~' that in the event of failure, the equipment needs to be placed out of service in accordance with the operator's defect management system until the failure is rectified and the system restored to full operation. Examples may include, additional temporary controls, reassigning duty of the EUC, or standing down the machine if operation cannot be continued safely. The mine can choose to include rigorous proof testing of these safety related ~~critical~~ components as part of its maintenance strategy for the plant item/s. Other component failures not classified as 'safety related ~~critical~~', should be rectified in the specified response period.

Safety related pre-engineered and integrated system components shall be validated to the environmental condition requirements.

Examples of 'safety critical' components of a collision management system could include:

- PAT system: mirrors, reversing siren, horn, flashing light.
- PDT system: camera, radar sensor, laser scanner, RF/EM transmitter and receiver.
- CAT system: any component.

3.14 Ongoing system monitoring and review

Equipment using a collision management system should be subject to an auditing/monitoring and review process. This should be part of the continual improvement process under the MSMP. This should include implementing processes to:

- a review of all record keeping.
- remedial action from hazard identification.
- analyse results, routinely, after events or incidents/accidents involving collision management systems.
- feed outcomes from analysis back into future planning and operational processes. (Information on past notifiable incidents or high potential incidents are available on government web pages.)

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- integrate the monitoring and review of collision avoidance systems and procedures into the MSMP.
- report of system failures or operational issues back to the OEMs in a timely manner.
- report unsafe events (notifiable incidents or high potential incidents) to the relevant state regulator as required by relevant state legislation.
- monitor industry developments associated with collision management technologies.

In the event of an unplanned event the site risk assessment should be reviewed to ensure that appropriate controls are in place to prevent a recurrence

Periodical reviews of the system need to be completed irrespective of the occurrence of an unplanned event to ensure that risk is being adequately managed within acceptable limits throughout the collision management system life cycle.

3.15 Record keeping and documentation

The records and documentation of the design, planning, development (if applicable) and operation of mining equipment should be integrated with the MSMP document control system. Accurate records may include:

- Risk assessments associated with the mine planning process.
- Risk assessment reviews.
- OEM provided design, operability and maintainability assessments.
- OEM provided documentation on type approvals and certificates of conformity.
- OEM provided information on operating limits (temperature, angles / positions, vibration limits, etc).
- Selection of a mining method that provides a safe work environment. This extends to the type/s of equipment selected for the chosen mining method.
- SOPs for repeating or high risk activities.
- The equipment selection process and purchase details.
- Operational checks.
- Workplace inspections.
- Testing, verification, modification, maintenance and decommissioning records for equipment and ancillary equipment.
- Training and competency assessments.
- Hazard reporting and follow up.
- Audit and monitoring records.
- Disposal and other life cycle considerations.
- Pro-forma documents for daily pre-start and routine checks on equipment functionality – based on the risks identified.

The material collected in this manner should be controlled – ideally being kept in the plant safety file.

3.16 Future proofing

As part of any mine safety strategy, collision management systems will form an integral and important part of the overall safety design. It is therefore becoming increasingly important that the system is both well specified, and has an established level of intercommunication. The end user should consider the level of integration of each interaction system at the functional definition phase of the process.

This may be achieved by the mine specifying the use of an “open” communication protocol to allow the collision management system/s to communicate between each other and other systems in operation. This protocol may also assist in other systems introduced to site through the contractors or hire equipment being able to be easily interfaced.

Mines should consider when discussing systems with OEM’s that the system is not locked into isolation and can communicate through an open protocol.

Consideration should also be made regarding;

- Integration with newer models.
- Intercommunication with newer devices.

Note: At the time of writing, an ACARP project is being conducted to develop an open communication protocol for collision avoidance systems on underground mining equipment.

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Appendices

The information in this appendix should not be used on its own. It should be used in the context of using the whole of this guideline. To provide input to site specific risk assessments to design specific drawings for each mine.

The information in this appendix has been provided by companies that have their own particular circumstances (mine layout, geological conditions, ventilation arrangements, workforce cultures, and competencies). The equipment types are not exhaustive but are intended to provide a representative sample of mining machines. This information has been provided as a sample by the MEPIAG and presented as generic samples only.

The dimensions ‘F’, ‘R’, ‘S’, ‘Ra’, ‘Rb’ and θc are to be developed by conduct of desktop engineering (stopping distance calculations etc) analyses and team based risk assessments considering the type of machine, direction of travel, speed and level of protection required by the system.

Appendix 1 – Sample surface equipment zones

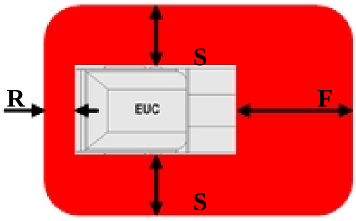

Figure 4 – Stop zones for a dump truck travelling in a forward direction

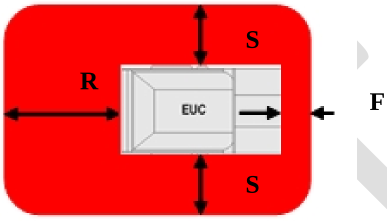

Figure 5 – Stop zones for a dump truck travelling in a reverse direction

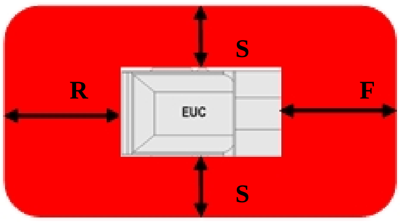

Figure 6 – Stop zones for a stationary truck

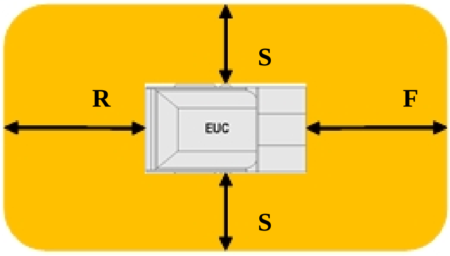

Figure 7 – Alarm zones for a dump truck

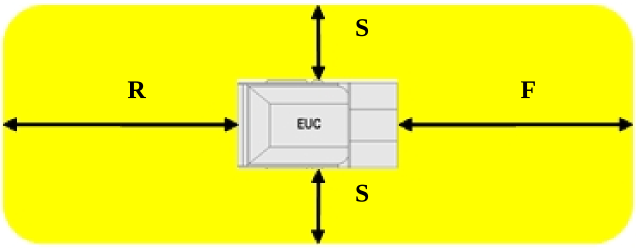

Figure 8 – Alert zones for a dump truck

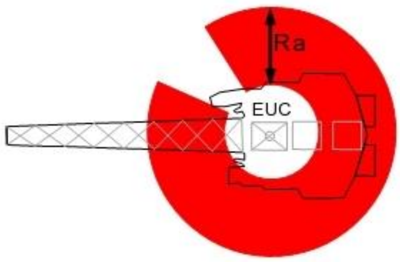

Figure 9 – Stop zone for a dragline in boarding mode

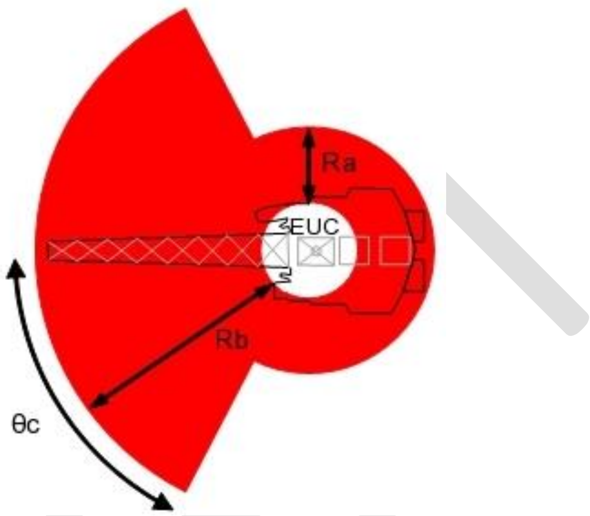

Figure 10 – Stop zone for a dragline in walking, and maintenance modes

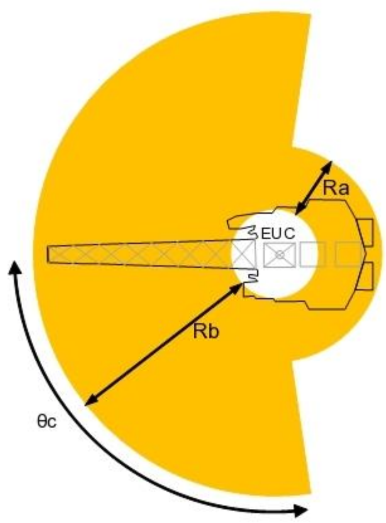

Figure 11 – Alarm zone for a dragline

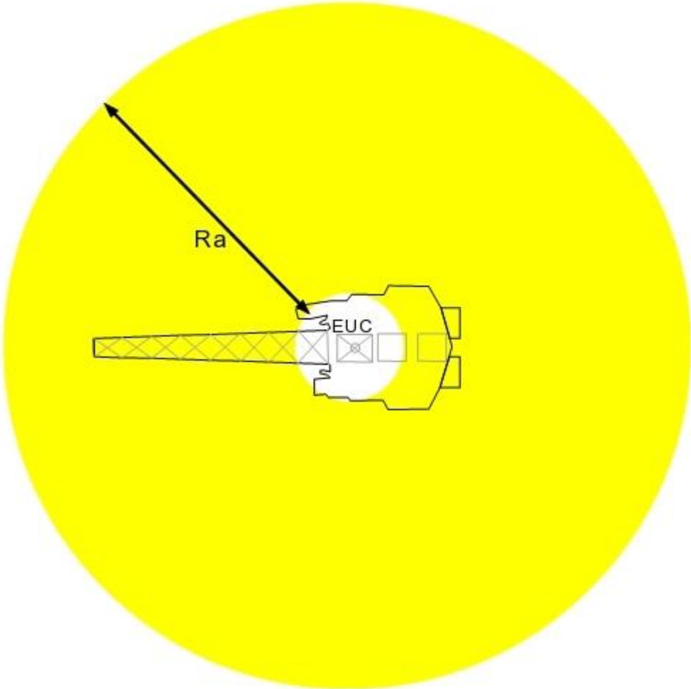

Figure 12 – Alert zone for a dragline

Appendix 2 – Sample underground equipment zones

Note: The following drawings are to indicate zones associated with the use of proximity detection / collision avoidance technologies. Users also need to consider No Go / Go Zones around underground machines. Detail to assist in deciding these locations can be referenced from AS/NZS 4240.3.

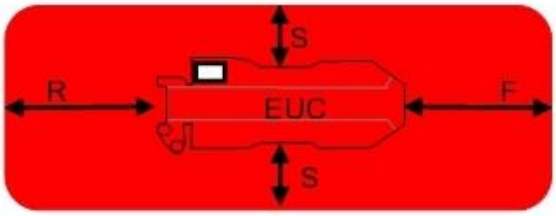

Figure 13 – Stop zone for a shuttle car

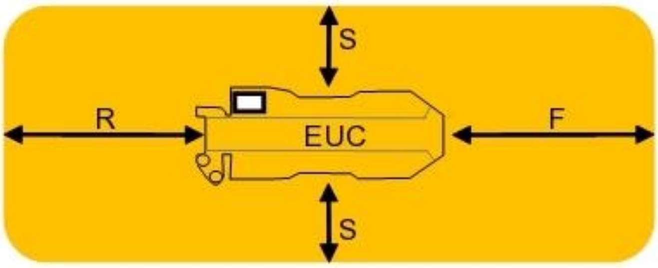

Figure 14 – Alarm zone for a shuttle car

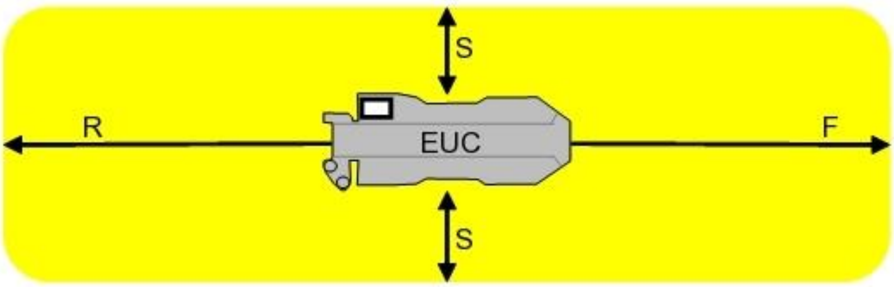

Figure 15 – Alert zone for a shuttle car

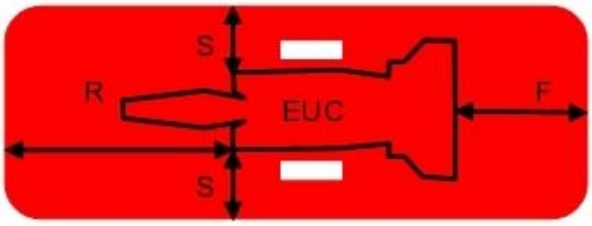

Figure 16 – Stop zone for a continuous miner

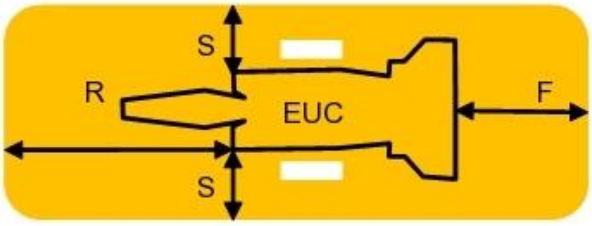

Figure 17 – Alarm zone for a continuous miner

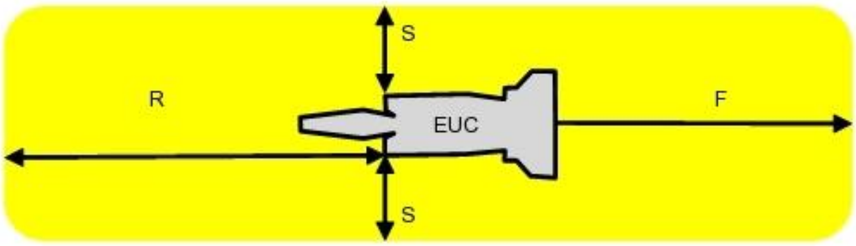

Figure 18 – Alert zone for a continuous miner

Appendix 3 – Sample hazard and zone requirement table

The following table is indicative only and each mine will need to develop its own.

Nominated Hazard	Criteria		Technology			
			SAT	PAT	PDT	CAT
Personnel	Zone	Alarm	Desired	Required	Not Required	Not Required
		Alert	Required	Not Required	Required	Not Required
		Stop	Required	Not Required	Not Required	Required
	SIL / PL		To be determined			
	Demand		N/A	High	High	Low
	Response Time		N/A	<1s	<1s	<1s
Plant / Infrastructure	Zone	Alarm	Desired	Required	Not Required	Not Required
		Alert	Required	Not Required	Required	Not Required
		Stop	Required	Not Required	Not Required	Required
	SIL / PL		To be determined			
	Demand		N/A	High	High	Low
	Response Time		N/A	<1s	<1s	<1s
Mobile equipment	Zone	Alarm	Desired	Required	Not Required	Not Required
		Alert	Required	Not Required	Required	Not Required
		Stop	Required	Not Required	Not Required	Required
	SIL / PL		To be determined			
	Demand		N/A	High	High	Low
	Response Time		N/A	<1s	<1s	<1s

Appendix 4 – Risk assessment

The approach taken by the MIPIAG team and that users should consider of proximity detection equipment is broadly in line with that described in Figure 19 – with the notable exception that as the subject matter was purely related to control deployment/failure that the matrix method of risk calculation could not be applied[1] – and a more qualitative priority setting approach was used.

Any risk assessment completed should utilise the cross section of the workers at the mine, and relevant stakeholders (e.g. OEMs, suppliers, installers) ensuring that all parties concerned understand the tolerable risk requirements of the mine.

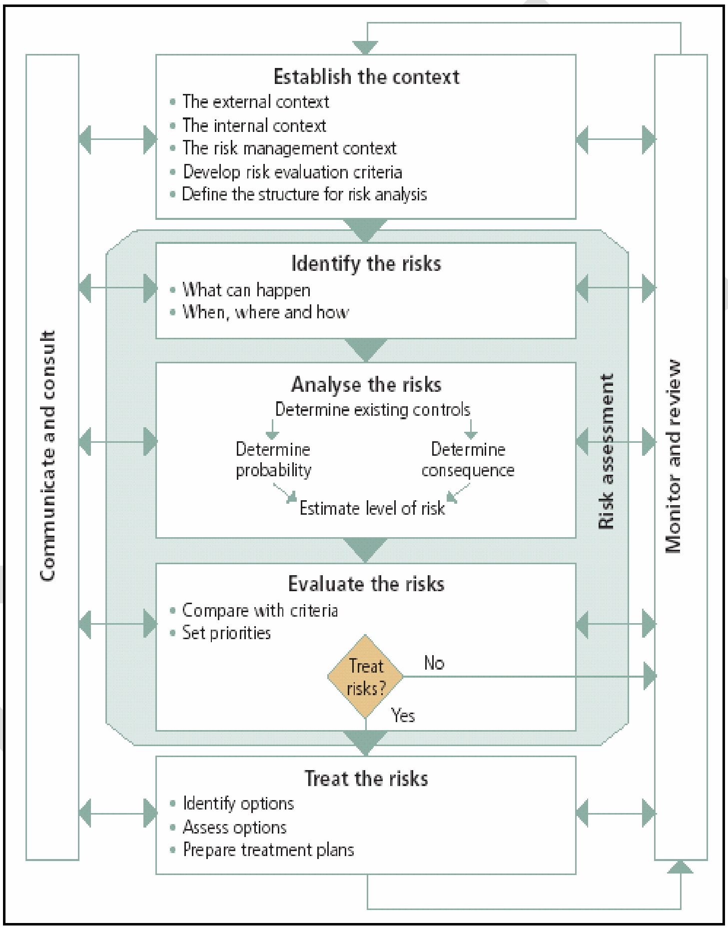

Figure 19 – Risk management process ISO31000

[1] The process of analysing the risks in this sample assessment was not completed using a risk ranking methodology. The reason for not using a ranking approach was due to the team's discrimination of only identifying issues with potential for significant consequences. This limits the usability of the risk matrix tool – which would see most issues rating with a probability of unlikely/rare.

Issue	Type[2]	Potential Controls
People's dependence on system - people depending on the system and leading to complacency/ reliance on the machine ceasing dangerous movement when they are in the wrong location. The hazards of total system reliance by operators. Don't want a culture that personnel to rely on proximity detection system for their protection. Desire to have proximity detection systems to support current controls - not replace them.	PE CWA	Hazard awareness training. Training of personnel in proximity detection requirements. Go/No-Go zones. Transitional introduction of proximity detection (data collection (monitoring) - warning system - machine control). Incident response system for proximity detection breach of zone. System health monitoring / alarm.
Over alarming - desensitising of personnel (no thought in acknowledging alarms); system too sensitive (false alarms); multiple system alarms occurring simultaneously - too many lights / alarms. Proximity detection systems need to cause only the required interruptions to mining processes (no false trips).	PE	Transitional introduction. Standardise Human Machine Interface (HMI) - consistent alarm sound and light. Minimise the number of alarms and implement shut down in consistent (hazardous) conditions.
Definition of zones and sizes. The required intervention for machines that operate at high speeds needs to be assessed (clashing effect of crash stops).	CWA EQ	Realistic (not too large / too small) setting of zone sizes - with regard to the method of mining occurring and the mode of operation. Speed of movement / operation of the Equipment Under Control (EUC). Tailored to the operation. Site specific operability / maintainability risk assessments.

[2] See the definitions section for more detail and PE = People, EQ = Equipment and CWA = Controlled Work Area

Issue	Type[2]	Potential Controls
Interaction/interface of systems (to achieve simplicity). Need to determine how different technology solutions will inter-operate (different brands on same site). Interaction of proximity, non-proximity fitted machines. Location of equipment - visual; damage; effect of zones (does the equipment move?).	EQ	Establish the framework at a broad brush risk assessment for proximity detection within the whole of mine system. Site procedures adequately reflect the presence of (multiple/variable) proximity detection systems. Site specific operability / maintainability Risk Assessments. OEMs developing a standardised interface.
The boundaries of proximity detection systems will likely be dynamic.	EQ	Transitional introduction. Consider speeds of vehicles and response times /types. Allow for variation in zone size required based on dimensional changes of vehicles (attachments, trailers, platforms etc.) and environmental conditions (floor conditions, grade etc.).
Data collection and analysis.	EQ	Monitoring capability and storage of data from proximity detection systems.
Don't attempt to build a "silver bullet" technology solution. Limitations of system.	EQ	Sites to develop functional specifications based on risk assessment of their particular requirements and CWA geometries
We need to provide reasonable levels of safety in line with societal values.	EQ	Organisational risk management standards – ALARP.
How to avoid operators being in no go zone? Place changing may require this - miner driver standing proximate to shuttle cars.	CWA	Transitional introduction. Site specific risk assessment as an input to functional specification.
Visitors/pedestrians interacting with machines.	PE	Functional specification. Site specific risk assessments to identify zone requirements.
Need to determine the over ride functions of proximity detection systems.	EQ	Functional specification. Risk assessment on running machinery with system defeated.
Making changes to the equipment.	EQ	Change management system.
Power on maintenance.	PE	Functional specification. Risk assessment on power on maintenance tasks.

Issue	Type[2]	Potential Controls
Source of alarm - where did the alarm originate?	EQ	Monitoring capability and storage of data from proximity detection systems. Functional specification on alarm logging, storage and display.
What common terminology to adopt?	CWA	Addressed in guidelines. Change management for the move from Go/ No-go zones to "bubbles" of proximity detection.
Machine becomes stuck in unsupported strata location.	EQ	Referred to site-specific processes for developing responses to unwanted operational conditions.
Poor quality or flawed assessment of risks.	CWE	Site systems for reviewing and continuously improving assessment and management of risks.
Training.	PE	General control - should be a competency based system of training.

Appendix 5 – links to references/associated documentation

Link to regulator website

- http://www.resources.nsw.gov.au/afety/publications/seminar-presentations/2011-proximity-detection-workshop
- http://mines.industry.qld.gov.au/safety-and-health/proximity-detection-workshops.htm
- http://www.msha.gov/Accident_Prevention/NewTechnologies/ProximityDetection/ProximitydetectionSingleSource.asp
- http://www.cdc.gov/niosh/mining/topics/topicpage58.htm

List and link to suppliers and advisory groups

- http://acarp.com.au
- http://www.emerst.org
- http://www.riskgate.org (login required)
- http://www.proximity detection.com
- http://www.acumine.com/
- http://www.za.becker-mining.com/runtime/cms.run/doc/English/47/Home.html
- http://www.booyco-electronics.co.za/cws800.php
- https://mining.cat.com/detect
- http://www.mmsi.com/RoadMap.html
- http://www.previewradar.com/products.html
- http://www.safe-mine.com/
- www.lsmtechnologies.com.au
- www.preco.com
- www.modularmining.com
- www.ivolve.com
- www.infotronix-cws.com
- www.previewradar.com
- http://www.matrixdginc.com/products/proximity-detection.htm
- http://www.nautilus-intl.com/index.htm
- http://www.spsolutions.com.au
- http://www.strataworldwide.com/usa/safety-products/proximity-detection.htm
- www.industrea.com.au
- http://minesite.net/applications/proximity-detection/