GMG

ZERO ENTRY MINING

An Exploratory White Paper

Executive Summary

Zero entry mining is a concept where mining is carried out without people in the mine, hence eliminating health and safety exposures whilst also improving efficiency and reducing capital and operating costs. Zero entry mining will unlock new resources currently unable to be mined using traditional methods.

Societal expectation is that the utmost be practically done to minimize the risk of injuries or fatalities in the workplace.

Accessing orebodies has become increasingly challenging as easily accessible ore is depleted. This has forced mining companies to pursue deposits in more remote regions and at greater depths, often involving lower-grade ore. Zero entry offers the potential to safely and efficiently mine these resources, positioning zero entry mining as a major evolutionary objective of mining automation.

Zero entry mining is not as much a technical challenge as it is a mindset challenge. To succeed, the mining industry needs to embrace change, foster critical and creative thinking, learn from mistakes, learn from established practice in other industries, and commit to the transformative journey ahead. Open discussions are crucial to foster and refine the ideas necessary to transition mining toward a zero entry future.

Zero Entry Mining Ecosystem

Introduction

Zero entry refers to the total removal of people from a mining operation (below ground or in a pit). A path toward zero entry exists where people are progressively removed from designated areas in a mine such as the immediate vicinity of mobile mining equipment operation.

Mining practices have evolved, and technology (specifically automation and remote operations) has developed to a point where zero entry operation should be considered. The design of a zero entry mine in its entirety has not been realized; however, its achievement is as much a mindset challenge as it is a technical challenge.

Zero Entry Mining

The mining industry faces significant challenges:
- Minerals and metals are becoming more difficult to access.
- The capital intensity to produce an annual tonne of metal has increased dramatically ($/installed capacity/year).
- The operating expenditure (OpEx) to produce metal has increased.
- Productivity improvements in mining have plateaued.
- Attracting skilled talent to mine resources is an increasing challenge.

Zero entry mining offers an evolutionary pathway to assist with many of these challenges.

If no one is in the mine, no one can get hurt or killed.

Mining has been practiced for centuries, leading to the depletion of easily accessible ore deposits. As a result, mining companies need to target deeper, more remote, and lower-grade deposits, which demand more complex mining methods and processing techniques.

The increased difficulty in accessing ore raises both financial and safety challenges. It heightens the risk to potential returns on investment, making it harder to secure capital funding to first access the deeper and more complex orebodies as well as encountering the increasing costs associated with ensuring the safety of miners working at the “face”.

Automation brings consistency to how an outcome is achieved. It alters the need for certain support (e.g. ventilation, ground support) in the working environment. Labour is often not eliminated but rather transformed into roles supporting automation rather than doing the task directly. Remote working roles are often more efficient as they do not need to travel to and from the working area, and the need for infrastructure to support this transit is reduced or eliminated thus reducing capital costs and increasing productivity.

Key Concepts

- **If no one is in the mine, then no one can get hurt or killed.**
- **Zero entry mining can lower capital and operating costs.**
- **Zero entry mining can reduce safety, operational, and financial risk.**
- **Zero entry mining has the potential to extend and unlock previously inaccessible orebodies.**
- **Zero entry mining alters the economics allowing for increasing the conversion of resources to reserves.**
- **Zero entry mining unlocks opportunities for new and novel mining methods.**
- **Zero entry mining will unlock opportunities to simplify mining (for example, eliminating the need for ground control in certain circumstances) and processing value chains, enabling whole of system benefit.**
- **Zero entry is already the operating mode in other sectors.**

Other sectors that heavily employ automation have not realized a reduction in labour because the roles that are displaced by the automated processes are almost certainly going to be replaced by new roles that currently don't exist, and those new roles require greater degrees of skill.

As mines get deeper, the travel time for operators to get to the face and equipment increases and significantly impacts productivity. The benefits derived along the path to zero entry mining are not linear, with significant discontinuities in value attained when the last person to enter the mine is removed and again when the mine (and mining process) is completely redesigned.

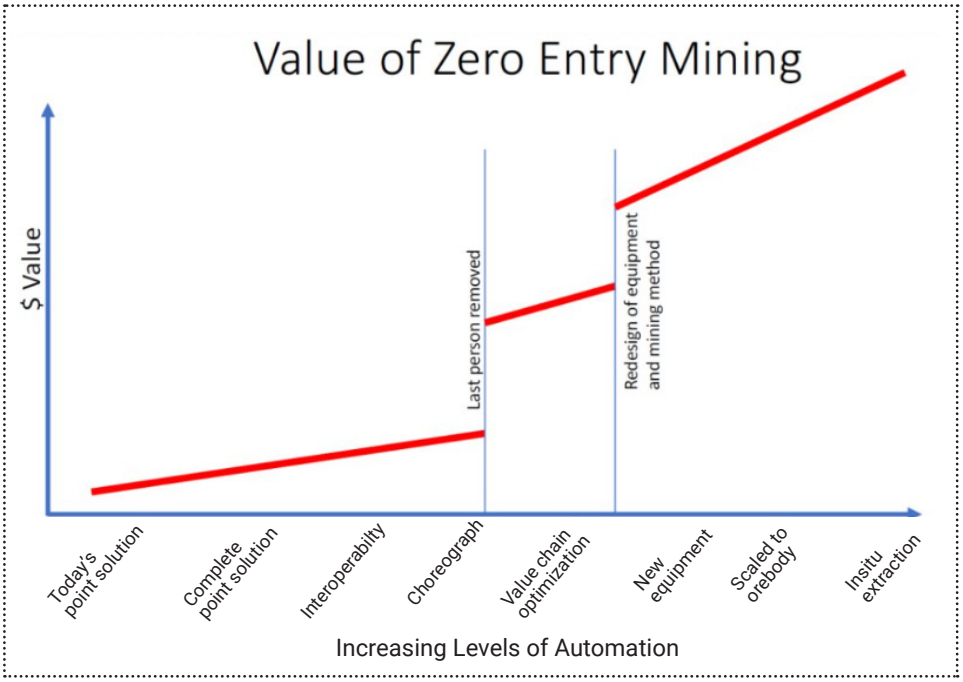

Figure 1. Value of Zero Entry Mining (Knights, P. & Yeates, G.)

Zero entry mining lowers capital and operating costs.

The mining industry faces a person-power issue. Demographics, urbanization, greater value being assigned to human life, and an expectation of work-life balance are global trends making recruiting and retaining people to work in remote, harsh environments difficult. People are choosing to migrate to urban centres far away from the areas where new mines are likely to be developed. There is a reduced number of people willing to perform more manual labour tasks, traditional in mining. Mining also has an image problem, being perceived as dirty, polluting, damaging the environment, contributing to climate change, and unsafe. These perceived factors aggravate the inability to recruit and retain staff to extract the target metals and minerals. These societal changes are forcing the mining industry to change tactics.

Zero entry mining reduces risk profile.

Zero entry mining is not synonymous with zero people mining, rather, zero entry mining requires people (often located remotely) to perform different, often more highly skilled and attractive roles.

Zero entry mining will require a combination of redesign of the mining process and mine design with application of automation and remote operation. This has the potential to unlock new ways of extracting metal-bearing ores and minerals from where they are found in the earth's crust.

Zero entry mining will eliminate the risk of fatalities or injuries in mining operations by removing the human presence. After eliminating a hazard, the next best option is remove exposure to a hazard to improve safety. If no one is in the mine, then no one can get hurt or die.

There is increasing social awareness of the risk associated with mining, and this is being reflected in new regulations. Recently, industrial manslaughter legislation in Australia has been introduced that holds company executives accountable for workplace fatalities. Despite all of these factors, as a largely untested approach, there are few urgent drivers compelling the adoption of a zero entry mindset. At the same time, risk aversion remains a key barrier. As with any new approach, some risks will be eliminated while other new risks will present themselves.

A whole of system engineered solution is required to successfully realize zero entry mining.

Zero entry mining has the potential to extend and unlock previously inaccessible orebodies.

Accessible ore grades are declining. Mining has been underway on Earth for centuries thus, easily accessed ore has been depleted. Miners are now forced to access lower-grade deposits requiring more complicated mining methods and processing techniques. The deposits are also more difficult to access; they are deeper and more remote. Increased difficulty to access ore increases the risk both to the potential return on investment, making raising of capital funds more challenging, and safety, making it more costly to support miners at the face.

Photo credit: Australian Droid and Robot (www.australiandroid.com.au)

Zero entry mining alters the economics allowing for increasing the conversion of resources to reserves.

Being able to access deeper, complicated orebodies in remote areas without the need for people to enter the active mining areas will become essential. Eliminating the need for people to enter the working areas of a mine eliminates many safety risks associated with mining. Every year, multiple miners are killed or maimed because of an unexpected release of energy. Taking people out of the line of fire by employing zero entry mining is a good thing.

There is a sharp rise in capital intensity[1] along with a continued rise in operating costs, driven by rising input costs (i.e., labour, energy, consumables) and lower productivity across the industry.

Zero entry mining can reduce capital intensity by eliminating development and infrastructure designed to allow a human presence. Items such as second means of egress, refuges, ventilation, refrigeration, size of openings, ground support, roads or berms, slope angles, working areas or clearances, and factors of safety will be eliminated or significantly reduced if there is no expectation for human presence in the mine.

In many operations, operating costs will be reduced under zero entry mining through:

- Higher equipment utilization (operating hours) driven by autonomous or remote operations eliminating human-related delays (e.g. shift change, meal and toilet breaks).
- Higher productivity (tonne per hour) driven by higher consistency, lower variability, and operating to machine limits rather than operator limits.
- Reduced delays and work-in-progress inventory through more consistent unit throughput and a systems approach supported by automation and digital feedback.

The productivity measured by metal output per unit of input needs to be improved. Revenue can also be improved through more selective and intelligent (sensor-based automated) decision-making such as where to mine and where material is to be taken. A more selective and accurate mining approach will reduce dilution and increase ore grade and could inform downstream processes of the ore type being fed ahead of time which can increase metal recovery. Also, additional resources can be converted to reserves through zero entry access to areas not previously able to be mined, increasing mine life and increasing the return on capital.


Photo credit: Morgan David, XCMG


Photo credit: Sandvik

Zero entry mining unlocks opportunities for new and novel mining methods.

The transition to zero entry mining requires automation of mining rather than the automation of mining equipment, meaning designing new mining methods suited to mechanization and automation will be required. The technology to support automated mining processes exists and is improving and becoming less costly.

Additionally, there are supporting technology capabilities with distributed intelligent networks that can allow for interoperability of equipment and systems owned by different vendors. These technologies are still maturing and will become more capable and supported by smart devices such as robotics and sensors.

The design of mines for conventionally crewed equipment and automated uncrewed equipment has not significantly changed for two primary reasons:

- Mining as an industry is risk-averse and continuing with known designs and operating methods is perceived as low risk and comfortable.
- To date, automation has proceeded on the basis of automation of unit operations rather than the whole mining process.

Zero entry mining will unlock opportunities to simplify mining and processing value chains, enabling whole of system benefit.

Photo credit: Scania. Concept image only.

Zero entry mining will benefit from automation of the mining process, reducing the need for direct human control. However, mining companies need to embrace a sustained transition to zero entry mining and avoid an expectation of periodic reversion to staffed operations with equipment or in underground operational areas that have no longer been designed with an expectation for human presence. This can potentially include:

- Adopting equipment that no longer has an operator cabin precludes onboard operation.
- Installing ventilation in the mine to only allow the machinery to operate (i.e. combustion versus battery) precludes a human presence and will also lower ventilation/cooling costs.

The zero entry mindset needs to be embraced by all parties or success is unlikely. The parties include:

- Mining company management
- Legislative bodies
- Communities and management
- Operations leaders
- Mine maintenance
- Equipment vendors
- Operations personnel
- Investors/market

Zero entry is already the operating mode in other sectors.

Other industrial sectors have already adopted the zero entry mindset and use it as their normal operating mode. These sectors include:

Offshore energy
Lights-out warehousing
Lights-out manufacturing
Vertical farming
Medicine
Nuclear
Defence
Aerospace

All of these sectors have adopted the zero entry mindset because it eliminates exposure to hazards and/or reduces capital and operating expenses, thereby lowering overall risk.

Many of these scenarios have hazardous operational uncertainties that parallel or exceed those faced by mining.

Some existing scenarios that benefit from zero entry are:

- Mining radioactive materials where because of exposure to radon and ionizing radiation it is not safe to put a person, yet the mineral reserves are sufficiently valuable to extract.
- Mining offshore on the seabed or below is not practical unless zero entry mining is adopted.
- Mining in areas that are not geotechnically sound, but economically viable.
- Mining in areas that are too hot or cold to support conventional crewed mining operations will require sufficient investment in additional infrastructure to make it safe for crews. The additional associated operating costs could be offset by adopting zero entry mining.
- Solution mining of salt deposits minimizes the disturbance footprint of the mine and negates the need for personnel to enter the deposit.

Zero entry mining is not as much a technical challenge as it is a mindset challenge.

Change, particularly in a conservative and capital-intensive sector, is daunting, especially because zero entry mining requires commitment to change, design of new mining processes, design of new equipment to support these new processes, and the technology to underpin it. Zero entry mining can be a viable and effective means to contribute to the demand for metals and minerals.

A zero entry approach will require a change in work and job design; therefore, requiring an adjustment in roles transitioning from operational to more technical functions. The advent of artificial intelligence has expanded the range of tasks machines can perform unsupervised, within certain limits. Nevertheless, machines struggle with resolving ambiguity, handling unfamiliar circumstances, or making decisions based on partial information – areas where humans excel.

An automated process can be set up for success by designing the system to eliminate or, at the very least, minimize the likelihood of ambiguous situations that the system needs to resolve unaided. If this is not feasible, it is essential to include a mechanism that allows the automated system to seek assistance in resolving the ambiguity. This involves:

- Communications.
- The ability to relay sufficient information to the party assessing the situation to be able to render a decision.
- The ability of the system to respond and return to normal operations.

Furthermore, developing systems for scenarios where humans interact with robots and other automated equipment is significantly more challenging than designing isolated automated systems without human presence. Creating automated systems that need to protect humans from harm places a much greater responsibility on the designer. Zero entry environments eliminate this complication, enabling simpler system designs. Careful consideration of the systems design, including its operating environment, can enhance safety, efficiency, and productivity.

Modern mine designs are made both with the benefit of having humans in the loop and to accommodate them. Important questions to ask include:

- How might the mine design for a zero entry mine differ?
- What are the potential ambiguities in a mining operation that can be designed out of an automated process? What are those that cannot?

The goal of a fully automated and fully integrated mine can be achieved by adopting the zero entry mindset. Zero entry mining steps over the barriers impeding mining for exploiting more challenging resources while improving safety, productivity, and capital efficiency. Whole-of-systems engineered solutions are required to successfully realize zero entry mining.

Next Steps

Open discussions are crucial to foster and refine the ideas necessary to transition mining toward a zero entry future.

Following the publication of this paper, a series of nine discussion papers is planned to address common challenges and opportunities in zero entry mining. These papers, developed in parallel, aim to spark industry-wide dialogue, encouraging knowledge sharing and exploration of new opportunities.

Discussion Papers	
1.	Mining Process
2.	Mining Methods
3.	Systems Engineering Approach
4.	Enablers and Barriers
5.	Interoperability
6.	Legal and Ethical
7.	People
8.	Business Case
9.	Brownfield Applications

While these papers are not intended as definitive guides, they aim to ignite industry-wide conversation and brainstorming to address common challenges by delving into mine design, economics, change management, and more.

Learn more about this project here. Contact us at zeroentrymining@gmggroup.org to get involved with the development of these discussion papers.

References

1. BHP, BHP Insights. How Copper will Shape Our Future. Retrieved from https://www.bhp.com/news/bhp-insights/2024/09/how-copper-will-shape-our-future
2. Knights, P. & Yeates, G. The Business Case for Zero-Entry Mining. IEEE-ICIT Automation in Mining Conference, February 13-15, 2019, Melbourne, Australia.

About Global Mining Guidelines Group

Global Mining Guidelines Group (GMG) is a network of representatives from mining companies, original equipment manufacturers (OEMs), original technology manufacturers (OTMs), research organizations and academics, consultants, regulators, and industry associations around the world who collaborate to tackle challenges facing our industry. GMG aims to accelerate the improvement of mining performance, safety, and sustainability by enabling the mining industry to collaborate and share expertise and lessons learned that result in the creation of guidelines and related documents, such as papers like this one, that address common industry challenges.

Interested in participating or have feedback to share? GMG is an open platform, and everyone with interest and expertise in the subject matter covered can participate. Participants from GMG member companies have the opportunity to assume leadership roles. Please contact GMG at info@gmggroup.org for more information about participating or to provide feedback on this paper.

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The following organizations and individuals were involved in the preparation of this white paper at various stages including content definition, content generation, and review. Please note that the white paper does not necessarily represent the views of the organizations listed below.

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