Resources Safety & Health
Queensland

Queensland Guidance Note

Autonomous mobile machinery & vehicle introduction & their use in coal mining.

Queensland Mines Inspectorate - Coal

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Reference is made to the following legislation as applicable to a Mine in Queensland:

- *Qld Coal Mining Safety and Health Act 1999*
- Qld Coal Mining Safety and Health Regulation 2017

This Guidance Note has been issued by the Queensland Mines Inspectorate of the Resources Safety and Health Queensland (RSHQ). It is not a Recognised Standard as defined in the *Coal Mining Safety and Health Act 1999* (CMSHA). Compliance with this Guidance Note may not be sufficient to ensure compliance with the requirements in the legislation. Guidance Notes may be updated from time to time.

For the most current version of in-force legislation visit the Queensland Legislation website:

https://www.legislation.qld.gov.au/browse/inforce or contact your local Inspector of Mines.

This publication has been compiled by Inspectors of Mines of Resources Safety and Health Queensland.

Contents

1 Purpose

This Queensland Guidance Note (QGN) is to provide practical guidance to the mine operators and Site Senior Executives (SSEs) of the requirements for safe introduction and use of autonomous mobile machinery and vehicles.

The content of QGN should be considered in addition to any Australian or International Standards that may be applicable for this type of equipment.

Acknowledgement is given to the *Western Australian Code of Practice - Safe mobile autonomous mining in Western Australia* which has been utilised in the development of this guidance note.

2 Scope

This document applies to:

- all Queensland coal mining operations, defined under the *Coal Mining Safety and Health Act 1999* (CMSHA)

This guidance note will assist those involved with mobile autonomous mining in Queensland to meet their legislative obligations.

It is designed to provide guidance on design, planning, change management, implementation and safe operation systems for mobile autonomous and semi-autonomous systems used in surface and underground coal mines.

3 Application

3.1 General

This guidance note applies to the control of autonomous loaders, trucks and other mobile equipment such as, but not limited to, drills and dozers at mine sites. It also applies to autonomous machinery used in underground coal mining activities such as, but not limited to, Longwalls and continuous haulage mining systems.

This guidance note focuses on the identification of the unique risk profiles in relation to new or existing autonomous mining systems.

This guidance note does not apply to:

- remote operations centres
- unmanned aerial vehicles (UAVs)
- remote controlled systems, but parts could be relevant to mobile tele-remote systems if they incorporate additional functionality that takes autonomous control of machines
- autonomous functionality of a process or machine that moves on:
    - o fixed infrastructure such as rail (e.g. trains, stackers, reclaimers)
    - o a fixed base (e.g. laboratory robots).

This guidance note should be followed if you have functions and responsibilities for planning, designing, implementing, and maintaining mobile autonomous mining systems. The guidance note may also be useful for supervisors, operations personnel, and safety and health representatives who need to understand the hazards associated with mobile autonomous mining systems.

Note: The term autonomous *is used in this guidance note to cover both autonomous and semi-autonomous mining system. It does not apply to remote controlled systems, but parts of the guidance note could be relevant to tele-remote systems if they incorporate additional functionality that takes autonomous control of machines.*

3.2 Legal requirements

Mining legislation requires for risk to a person from operations to be at an acceptable level, the operations must be carried out so that the level of risk from the operations is—

a) within acceptable limits; and
b) as low as reasonably achievable.

To decide whether risk is within acceptable limits and as low as reasonably achievable regard must be had to—

c) the likelihood of injury or illness to a person arising out of the risk; and
d) the severity of the injury or illness.

4 Introduction

4.1 Aims

Mobile autonomous mining, like any large-scale mining activity, is hazardous with many inherent risks. When integrated with a manually operated mining operation, additional risks may be present beyond those recognised for conventional mining techniques.

The aims of this guidance note are to describe:

- a set of desired safety outcomes for mobile autonomous mining.
- the variables to be considered to demonstrate that a mobile autonomous mining system is safe and performing as designed
- the broader occupational health and safety requirements for operating in accordance with the Queensland Mines Safety and Health Acts and Regulations.

The guidance note promotes a proactive approach to the introduction and operation of mobile autonomous mining systems to ensure the safe use of mobile autonomous (and semi-autonomous) technology. It also promotes continuing communication and consultation between system and component suppliers and the mining operation as the end user.

The obligations apply to all stakeholders from systems design, construction of mobile equipment, control centres, mine planning, commissioning of systems, implementation, operation, and maintenance, to achieve the desired safety outcomes for both surface and underground operations.

4.2 Roles and responsibilities

A senior position within the mine's management structure should be assigned the role and responsibilities for the introduction, implementation, and operation of autonomous mining systems.

There are two main groups involved in the introduction, implementation, and operation of autonomous mining systems:

- system builders — those who design, manufacture, import, supply, and commission or install the system

- system operators — those who use the system, including operators, contractors, and maintainers.

The first group may comprise multiple parties, including original equipment manufacturers (OEMs), or the system may be built in-house by the coal mine operator, or by a third party developer.

Communication and cooperation are keys to a successful autonomous operation. The roles and responsibilities of those involved should be defined and agreed upon by all parties. While some roles and responsibilities have been assigned to certain stakeholders, it is noted that many are dependent on information supplied by another party. Circumstances, unique to each operation may result in assignment of some of these roles and responsibilities differing from those outlined below.

System builders

The responsibilities of system builders should include:

- assessing the proponent's proposal and determining the suitability and compatibility of system components
- participating in initial site risk assessments to determine the suitability of the proposed autonomous mining approach
- establishing standards to which the machine and system will comply
- determining requirements for mine supplied componentry to allow the system operator to ensure the safety integrity of final system (e.g. communications infrastructure)
- establishing performance specifications that ensures the safety and health of coal mine workers is not affected
- sharing residual risk information with the system operator for inclusion in the operator's safety and health management system
- supplying safety information for maintaining the system's integrity over its life cycle
- providing information and instructions on use of the system regarding:
    - operation, maintenance, and servicing
    - calibrating test procedures
    - commissioning information
    - trouble shooting test procedures
    - performance parameters (e.g. system response for use in safety plans)
- providing information and instructions on how tailored or bespoke systems may affect or be affected by other components and systems
- providing assurance of certification-type testing of the system and components (e.g. electromagnetic compatibility, EMC; base machine performance)
- establishing communication security and making recommendations regarding cyber security
- Communication of information relating to learnings from events where system is used (globally, independent of system operator), in particular controls implemented following incidents.

System operators

The responsibilities of system operators should include:

- developing the proposal and requirements for the introduction of autonomous mining machinery

- conducting an initial site risk assessment to determine the suitability of the proposed autonomous mining approach
- understanding the risks associated with the system, including any residual risks
- using the system in accordance with the specifications, and seeking advice if design specifications or system components are to be modified after commissioning
- incorporating information from system builders into the site's safety management plan
- developing safe work procedures to integrate the autonomous operation into the mine
- establishing change management processes
- consulting with coal mine workers on autonomy implementation and hazards
- training mine personnel in relation to autonomous operations, including
    - operation of equipment within autonomous areas
    - processes and procedures for work in autonomous areas
- managing communication associated with the development and deployment of a system (e.g. general awareness training for all personnel on site to make them aware of the hazards associated with autonomous mining) auditing any site-supplied componentry (e.g. computers, servers, radios, positioning system, Wi-Fi, telecommunications) to confirm its compatibility with systems security, and that builder requirements for safety integrity are met
- maintenance management plans
- recording, reporting, investigating incidents and taking action to prevent similar incidents reoccurring

5 Safety and risk management process

5.1 Introduction

Autonomous mining machinery can support significant reduction of risk exposure. It can also introduce hazardous situations not normally encountered on a conventional manually operated mine site.

Legislation requires that if there is a significant change to the coal mining operations of the coal mine the following must occur:

- Plan to immediately review the safety and health management system so that risk to persons is at an acceptable level
- The site senior executive must review the principal hazard management plans and standard operating procedures in consultation with coal mine workers affected by the plans and operating procedures.

The effective management of the risks associated with operating a mobile autonomous mining system requires input from diverse operational groups including researchers, design engineers, project managers, team leaders, controllers, safety and health representatives, coal mine workers involved in the tasks, and emergency response personnel.

The risk management process should address the following questions.

- What are the potential scenarios for mobile autonomous mining incidents?
- What are their potential consequences in terms of safety and health?
- What controls are available and how effective are they?

5.2 Communication and consultation

Communication and consultation are fundamental for ensuring the most effective risk management. It is essential that those with knowledge of the design, engineering, commissioning, operation and maintenance of the autonomous mining systems are involved in assessing and minimising associated risks during the operational life cycle.

5.3 Information for risk management

Mining operations should be able to demonstrate that the hazards associated with mobile autonomous mining are being controlled so far as is reasonably achievable by considering issues such as:

- any previous events or information (e.g. incident and injury reports, the chief executive officer's database, and data from similar technology applications)
- reliability, maturity and available safety features of autonomous equipment and systems
- provision and frequency of validation processes (e.g. trials, functionality testing)
- suitability of established work procedures (e.g. separation, inspection, and maintenance processes)
- whether established emergency procedures are sufficient
- the provision and competency of operational and support personnel (e.g. assessment of knowledge and training needs)
- identification of specific risks and provision for regular reviews of controls.
- potential event escalation

5.4 Risk identification

The use of autonomous technology in an operating mine environment will change established safety systems. It is important to identify these changes and the associated risks.

Some potential mobile autonomous mining risks are listed in Section 12.

5.5 Risk analysis

It is important that those undertaking a risk assessment have the necessary information, training, knowledge and experience of the:

- operational environment (e.g. scale, complexity, and physical environment of mining activities)
- operational processes (e.g. maintenance systems, work practices, interaction, separation)
- autonomous systems (e.g. functionality, safety features).
- autonomous mining system reducing exposure consequences or likelihood

5.6 Risk evaluation and management

All hazards related to mobile autonomous mining need to be identified and controlled. Higher-order control measures eliminate or reduce the risk more effectively than administrative controls or personal protective equipment.

For mobile autonomous mining, it is advisable to implement:

- primary controls that
    - o avoid the risk by deciding not to start or continue with the activity (e.g. excessive slip

detection)
  - remove the source of the risk (e.g. isolate or provide alternative access for personnel not directly involved with the autonomous activity)
  - change the likelihood (e.g. restrict specific functions to authorised personnel, systems that fail to safe state)
  - change the consequence (layers of protection e.g. decrease speed)

Prevention and management controls should be based on established processes and relevant standards, including:

- safe design, construction, and installation (according to specifications and design parameters)
- separation from mining equipment not fitted with the autonomous proximity technology / infrastructure
- effective change management processes
- operational and maintenance safe operating procedures (SOPs)
- competency-based training and assessment of workers
- supervision and management oversight.

5.7 Monitoring and review

To ensure the effectiveness of controls is maintained at the site, a monitoring and review program should be implemented that includes control audits, verification, and validation.

As part of the site's validation process, responsibilities and accountabilities should be clearly defined and assigned, and may include independent auditing. The findings should be used to:

- confirm that the recommendations of previous reviews have been actioned
- confirm that appropriate responses have been made to any incidents or issues arising
- verify compliance with specifications (e.g. inspection, monitoring, quality control)
- recommend any necessary operational or system design modifications, which are documented and managed through a formal change management process.

5.8 Documentation

Results of risk assessments need to be formally documented in the operation's risk register, as well as review outcomes and actions. The documentation of this information forms the basis of the site's safety and health management system for mobile autonomous mining systems.

6 Information, instruction, training, and supervision

6.1 Introduction

The provision of information, instruction, training, and supervision is an essential component of any safe system of work.

6.2 Information

Personnel must have the information necessary to complete tasks safely. Such information may include:

- manuals, specifications, and operating instructions provided by the system builder
- the operation's policies, procedures, and plans

- applicable legislation, Australian and International Standards, and other guidance material.

6.3 Instruction

Personnel must be instructed about system functionality and specific tasks to be undertaken, including the hazards and risks, the controls to be applied, and the job steps necessary to complete the tasks safely and correctly.

Instructional tools such as safe work instructions or procedures (SWIs or SWPs) and standard operating procedures (SOPs) may be used to document the process but should be reviewed and amended if there are any changes (e.g. equipment, conditions).

If there is to be a deviation from the SWPs, a job safety or hazard analyses (JSAs or JHAs) should be undertaken to capture the hazards for the task and ensure controls are implemented.

Such instructional tools must be approved as per the mine's risk management process.

6.4 Training

Personnel must be competent in the tasks they are assigned. This means they must have the knowledge and skills necessary to perform the task safely and correctly.

The risk management training provided must be appropriate to the assigned roles and responsibilities, and provide information on:

- the risk management process
- task-specific safe work methods, including the safe use of equipment and safe systems of work.

All personnel should understand the effects that their activities may have during commissioning, operation, and maintenance of the mobile autonomous mining system. They should also understand:

- what to expect if environmental or operational conditions change
- site requirements for monitoring of machine performance
- how to recognise when machines are not operating as intended
- how to report incidents.

Assessment of competency should be evidence based and verified before work commences. Competency may be verified by:

- recognition of prior learning
- on-site recognition or validation of current competency
- using the operation's training and development program.
- Verifications of competency must include a documented assessment.

Whenever systems of work or plant and equipment change, or new systems of work or plant and equipment are introduced, there must be a system to ensure affected personnel are consulted, retrained as necessary and reassessed.

6.5 Supervision

Supervision is a fundamental safety function that complements the provision of information, instruction and training. Effective supervision sets and maintains the required standards of performance.

Supervisors help achieve the operation's safety and health policy in a variety of ways, including:

- leading and managing their team using their understanding of the key principles and safety features of technology
- ensuring work is carried out in accordance with the safety and health management system
- confirming workers (including contractors) are trained and assessed as competent to perform their duties
- communicating regularly with those affected by work
- confirming fit-for-purpose equipment is available and used
- monitoring the workplace, and identifying and controlling hazards in accordance with site rules
- reporting and recording performance issues (e.g. equipment failures, variances to approved operating parameters)
- referring new and changed circumstances not covered in site rules to management for further instructions
- communicating learnings from incidents.

7 System planning and design for hazard control and safety integrity

System builders and users are required to identify, assess and control the hazards associated with autonomous operations. Safety integrity provides assurance that the safety-related elements of the autonomous system and operational controls provide suitable risk reduction to achieve the safe operation of the autonomous systems. The safety functionality of autonomous control systems should be designed:

- in accordance with relevant standards
- to meet statutory obligations (e.g. communication network licences).

The criticality of the safety functions, and the performance levels required of them, should be determined by the hazard identification and risk assessment process, including:

- roles and responsibilities of system operators and system builders
    - agreed, defined and documented to reflect the operating model
    - controls and authority levels are established to ensure changes do not increase the risk due to modified performance
- fail-to-safe state
- if elements of the system fail then the system is designed to fail (shutdown) to a safe condition
- assessment of human interactions with the autonomous systems (e.g. operational and maintenance personnel in autonomous areas)
- the impact of human interactions and behaviours on autonomous system performance (e.g. level of intervention actions for alarms and warnings)
- systems security
    - controls that prevent unauthorised changes
    - approval process to authorise system changes
    - access control to manage implementation of changes (e.g. who, when).
    - Protection against cyber-attacks.

8 Commissioning hazard controls

To achieve the desired safety outcomes, commissioning activities for autonomous equipment should adequately address matters such as:

- risk management process
- technology and specific functionalities are understood
  - identify hazards specific to the commissioning phase (e.g. safety critical tests)
  - ensure appropriate controls are in place
- commissioning planning
  - communications and reporting plan
  - commissioning project plan and timeline
  - selection and survey of suitable commissioning area (e.g. segregated, isolated)
  - checklists for installation, assembly, and commissioning
  - management of change
- commissioning test plan
  - based on the recommended test procedures from the system builder
  - safety systems tests
  - operational performance tests
  - system integration tests
  - documented test procedures
- functional and user acceptance testing
  - tests conducted in line with documented test procedures
  - testing should be traceable to the system version or type to confirm systems meet the system builders' and operational requirements
  - compliance with relevant standards
  - test results are documented (e.g. pass, fail, defects, issues)
- systems acceptance
- formal process for managing unresolved defects and issues
- user acceptance based on system builder specifications
- training and assessment of competency for the various roles.

9 Operational hazard controls

To achieve the desired safety outcomes, the design and function of operational practices should adequately address matters such as:

- management and supervision, including support functions
- technical and system knowledge within operating teams
- roles and accountabilities
  - job descriptions
- appointments
  - changes introduced by autonomy
- competency validation (e.g. supervision, technical support, operators, maintainers)
- change management such as
  - system updates and upgrades

    - changes to operational practices, documentation, and training requirements
    - sharing safety learnings
- interaction rules
    - how changes between autonomous and manually operating modes are managed, documented and communicated
    - interaction management and associated procedures to govern interactions between autonomous equipment, operated equipment, and pedestrians
- human factors (e.g. response to system information or warnings, adherence to exclusion zones)
- performance monitoring of continuous improvement and change management (e.g. equipment, systems, personnel)
- area security and control
    - access control for autonomous, non-autonomous and mixed fleet areas
    - area or hazard inspections that incorporate checks for area security and control
- tools and processes
    - risk management (SWPs, JSAs, risk assessments, risk register)
    - communication protocols and considerations (e.g. radio network)
    - monitoring
    - incident reporting
    - emergency response
- technical support provision.

10 Maintenance hazard controls

To achieve the desired safety outcomes, maintenance activities for autonomous equipment should adequately address matters such as:

- safety-related parts of control systems and safety integrity considerations for system maintenance
- scheduled maintenance and inspections processes
- in situ inspection and servicing
- base platform
- autonomous components
- system (e.g. database management and maintenance)
- recovery procedures in autonomous areas
- area and activity isolation
    - physical and virtual demarcation to provide safe area of work
- condition monitoring and diagnostics
- understanding criticality of autonomous components
    - alarm and error reporting analyses to indicate system behaviour
- calibration and testing (including designated testing areas)
    - after repairs and scheduled maintenance
    - as indicated by system reporting tools
    - following a component upgrade, system change or return to autonomous service
- other equipment considerations.

11 Introducing mobile autonomous systems to mining operations

11.1 Mobile autonomous applications

Autonomy can be used to move a variety of plant and equipment used in mining and exploration. Examples include, but are not limited to:

- haul trucks
- drill rigs
- loaders
- underground load-haul-dump (LHD) units (e.g. boggers)
- dozers
- continuous miners feeding trucks or conveyor systems
- mobile crushing and screening plants
- light vehicles
- haulage trains in loading and unloading applications.
- Longwalls
- Underground coal continuous haulage systems

11.2 Decision to automate

The decision to automate parts or all of a mining operation is a business decision based on perceived future gains in safety, productivity, cost and sustainability.

11.3 Assessing suitability of operation for automation

People

The workforce will be affected by the introduction of automation, particularly in regards to training and skills development. Furthermore, roles and skill requirements will change — new skills will be part of new organisational structures and some existing skills might no longer be applicable.

Potential changes need to be identified and managed carefully for the implementation of automation to be successful.

Processes

Automation will change the way in which the mine operates. It will impact many procedural aspects of mining such as:

- traffic management plans
- safety management plans
- safe work procedures
- work instructions.

These will need to be identified and developed in a timely manner to ensure the introduction of automation has the best chance of success.

The mine layout, mine design, mine plans and schedules will need to be tailored to accommodate autonomous mobile equipment and modifications need to be identified as early as possible to allow for sufficient time to incorporate any changes.

Technology

The implementation of mobile equipment automation requires the application of other technology such as sophisticated and robust wireless communications networks and control rooms. These will need to be identified and be part of the deployment process.

11.4 Organisational readiness

The ease with which automation can be introduced to a site will depend on the organisation's level of preparedness, at all levels, for the new technology. The greater the complexity of the proposed changes, the greater the importance of understanding whether there is a readiness for change and identifying the actions required to achieve the desired safety and performance outcomes.

Factors influencing organisational readiness include:

- robustness of safety culture
- commitment to effective change management
- responsiveness to change
- existing knowledge and understanding of autonomous mining, its risks and consequences
- human resourcing
    - identification of new roles, responsibilities and reporting relationships
    - recruiting to address skill gaps
- capacity of workforce to transition between mechanised and autonomous mining
    - ability to learn
    - adaptability of process and operation personnel
- awareness of the level of discipline required for autonomous mining.

11.5 Change management

The change management strategy may need to be different for each part of the site and type of mobile autonomous technology introduced.

Key aspects to be managed should include:

- procurement and installation
    - selection of autonomous system, including equipment specifications and associated technologies
    - commissioning of the autonomous system (both the "conventional" equipment as well as the on- and off-board control systems)
    - hand-over, including testing and monitoring requirements.
- mine planning
- mine design — automation will have specific operating requirements (e.g. mine dimensions, layout
- of road network or underground development)
    - mine plans and schedules — although automation systems are designed to be intrinsically safe, further reduction of risk is best accomplished by minimising interactions with autonomous equipment at the mine planning and scheduling phases.
- operational procedures
    - traffic management

- access to and egress from an autonomous area
  - workplace inspections in an autonomous area
  - working near autonomous equipment
  - autonomous equipment inspection, servicing and maintenance
  - verification and validation to assess system integrity.
- personnel
  - organisational structure and control of safety — new roles and organisational structures may need to be considered
  - training and competency assessment in advance of system implementation is challenging prior to system implementation — equipment suppliers and service providers may have specialist skills and facilities that can be used
  - a system to ensure affected personnel are retrained and reassessed whenever systems of work or plant and equipment change, or new systems of work or plant and equipment are introduced.
- communication
  - implementation strategy
  - integration of autonomous systems into the operation
  - potential impact of changes on procurement, mine planning, operational procedures and personnel.

11.6 Integration of autonomy into mine planning process

The introduction of an autonomous system is typically a staged process that takes time to design and implement. Automation should not be simply seen as a "plug and play" system due to the complexity of the system and layers of safety that need to be built in.

Companies need to carefully evaluate why they wish to automate a site. They should evaluate their mine design and undertake a comprehensive risk assessment of the mining processes with support from site representatives and subject matter experts to satisfy the regulator that there are sufficient and robust controls.

The following fundamental principles need to be built into mine design and planning processes:

- risk management
- designing and planning for autonomy
- managing and minimising interactions
- autonomous infrastructure.

Risk management

Issues that subject matter experts should considered when undertaking a risk assessment for mobile autonomous mining include:

- any previous events or information (e.g. incident and injury reports, data from similar technology applications)
- reliability, maturity and available safety features of autonomous equipment and systems
- provision and frequency of validation process (e.g. trials)
- suitability of established work procedures (e.g. inspection and maintenance processes)

- whether established emergency procedures are sufficient
- the provision and competency of operational and support personnel
- identification of specific risks and provision for regular reviews of controls.

Designing and planning for autonomy

Mine designers and planners should understand both the benefits and limitations of any technology being considered, including the:

- application of engineering and system controls to safety processes and practices
- modification of established planning and operational processes
- verification of system data (e.g. surveys) to validate mine designs and plans
- adaptability of planning and operational personnel
- application of positive outcomes to non-autonomous operations.

Managing and minimising interactions

Mine designers and planners should ensure work area design and construction are suitable for autonomy and minimise interaction with personnel and equipment, considering:

- access controls and processes for exclusion and interaction areas, such as
- resupply of consumables (e.g. fuel, water) – breakdown and recovery of equipment
- loading and unloading (e.g. excavated material, drill core)
- traffic management (e.g. road network, intersections, park-ups, load and dump locations, movement of mobile processing units for explosives)
- transitions between autonomous and other operating modes (e.g. procedures for checking, clearing and acknowledging the transition)
- placement of infrastructure within the autonomous area such as:
    - fuel facilities
    - crushers or ore passes
- stockpiles
    - workshops and service areas
      – crib rooms
- services (e.g. electrical reticulation, dewatering bores).

Autonomous infrastructure

The design, location and integration of autonomous infrastructure should consider:

- equipment specifications, fleet size and system capabilities (e.g. turning circle, road network layout, gradient)
- communication systems (e.g. wireless, fixed), and matters such as
    - latency.
- bandwidth
    - spectrum allocation
    - packet loss
    - maintaining connectivity (e.g. wireless cell switch time).
- redundancy
    - network monitoring

- autonomous zone signage and delineation.

12 Potential mobile autonomous mining risks

12.1 Site-specific risks

If there are no existing operations, then planning for automation can be tailored from the start to address risks common to autonomous operations.

Risk factors to consider as part of a comprehensive risk management strategy include:

- capture of changes to work areas, especially before switching work areas between manual and autonomous
- loss or interference with communication systems for autonomous equipment
- loss of control of movement of autonomous equipment (sliding or skidding)
- autonomous equipment deviating from its programmed path, leading to a fall to another level
- other human errors
- inadvertent access
- natural phenomena.

12.2 Introduction into an existing operation

Where there is an existing operation, a phased approach may be necessary to manage additional risks associated with integration and segregation, such as:

- infrastructure
- communication
- traffic management.

The following scenarios should be considered for inherent risks, as well as those hazards identified for manually operated operations:

- access into autonomous area by unauthorised personnel or equipment (surface or underground)
- human errors that may lead to autonomous equipment going into unauthorised areas or performing tasks that cause safety risks (e.g. human intervention, overriding an alarm condition, failure to update information such as survey plans)
- design speed of equipment failing to consider operating tolerances
- communications failure leading to lost, degraded, delayed, misdirected or hacked communications, on-board sensor or controller failures
- loss of control movement of autonomous equipment (e.g. sliding, skidding)
- autonomous equipment deviating from its programmed area
    - o into the path of another vehicle (manually operated or autonomous)
    - o leading to a fall to another level
- autonomous interactions in an autonomous environment and traffic management interactions (e.g. failure to convert virtual intersection to actual on the ground)
- failure to communicate changes (e.g. system updates, upgrades, changes to operational practices)
- manual interactions in an autonomous environment and traffic management interactions (including escorting of non-system equipment or non-system trained personnel)

- inadvertent switching between autonomous and other operating modes leading to loss of control
- interactions with pedestrians
- interactions with walls, windrows or other infrastructure
- passengers, observers and technicians aboard an operating autonomous vehicle
- remote re-starting of autonomous vehicle from a position without appropriate situational awareness
- fire
- accessing or checking autonomous equipment that has failed.

13 Incident reporting

Mobile autonomous mining should be as safe as or safer than conventional manually operated mining operations. An incident in an autonomous mining environment that could happen in a manually operated operation (e.g. fire, blasting incident) has the same reporting requirements. However, there are some incidents unique to the autonomous environment and their suggested reporting treatment is listed in Table below.

Examples of autonomous-specific incidents that result from system malfunctions or operator errors, and the reporting requirements under the Queensland mining legislation.

Incident	**Examples**	**Reporting requirement**
Uncontrolled movement	Autonomous equipment fails to stay within the designed travel parameters due to a system malfunction Any uncommanded motion of autonomous equipment Autonomous equipment starting / moving without pre-start alarms operating where fitted Autonomous equipment fails to stop when commanded Failure to change motion when so commanded due to system failure	Reportable HPI
Unauthorised entry into Autonomous Zone	Unauthorised entry of vehicle / equipment into the autonomous zone Unauthorised entry of person into the autonomous zone	Reportable HPI
Failure to follow critical control steps within the autonomous system	Failure to correctly establish exclusion zones within the autonomous operating area	Reportable HPI
Collision	A collision or near miss with other	Reportable HPI

	equipment or infrastructure that endangers the safety or health of a person A collision with a person	
Any other autonomous incident that causes, or has the potential to cause a significant adverse effect on the safety or health of a person		Reportable HPI

14 For more information

Contact the inspectorate at QldMinesInspectorate@rshq.qld.gov.au

Other contact details are available on our website: www.rshq.qld.gov.au/contact/mines-inspectorate

Appendix 1: Selected standards and other guidance

Examples of Australian and International Standards and other guidance that may apply to mobile autonomous mining systems are listed below.

Note: This list is not exhaustive but gives an indication of the many aspects to be considered.

Safety lifecycle (risk assessment)

- AS/NZS ISO 31000 - Risk Management – Principles and guideline
- AS/NZS 3100 - Approval and test specification – General requirements for electrical equipment
- ISO 12100 - Safety of machinery – General principles for design – Risk assessment and risk reduction
- AS/IEC 61508.1 - Functional safety of electrical/ electronic/programmable electronic safety-related systems – General requirements

Design

- ISO 5006 - Earth-moving machinery – Operator's field of view – Test method and performance criteria
- ISO 13849 - Safety of machinery – Safety-related parts of control systems
- ISO 16001 - Earth-moving machinery – Hazard detection systems and visual aids – Performance requirements and tests
- AS 17757 - Earth-moving machinery and mining – Autonomous and semi-autonomous machine system safety
- ISO 20474 - Earth-moving machinery – Safety
- IEC 61508.2 - Functional safety of electrical/ electronic/programmable electronic safety-related systems – Requirements for electrical/electronic/programmable electronic safety-related systems
- IEC 61508.3 - Functional safety of electrical/electronic/ programmable electronic safety-related systems – Software requirements
- AS/NZS 60529 - Degrees of protection provided by enclosures (IP Code)
- AS ISO 19014 (series) - Earth-moving machinery – Functional Safety

Note: https://www.cmeig.com.au/wp-content/uploads/CMEIG-EMESRT-ICMM-White-Paper-and-Guiding-Principles-for-Functional-Safety-on-Earthmoving-Machinery-Ver.-0.5-March-2020.pdf provides additional information on functional safety

For smart tele-remote

- AS 4240 - Remote control systems for mining equipment – Design, construction, testing, installation and commissioning

Training guidance

Resources and Infrastructure Industry (RII) autonomous and remote operations units of competency

- RIIARO301 - Work safely in autonomous environments
- RIIARO303 - Operate equipment in autonomous environments
- RIIARO304 - Coordinate and interact with autonomous systems
- RIIARO305 - Build and maintain routes for autonomous operations

- RIIARO306 - Respond to obstructions to autonomous operations
- RIIARO307 - Activate and deactivate autonomous systems
- RIIARO401 - Supervise autonomous operations

Appendix 2: Glossary

To reduce confusion and ambiguity, it is recommended that standard terminology is applied. For the purposes of this document, the following terms are defined.

Automatic — term used for (part of a) process when a machine follows well defined rules

Automation — the technique, method or system of operating and controlling a process or machine by automatic means with minimal human intervention

Autonomous area — designated area in which machines are authorised to operate in autonomous mode

Autonomous machine – mobile machine that is intended to operate in autonomous mode during its normal operating cycle

Autonomous mode – 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

Collision — unintended contact between two or more objects

Manual mode – mode of operation in which a machine is controlled by an operator who is responsible for monitoring the surroundings and for safe operation of all machine controls

Mechanised — commonly used when a certain process is done with the aid of machines

Mobile autonomous mining — mobile equipment operated using an autonomous system

Mode indicator — means by which a machine shows whether it is in manual mode, autonomous mode or remote control mode

Operator interaction – involvement of an operator to provide information to or control of an autonomous or semi-autonomous machine, such as the transition between the autonomous mode and manual mode, or to provide any type of exception handling

Remote controlled — operator control of a machine from a device not located on the machine

Safe state — condition, whether or not an autonomous machine or semi-autonomous machine is operating or is shut down, such that a hazardous safety, health and environment event is at an acceptable level of risk based on a risk assessment

Semi-autonomous — mobile machine that is intended to operate in autonomous mode during part of its operating cycle and which requires active control by an operator to complete some of the tasks assigned to the machine