NSW GOVERNMENT

NSW Resources Regulator

GUIDELINE

AUTONOMOUS MOBILE MINING PLANT

September 2020

NSW Resources Regulator

Document control

Published by NSW Resources Regulator

Title: Guideline - Autonomous Mobile Mining Plant

First published: September 2020

Authorised by: Chief Inspector

CM9 reference: DOC20/690069

AMENDMENT SCHEDULE		
Date	Version	Amendment
September 2020	1	First published

Contents

1. Introduction

Mining is a high hazard industry. Since the introduction of mechanisation in the mid-20th century, workers have been exposed to the hazards arising from operating or working in close proximity to mining machinery.

The risks posed by mechanisation have continued to evolve as larger and more complex machines have been introduced. This has included larger diesel engine systems with high surface temperatures, high pressure hydraulics and exhaust emissions from mobile plant. This has also included higher voltages and power ratings in electrically powered equipment.

Adopting remote controlled, semi-autonomous and autonomous mining equipment can reduce the number of hazards and improve operational performance. However, the change in process and machine functionality will introduce new risks. These risks must be identified and controlled.

The introduction of remote controls enabled people to be removed from the risks arising from a machine such as load haul dump vehicles (LHDs) being buried in a stope, or a continuous miner being buried during pillar extraction. But new and different risks emerged. Operators have been crushed by the machine they controlled when they placed themselves too close to the machine. While enabling workers to be removed from places of high risk, automation associated with longwall mining equipment has created new risks, such as being crushed by an automatically advancing roof support.

The introduction of tele-remote operation eliminated some risks for machine operators, however introduced new risks for maintenance workers who must approach a machine to undertake fault-finding and repairs. Removing machinery operators from the mining environment has also resulted in a loss of sensory awareness (sight, hearing, touch and smell). This loss of sensory awareness impairs the ability to quickly identify developing problems on a machine and may lead to a more significant incident. Delays in being able to access the machinery after an incident may also increase financial loss attributable to the incident.

The introduction of autonomous mining equipment, while reducing risks to some workers, will expose other workers to additional and different risks. This necessitates a thorough and rigorous risk assessment process to be completed to understand the limitations of existing controls, the identification of new controls and the implementation of these controls to ensure that risks are managed to an acceptable level.

2. Definitions

autonomous mode (from ISO 17757:2019 clause 3.1.3)
Mode of operation in which a mobile machine performs all machine safety-critical and earth-moving or mining functions related to its defined operations without operator interaction.

Note: The operator could provide destination or navigation input, but is not needed to assert control during the defined operation.

autonomous operating zone (AOZ) (from ISO 17757:2019 clause 3.1.4)
Designated area in which machines are authorised to operate in autonomous mode.

autonomous machine (from ISO 17757:2019 clause 3.1.3.1)
Mobile machine that is intended to operate in autonomous mode during its normal operating cycle.

critical control (from ICMM *Health and safety critical control management implementation guide*)
A control that is crucial to preventing the event or mitigating the consequences of the event. The absence or failure of a critical control would significantly increase the risk despite the existence of the other controls. In addition, a control that prevents more than one unwanted event or mitigates more than one consequence is normally classified as critical.

critical control management (from ICMM *Health and safety critical control management implementation guide*)
A process of managing the risk of MUE's that involves a systematic approach to ensure that critical controls are in place and effective.

collision avoidance technology (from MDG 2007)
Technology or device/s that actively scan for other vehicles or personnel and take automatic action to render the equipment to a safe state (e.g. reversing radar with brake control).

material unwanted event (from ICMM *Health and safety critical control management implementation guide*)
An unwanted event where the potential or real consequences exceeds a threshold defined by the company as warranting the highest level of attention – for example, a high-level health, safety or environmental impact.

perception system (from ISO 17757:2019 clause 3.1.19)
System comprising sensors used to detect, locate and recognize a potential feature of interest.

proximity detection technology (from MDG 2007)
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).

situational awareness (from ISO 17757:2019 clause 3.1.23)
Perception of elements in the environment and a comprehension of their meaning. It could include a projection of the future status of perceived elements and the risk associated with that status.

3. Scope

This guideline is applicable to the introduction of the following types of autonomous equipment:

- haul trucks
- loaders
- dozers
- graders
- water carts
- blast hole drill rigs
- excavators
- load haul dumps (LHDs) / boggers.

It is considered this guideline will also be applicable to other types of mining machinery, such as shuttle cars and continuous miners for underground coal, as the autonomous systems for this type of equipment is further developed.

4. Legislative requirements

The *Work Health and Safety Act 2011* imposes a primary duty of care (S19) on persons conducting a business or undertaking (PCBU) to ensure, so far as is reasonably practicable, the health and safety of workers, and others, at work in the business or undertaking.

Part 3.1 of *Work Health and Safety Regulation 2017* and Part 2 of the *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014* also impose specific duties regarding managing risks to health and safety which are particularly important when considering the introduction of autonomous machines. This includes:

- conducting risk assessments with appropriate regard to the nature of the hazard, the likelihood of the hazard affecting the health and safety of a person, and the severity of the potential health and safety consequences
- the application of the hierarchy of controls
- maintenance of control measures to ensure they are:
  - fit for purpose

- suitable for the nature and duration of the work
- installed, set up and used correctly

- the circumstances under which a review of control measures must be undertaken, including
  - that such a review is undertaken prior to any change
  - whenever a new relevant hazard or risk is identified
  - when a control measure does not control the risk it was implemented to control
  - whenever an incident occurs which is required to be notified to the regulator under the WHS laws

The introduction of autonomous equipment will also necessitate a detailed review of principal hazard management plans and principal control plans in consideration of (but not limited to):

- the performance characteristics of the plant
- the effects on performance characteristics due to all anticipated environmental conditions
- the design of existing and proposed roads and intersections
- the potential for interaction between pedestrians, other types of plant and fixed structures
- the reliability of safeguards on the equipment intended to protect persons from the hazards posed during each phase of its lifecycle
- the competency required by workers in order to safely work on the equipment

The *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014* requires mine operators to notify the regulator of incidents involving:

- any loss of control of heavy earthmoving machinery that is operated remotely or autonomously, including any failure of braking or steering.
- the unintended activation, movement, or failure to stop of machinery, or
- a collision involving a vehicle or mobile plant

5. Controlling the risk

Regardless of the justification for introducing autonomous machines, a consequential increase in the level of risk to workers is not acceptable.

The movement or operation of an autonomous free-steered machine that puts one or more people at risk should be considered a material unwanted event (MUE).

The maximum reasonable consequence of an unintended interaction between an operating autonomous free-steered machine and a person is a single fatality. Where a group of people is involved, it is reasonable to assume there may be multiple fatalities resulting from the interaction.

An interaction may occur between an autonomous free-steered machine and a person, when the person is:

a) a pedestrian, whether authorised to be in a work area or not

b) the operator of, or a passenger in, a light or heavy vehicle

c) a person on or in infrastructure, such as a skyline conveyor for a stockpile.

While autonomous operation, by definition, means there will not be people onboard machines, it does not mean there will be no people in the autonomous operating zone (AOZ). There are tasks such as workplace inspections, machinery inspections, maintenance tasks and repairs. The intent of these tasks is to ensure a safe work environment and the correct operation of the autonomous machines and other plant. Other activities form an essential part of the mining process, such as road maintenance, operator change-over for manually controlled plant and operating service and ancillary vehicles.

Risk assessments for the introduction and operation of autonomous machines must consider all foreseeable scenarios where it is possible for people to interact with the machines, or where the machines may interact with other equipment or infrastructure.

In undertaking these risk assessments, it is considered essential the mine operator identify critical controls that will prevent incidents associated with the autonomous machines and identify and implement effective mitigating controls to protect workers if a MUE occurs.

The risk assessment should consider the following:

- establish and operate an AOZ
- AOZ egress controls
- AOZ access controls
- mine design

- traffic management and standard road rules
- integrity of the autonomous control system and safety functions,
- perception systems for proximity detection and collision avoidance of other machines, personnel and obstacles
- autonomous stop systems
- approach to an autonomous machine for inspection, maintenance or recovery activities
- autonomous machine isolation
- mode selection
- communications systems for control and monitoring data
- cybersecurity
- for surface operations, changes in the weather
- emergency management.

In developing and implementing risk controls, consideration must be given to the full lifecycle of the equipment, including commissioning, operation and maintenance, as well as recommissioning following repairs, modification and upgrades.

Mine Operators intending to introduce and operate autonomous machines should implement a critical control management (CCM) process that is robust and effective in identifying and managing risks. This includes applying functional safety to critical engineering controls. The CCM process should also include routine verification of critical control effectiveness, which should be integrated into the mine's programmed maintenance and inspection scheme.

Another essential requirement to manage the risks associated with autonomous machines is a properly implemented change management process. Mine operators must be vigilant in applying their risk management processes to changes as the operation of autonomous machines evolves and expands. The temptation to expand the scope and broaden the use of autonomous machines without appropriate risk management will lead to weakening or loss of existing controls. It may also lead to a failure to identify that additional controls are required due to the changes. Change management processes must be applied to all aspects of machine operation, including hardware and software, and should be used during the complete lifecycle of the machine, including commissioning, maintenance and repair activities.

MDG15 provides further information regarding hazards associated with autonomous machines.

6. Guidance material

Further guidance is available in the following publications:

WA Code of Practice – *Safe mobile autonomous mining in Western Australia*

Global Mining Guidelines Group - *Guideline for the implementation of autonomous systems in mining*

MDG2007 – *Guideline for the selection and implementation of collision management systems for mining*

MDG15 – *Guideline for mobile and transportable plant for use at mines other than underground coal mines*

ICMM – *Critical control management implementation guide*

NSW Resources Regulator Investigation Report – *Collision between semi-autonomous dozer and manually controlled excavator* – 27 May 2019

ISO 17757:2019 – *Earth-moving machinery and mining – autonomous and semi-autonomous machine system safety*