

# **FINAL PROJECT REPORT**

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Contract Number: 75D30122C14149

## **Eliminating Barriers for the Implementation of Automation in the Mining Industry**

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Date: October 30, 2024

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Period of Performance: September 30, 2022, to December 31, 2024

## **EXECUTIVE SUMMARY**

The integration of new technologies into U.S. mining operations is a necessary requisite for achieving continuous improvement in worker health and safety, as well as staying economically viable in an everchanging operating and regulatory environment. The implementation of these technologies is often limited or blocked by real and perceived barriers believed to exist as a consequence of safety regulations, financing requirements, economics, and a host of other factors. To quantify these barriers, a comprehensive review and analysis of the regulatory framework and other external factors that potentially influence technology development and integration into U.S. mines is needed to determine whether these barriers to innovation exist and if so, to characterize the causation factors behind their existence and how they can be functionally eliminated. In addition, work is needed to understand the implications of alternative regulatory approaches, the political/social risks associated with adopting innovation, and the required research necessary to advance automation and technical innovation in our nation's minerals industry. The ultimate goal is to encourage the integration of advanced technologies to improve the safety and welfare of workers in U.S. mines and mineral processing facilities.

With specific regards to mining operations, the objectives of this research are to (1) Identify and evaluate current U.S. federal regulations and other influencing factors that may deter or hinder the implementation of automation and new technologies; (2) Identify regulatory strategies that have been successfully utilized in other countries and jurisdictions to encourage the safe and effective implementation of automation and technology, and (3) Describe potential avenues for the successful implementation of automation in U.S. mines. To achieve these objectives, a research methodology was adapted that consisted of 4 primary tasks. The first project task focused on a review of U.S. regulations pertinent to mining that may limit or discourage the adoption of new technology and automation. The second project task involved organizing technical workshops associated with Society for Mining, Metallurgy & Exploration (SME) conferences to solicit input from professionals from each major industry sector on their experiences and insights into barriers to the implementation of technology. For each workshop, the project team identified appropriate stakeholders representing diverse populations within each industry sector and invited them to participate in the workshops. A total of 708 invitations were extended to knowledgeable professionals to participate in the workshops, representing 480 companies. In Task 3, nine different workshops were held across the U.S. to collect data and promote in-depth conversations with stakeholders who were knowledgeable with technology and automation in the mining industry. In addition to these in-person workshops, individual meetings were held with Mine Safety and Health Administration (MSHA) Leadership, and miscellaneous professionals from NIOSH, SME and academia. The final task (Task 4) included data analysis and the preparation of project deliverables, including workshop summaries, quarterly reports, and the Final Project Report. A preliminary comprehensive regulatory review was also completed during the first year of the project. Similarly, several presentations have been given on the preliminary findings of the research and a technical paper will be published to disseminate the research results.

The research findings from each workshop varied considerably, predicated on industry sector, mineral commodity, and the specific technologies being pursued. In addition, the workshops

highlighted that there were different perspectives on the challenges inherent with innovation and technology implementation that were dependent upon whether participants self-identified as an operator, contractor, manufacturer, supplier, technology specialist/consultant, or as an employee of a government agency or academic institution. A synopsis of the participants and their associated employment categories for each workshop is provided in the minutes and summary findings provided in Appendix C and in the body of the report (Section 5).

During discussions held in the first workshop, the participants organically identified 5 general categories (types) of barriers. While inter-related, these categories proved to be beneficial in soliciting input from the participants and were used in all eight of the remaining workshops. These categories included Regulation, Economics, Technology Readiness, Corporate Willingness, and Social License. Given the potential overlap and ambiguity of these categories, some guidance was given to each group in terms of definitions and scope to assist in their discussions. This process also provided a means to identify differences between each workshop and industry sector on what was deemed to be the primary drivers and impediments to technology implementation.

The key outcomes and findings that emerged from these workshops and other research related activities included:

- With the exception of coal, regulation was not perceived to be a primary barrier to automation as compared to other influencing factors. Issues related to “Duty of Care,” permissibility requirements related to the integration of technology in coal and gassy status mines, constraints associated with Federal Communication Commission (FCC) regulations, and the prescriptive regulatory structure in the U.S., were all perceived to be contributing factors responsible for impeding automation in some capacity depending on the industry sector. Furthermore, the regional differences in MSHA enforcement and the interpretation of regulations were also viewed as a concern and potential deterrent. Appendix A of this Final Report includes a detailed review of potential regulatory barriers that exist as a consequence of health and safety regulations within U.S. 30 CFR.
- With rare exceptions, most of the workshop participants believed that workforce challenges are currently driving automation throughout much of the industry. That said, most of these participants believed that automation, including equipment autonomy, will not diminish staffing or labor requirements at most operations in the near-term, but rather necessitate upskilling and diversification of the workforce. Workforce shortages did not appear to be a major concern for operators mining iron ore (taconite), urban aggregate, and in specific regions affiliated with steam coal.
- Economics proved to be the most dominant barrier to technology integration in all but one of the workshops. These economic concerns extended from financial risks associated with the failure of the technology to more conventional evaluation approaches related to a cost: benefit type assessments, incorporating capital and operating costs and the expected benefits derived from the use of the technology. A common concern raised during group discussions focused on unintended ramifications of technology utilization on other

systems and the constraints associated with lack of compatibility of implementing certain types of technology into mature operating environments. Besides technological risk, significant deterrents also included the perceived risks associated with the loss of production and the implications associated with change management. While still a consideration, it was the opinion of many that the influence of economics as part of the decision-making process associated technology investment was lessened in situations involving safety and/or in order to achieve compliance with new tech-ratching regulations (e.g., diesel emissions). From the perspective of equipment manufacturers and suppliers, the market for new technology in the mining industry is relatively small, where there is insufficient capacity to amortize research and development costs over a sufficiently large quantity of equipment sold to make innovation attractive. As such, different equipment manufacturers and suppliers during several workshops reiterated their concerns regarding the high cost of technology and automation and the limited opportunities for sufficient economic return as a major barrier to the implementation of technology in mining unless the technology could be readily adapted for use in construction or other industries.

- Corporate willingness to invest in technology proved to be a significant consideration for many companies and varied greatly depending on their tolerance for risk, economic and market situations, and corporate strategic objectives. Interestingly, unit mines that were owned by companies that controlled the manufacturing and distribution of finished, value-added products down-stream of raw mineral production, generally had fewer financial incentives for investing in mining technology. These corporate investments were usually committed to processes associated with product production and manufacturing rather than the mining of raw materials. Similarly, companies in highly competitive markets, such as aggregates, industrial minerals, and coal, generally had minimal research & development budgets, low risk tolerances for new technology, and less capacity to explore potentially new innovations.
- There was recognition that a number of countries outside the U.S. that have regulatory frameworks that are better suited for encouraging the development and integration of new technology into operating environments. The differences in the underlying regulations between the U.S. and countries, like Canada and Australia, were reviewed relative to autonomous haulage and a number of recommendations were made (Appendix B). Given the complexities and timeframe associated with amending current regulations, a recommendation was made for developing a guideline that provides a formalized interpretation of regulations regarding autonomous equipment operations. The framework of this guideline should be developed collaboratively with industry, manufacturers, organized labor, and regulators to evaluate standards and provide clarity on the requirements associated with the use of the technology.
- Discussions with MSHA Leadership proved to be extremely valuable and provided insights into the challenges associated with integrating technology into mining operations. MSHA is fully aware that technology is evolving at a rapid pace, and they acknowledge the need to increase their capacity and capability relative to these new innovations in order for them to successfully achieve their mission and remain relevant.

- Unfortunately, MSHA is significantly hampered by labor and budgetary constraints, where a vast majority of their budget is devoted to enforcement as mandated by law. That said, they are attempting to be responsive to changes in technology by reinterpreting existing regulations and promoting technology that supports their mandated mission and addresses immediate health and safety priorities.

The analysis and concluding remarks associated with the Regulatory Review and the International Approaches and Comparisons to technology implementation are presented in Appendix A and Appendix B, respectively. The discussion includes recommendations for further analysis and suggested revisions to existing processes for improving the overall integration of technology and automation in the mining industry. Appendix C is comprised of the summary findings from each workshop and Appendix D contains the materials used in each workshop.

Generally, in the case where it is critical to understand barriers in the industry around health and safety, especially across several sectors the workshop model yielded outstanding feedback. Academic and consulting partners agree that SME is seen as a well-respected organization and key industry representatives are eager to participate in workshops convened by SME, especially in conjunction with major meetings.

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## STATEMENT OF WORK

### Focus Area: Regulatory Review for Automation

#### 1. Project Introduction

Automation is revolutionizing the mining industry and has the potential to substantially improve worker health and safety while simultaneously improving efficiency and sustainability of mining operations. In many instances, companies are incentivized to automate processes and operating systems in hopes of increasing productivity, reducing costs, improving safety, and to achieve quality gains. These incentives, however, are often eroded by perceived and actual barriers that impair or restrict the development and/or implementation of these technologies by industry. The source of these barriers has traditionally been a matter of conjecture but likely stems from a variety of sources that vary by industry sector and regulatory and economic considerations. For example, the regulatory standards under which U.S. mines operate are prescriptive in nature as compared to most other countries [1] and were promulgated in an environment in which regulators sought to hold operators strictly liable for not complying with prescribed standards of safety and health. The authors of the Mine Act [2] and subsequent statutes could not have foreseen the rapid development of technical advances that have occurred in the industry, including the introduction of fully autonomous mining systems. Consequently, the prescriptive regulatory system under which U.S. mines operate often provides little motivation – and at times, creates barriers – to the implementation of new technologies and highly automated systems that could not only achieve superior economic outcomes but also improve both worker safety and health.

The introduction of Autonomous Haulage Systems (AHS) is a classic example. Multiple researchers recognize that the earliest self-driving vehicles were pioneered on mine sites [5], [6]. Costner and others reported that Caterpillar successfully tested a fleet of autonomous haul trucks at a U.S. surface mine as far back as 2014, showing that these systems were not only reliable but also safe. Today, more than 900 trucks have been deployed globally and are collectively moving more than two billion tons annually with zero lost time accidents [11], [12]. Unfortunately, acceptance of such technology in the U.S. remains problematic and is a significant challenge.

Similar barriers exist in the integration of new processes, equipment, and technology in all underground coal and non-coal mines classified as “gassy” by MSHA under 30 C.F.R. § 57.22000 et seq., as well as new mines undergoing permitting and financing, where new technology is often perceived to be a contributing factor in greater economic or operational risk. It is interesting to note that the standards that govern the use of permissible equipment in U.S. mines were examined by researchers and it was determined that alternatives or additions to the regulations would not reduce the standard of safety provided to miners [8]. Notwithstanding that finding, MSHA has not allowed the use of consensus standards (such as IEEE, UL, or IEC) to determine the permissibility of equipment for use in gassy underground environments. See 30 C.F.R § 6.30(a).

The original due date for the Preliminary Final Report was Oct. 31, 2024 so MSHA’s recent rulemaking allowing for adoption of 8 ANSI (American National Standards Institute) standards to be used as alternatives to MSHA unique standards ([Testing, Evaluation, and Approval of](#)

[Electric Motor-Driven Mine Equipment and Accessories](#) 89 FR 99085 December 10, 2024) was not addressed.

This rulemaking is MSHA's first attempt to incorporate consensus standards into its approval and certification process. Although MSHA should be credited with making an effort in this direction, this rulemaking falls far short of what is needed to address the issue it faces for several reasons.

First, although MSHA did indeed incorporate consensus standards that could be used in lieu of or in combination with its unique standards, MSHA retained ultimate approval authority. That is, the rule only allows applicants to cite different standards when it submits its application to the Approval and Certification Center (A&CC) for approval. As was pointed out by numerous commenters, the approval process is extremely lengthy and costly, thus making it uneconomic for many potential equipment providers. This problem is only amplified when one considers that the ultimate market for mining equipment certified permissible in the U.S. is extremely small.

Second, rather than stating that it would accept test results or design criteria meeting certain ANSI standards as equivalent to meeting MSHA unique standards, the 8 ANSI standards addressed in the rulemaking were "incorporated by reference" into MSHA's regulation. Incorporation by reference is governed by the Administrative Procedure Act (5 U.S.C. 552(a)) and regulations published by the Office of the Federal Register. Without going into detail, both the statute and the regulations require that, when incorporating material by reference, the agency must specify the particular edition on the consensus standard it is adopting. Each adopted standard then becomes "frozen in time" as of the edition that is incorporated. Many commenters pointed this out and MSHA replied that it would consider adopting new standards as they came up. However, MSHA's track record in this area is far from stellar. See e.g., 30 C.F.R. § 77.516 which incorporates the National Electrical Code of 1968 and has not been changed. Not to mention that the rulemaking process is extraordinarily time-consuming. The proposed rule that led to this final rule was published on November 19, 2020 (85 FR 73656), over five years prior to the adoption of the final rule. MSHA's approach will make it virtually impossible to keep up with the rapidly increasing pace of progress in the technologies with which this rule deals.

Finally, MSHA is handcuffed as to what consensus standards it can incorporate. Its original proposal included 6 IEC (International Electrotechnical Commission) standards in addition to the 8 ANSI it ultimately adopted. It rejected those standards (along with many others suggested by commenters) for a number of reasons, but one of those reasons is particularly relevant to this topic. In the final rule, MSHA pointed out that its unique standards are intended to approve equipment to operate in an NFPA (National Fire Protection Association) Class 1 Zone 0 environment. That environment is described by NFPA as one in which equipment is expected to operate in atmospheres that always or frequently contain explosive concentrations of gas. Of course, that is not the case in coal mines as 1) MSHA's own ventilation regulations prevent that from occurring in all but rare circumstances and, 2) MSHA's regulations require that power be cut off to any equipment exposed to 40% of the lower explosive level of methane. In other words, while coal mines might at one time have been legitimately considered to be Zone 0 environments, the environment in which permissible equipment now operates is far from a Zone 0 environment. Nevertheless, Section 109 of the statute under which MSHA operates forbids MSHA from adopting any standard that provides any lesser degree of safety than the standard it is replacing, thus effectively preventing MSHA from ever adopting standards that are more

amenable to the current environment as more and more engineering controls are added to prevent explosive gases from rising to explosive levels in the first instance.

In processing mined ores, the implementation of technologies related to process automation and control has become prominent throughout the industry. This is particularly evident in the use of distributed computer control systems that leverage innovative sensor technologies to reduce energy consumption and improve process efficiency [4]. Further, automation provides opportunities to isolate workers from potential safety hazards and adverse health exposures (e.g., dust, noise, heat, chemical reagents, and toxic substances). Despite these benefits, some processing facilities have elected not to utilize these technologies [7] for a variety of reasons. Identifying these reasons is a central objective of this research.

To encourage the rapid integration of new technology into U.S. mining operations and to promote worker safety, better resource utilization, and greater economic utility, a comprehensive review and analysis of the regulatory framework and external factors influencing technology integration in mine/plant development and operations is needed in order to characterize the potential barriers that exist and the causation factors that govern why these barriers exist and how they evolve. Additionally, this work sought to provide an understanding of different regulatory approaches, the political/social risks associated with innovation, and research that could enable high levels of automation in U.S. mines and processing plants to occur. This part of the analysis also relied on an examination of how technology is adopted in other countries using alternative regulatory structures. This work is a necessary component to eliminate barriers for future technological initiatives in the mining industry (e.g., [7], [10]) with the ultimate goal of increasing worker safety and improving worker health.

## **2. Research Objectives**

The objectives of the proposed work are:

**OBJECTIVE 1.** Identify and evaluate current U.S. federal regulations and other influencing factors that may serve as barriers to the implementation of automation and new technologies into the mining industry, particularly those that could translate to significant improvements in worker safety and health.

**OBJECTIVE 2.** Identify regulatory strategies that have been successfully adapted in other industry jurisdictions and countries that encourage the safe and effective implementation of automation and other new technologies into operating environments.

**OBJECTIVE 3.** Describe potential avenues for the successful implementation of automation in the U.S., including research required to demonstrate that an equal or higher standard of mine and plant safety and health may be achieved.

Autonomous mining, advances in equipment and unit operating systems, and a wide variety of related innovations currently exist at the highest levels of technology readiness (TRL 10). The mining industry globally is home to, perhaps, the largest automation projects on earth, and these processes continue to evolve and advance rapidly. These projects are progressing in Australia, Canada, and other countries with real potential to improve safety and health for mine workers.

For example, Fortescue Metals Group and BHP are currently working towards fully autonomous surface operations in Pilbara and several new mines are planned that rely extensively on autonomous haulage (AHS) [10]. There are numerous examples of where large fully autonomous AHS fleets, as well as automated underground systems, are being planned and deployed globally. One such example is the Syama Mine in Mali that is being designed as a fully autonomous underground mine. It is difficult to point to such revolutionary examples in the U.S. The U.S. has only had one trial in recent years. Barrick and ASI had a system operating for approximately 1 year. Unfortunately, it was indicated in the workshops that it has since been decommissioned.

Although the system was initially cited for non-compliance with Mine Safety and Health Administration (MSHA) regulations requiring that mobile equipment be "attended" while in operation, (30 C.F.R. § 56.14207) it was later determined that the equipment was "attended" by the operators of the automated system.

On a smaller scale, a wide variety of other technologies, such as sensors, artificial intelligence, and communication/data transmission systems, are also advancing at a rapid pace. Despite falling costs and increasing reliability, the technology associated with limited autonomy can still be difficult to implement in the U.S.

While the current state of computer control systems and automation in mineral processing facilities has become commonplace, many of these efforts require operator interaction to ensure plant safety and to adapt to dynamic operating environments. Various tasks (irrigation system placement for leaching, cathode harvesting in electrowinning, sludge removal, crud treatment, flotation control, etc.) are often difficult to automate because they utilize complex motions and/or require judgmental decision-making processes. As technology advances, however, the opportunity to automate these applications will likely exist if the barriers and challenges associated with implementation can be overcome.

Regulation and economics are not the only drivers of autonomous mining systems. Most of the workshops cited labor availability, productivity, efficiency, and corporate willingness are all important factors. It should be noted that AHS is being deployed in several countries in South America, where mine labor rates are significantly less than those in the U.S. In these AHS applications, the principal incentive is associated with an overall increase in equipment available hours (11).

### **3. Research Methodology and Scope of Work**

**TASK 1:** Review of regulation, and changes in regulation that have encouraged mine automation in other countries.

The first project task requires a thorough review and identification of U.S. regulations that may limit or discourage adoption of automation in both underground and surface operating environments for a variety of commodities. Elements of this Task were addressed in Appendix A and B. With an emphasis on mine safety and health, this research required a comprehensive review of Title 30 Code of Federal Regulations (30 C.F.R. Parts 1-199), the regulations governing mine safety and health in the U.S. In addition, other statutes, regulations, and corporate policies may also directly affect the ability of an operation to implement new automation in a reasonable period of time. For example, an operation undergoing the long and

arduous process of permitting in feasibility may be discouraged from implementing new technologies or processes into their mine design out of concern that such changes will result in significant delays or legal challenges. Similarly, regulations promulgated by the Federal Communication Commission (FCC) regarding wireless communications can hamper the utilization of new technologies due to access constraints, legal obstacles, and economic risks. With regard to the FCC regulations, commenters stated that major telephone carriers such as AT&T and Verizon had bought up and therefore, controlled the most desirable frequencies for establishing the communication networks necessary to allow a fully automated mining system to operate. They also stated that most of the remaining frequencies were either too slow to provide communications necessary to prevent metal to metal contact or too broad to detect objects in the equipment environment with sufficient accuracy to enable the equipment to identify objects accurately. See, generally Sections 2.104-2,106 for the Federal Communications Commission rules. Within this research, emphasis was placed on identifying the detrimental impacts of federal and state regulations on technology integration. Primary review and identification of relevant statutes and regulations occurred during the first two quarters of the project but expanded during activities relevant to Tasks 2 and 3. Similarly, a review of standardized policies and provisions commonly associated with project feasibility and financing was also performed.

This task also included the examination of other industry sectors that are federally regulated and utilize high levels of automation (e.g., petroleum, petrochemical refining, and transportation) to understand regulatory barriers and incentives. Finally, this task also considered regulatory approaches in countries that have quickly and successfully adopted high level of mine automation (e.g., Australia, Sweden, Canada), and whether similar approaches can be adopted under a U.S. regulatory structure.

## **TASK 2:** Identification of stakeholders, and organization of workshops

SME is uniquely positioned to identify appropriate stakeholders and to organize technical workshops in conjunction with existing national and regional meetings organized by the Society. The objectives of the research are consistent with the mission of SME and greatly benefited from the technical scope of SME membership. The SME membership includes equipment manufacturers, suppliers, mine operators, consultants, regulators, and other professionals who are intimately involved in technology and nearly every mineral commodity mined and processed in the U.S. Two primary groups of stakeholders were identified for participation in the industry Workshops:

### **Stakeholders who are advancing and using automation in the US**

These individuals include global equipment manufacturers and suppliers who are advancing automation throughout the U.S. mining industry. Stakeholders from this group also include operators and mines that are recognized leaders in cutting edge automation. Under this task, emphasis was given to soliciting input from a diversity of companies representing different segments of the industry, including focus (e.g., operators and contractors), mining methods (e.g., surface and underground), geographic location, and the types of mineral commodities being mined. This task also identified groups representing industry professionals that play pivotal roles in the advancement of technology, including universities, government scientific and regulatory entities, private and public research organizations, and professional societies and trade organizations.

Technical groups who understand barriers that are commodity or method specific

As an organization, SME utilized its own technical groups and committees, as well as leveraged relationships with other professional organizations that assisted in identifying experts and summarizing issues related to regulation and automation in their specific commodities and areas of concentration.

**TASK 3:** Workshops and Data Collection

Workshops and consultation with industry professionals allowed for primary data collection and promoted in-depth discussion with stakeholders who have the expertise and knowledge to identify barriers to automation in the regulation. This included stakeholders who have had experience (successfully or not) with implementing automation at mining operations. A total of nine in-person workshops were held as well as separate meetings with MSHA Leadership and MSHA professionals at the Approval and Certification Center (ACC). Each workshop was led by at least three members of the research team with a targeted participation of 10 to 20 attendees. A table of these workshops is presented below:

**Completed Workshops:**

<b>WS</b>	<b>Day</b>	<b>Date</b>	<b>Time</b>	<b>Location</b>	<b>Conference</b>	<b>Attendees</b>
1	Sun	12/4/22	10:00 AM -4:30 PM	Tucson, AZ	SME Arizona Conference	21
2	Tue	2/28/23	7:30 AM - 12:00 PM	Denver, CO	MINEXCHANGE 2023 SME Annual Conference	17
3	Mon	4/17/23	10:00 AM - 4:30 PM	Virginia, MN	SME Minnesota Conference	15
4	Sun	6/11/23	11:00 AM -4:30 PM	Boston, MA	Rapid Excavation and Tunneling Conference	16
5	Sun	8/20/23	10:00 AM -4:30 PM	Phoenix, AZ	Hydrometallurgy 2023	24
6	Wed	10/18/23	10:00 AM -4:30 PM	Canonsburg, PA	SME PCMIA Conference	17
7	Fri	3/22/24	10:00 AM -4:30 PM	Nashville, TX	NSSGA Conference	12
8	Thu	4/18/24	10:00 AM -4:30 PM	Triadelphia, WV	MSHA A&CC and NIOSH Federal Advisory Committee	14
9	Wed	6/5/24	10:00 AM -4:30 PM	Elko, NV	Elko Mining Expo	10

*Completed Workshops Chart Description: The chart shows the Completed Workshops and lists the Workshop Number, Day, Date, Time, Location, Conference and Number of Attendees*

**Other Meetings:**

<b>Meeting/Event</b>	<b>Day</b>	<b>Date</b>	<b>Time</b>	<b>Location</b>	<b>Attendees</b>
Meeting with MSHA Group	Wed	3/20/24	2:00 PM-4:30 PM	MSHA Offices, Arlington, VA	9
SME Membership Mixer – Presentation of Project by Ben Miller and Mark Savit	Wed	7/10/24	8:45 AM–9:30 AM	Online virtual meeting hosted by SME	30
NIOSH Automation Partnership Meeting – Presentation of Project by Kray Luxbacher and David Kanagy	Mon	9/23/24		Online virtual meeting	50 estimated
NIOSH Automation Partnership Meeting – Presentation of Project by Kray Luxbacher	Thu	10/10/24		Online virtual meeting hosted by University of Arizona Mining and Geological Engineering	50 estimated

*Other Meetings Chart Description: The chart shows Other Meetings listing the name of the Meeting/Event, Day, Date, Time, Location, and Number of Attendees.*

**TASK 4:** Development of Deliverables

The preparation of deliverables took place throughout the duration of the project, including summaries of each workshop, the quarterly project reports, and the draft Final Project Report. Additionally, a preliminary comprehensive regulatory review was completed during the first year of the project with the assistance of our legal consultant. Two presentations were made on the preliminary finding of these workshops, and a SME presentation will be made during the 2025 Annual Meeting in Denver. A schedule of specific deliverables is presented below.

#### 4. Schedule of Completed Activities

The project schedule is provided below. The black diamonds represent complete milestones. All other tasks listed below were completed or modified in the contract. Modifications to this original schedule include the completion of nine workshops instead of six and changing the reporting requirements to a quarterly instead of a monthly schedule.

Task	2022			2023									2024											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
<b>1 Regulatory Review</b>										◆														
1a Identify Relevant Regulation																								
1b Analyze Specific Standards																								
1c Describe barriers created by standards in 1b																								
<b>2 Stakeholder Identification &amp; Workshop Organization</b>				◆																				
2a Kick-off meeting of all consultants and investigators																								
2b Identify key stakeholders across commodities and mining methods																								
2c Identify meeting venues for workshops																								
2d Secure physical space and meeting peripherals																								
2e Advertise meetings and invite attendees																								
<b>3 Workshop &amp; Data Collection</b>																								
3a Develop facilitation strategy, provide materials to leaders																								
3b Conduct six face-to-face workshops																								
3c Develop targeted virtual small focus groups as needed																								
<b>4 Development of Deliverables</b>																								
4a Provide monthly reports to NIOSH																								
4b Draft preliminary regulatory review																								
4c Create and update simple organizational website																								
4d Draft Final Report																								

Picture of a chart showing the Schedule of Completed Activities by each month from October 2022 to September 2024 with start and complete times indicated. These include 1. Regulatory Review, Oct 2022-Sep 2024; 1a. Identify Relevant Regulation, Oct 2022-Dec 2022; 1b. Analyze Specific Standards, Nov 2022-Feb 2023; 1c. Describe Barriers created by standards in 1b, Dec 2022-Sep 2024; 2. Stakeholder Identification and Workshop Organization, Oct 2022-Aug 2023; 2a. Kick-off Meeting of all consultants and investigators, Oct 2022; 2b. Identify key stakeholders across commodities and mining methods, Nov 2022- Jun 2023; 2c. Identify meeting venues for workshops, Jan 2023-Jul 2023; 2d. Secure physical space and meeting peripherals, Mar 2023-Aug 2023; 2e. Advertise meetings and invite attendees, Nov 2022-Aug 2023; 3. Workshop and Data Collection, Jan 2023-Apr 2024; 3a. Develop facilitation strategy, provide materials to leaders, Jan-Feb 2023; 3b Conduct six face to face workshops, Jan 2023-Apr 2024; 3c. Develop targeted virtual small focus groups as needed, Apr 2023-Apr 2024; 4. Development of deliverables, Oct 2022-Sep 2024; 4a. Provide monthly reports to NIOSH, Oct 2022- Sep 2024; 4b. Draft preliminary regulatory review, Jun 2023-Jul 2023, 4c. Create and update simple organizational website, Jun 2023-May 2024; 4d. Draft Final Report, Jul 2024-Sep 2024.

## **5. Findings and Discussion**

Participants in the workshop universally commented that regulations are outdated, regulators take non-mandated actions and engage in a reactive rather than a pro-active approach, and there are widely divergent experiences depending on the specific technology. Participants felt that most other countries do not have a problem with regulations. Australia, which has a risk-based approach, was noted as an example of a system that works well because regulators and operators cooperatively develop guidelines and principles. South Africa was noted as an example where regulations were prescriptive and generated barriers.

However, the majority of participants did not believe the regulations themselves are the primary problem in the United States. They stated that the biggest barriers are outdated science and technology, the long gap between the design of a project and its approval, (wherein technology may change), a lack of education and understanding among regulators and a need for improved (and non-adversarial) relationships between companies, regulators, and original equipment manufacturers (OEMs).

Our recurring format of workshops generated good response. Participants generally fell into two camps: miners with some interest in automating some functions at their mine and third-party companies either as equipment suppliers or as consultants.

Our workshops generally indicated that the regulatory impact to deploying autonomy is limited in comparison to economic factors. The opening discussions around automation always included MSHA, but often those discussions were brief and moved quickly to economic factors. A summary of the workshops is provided on the following page.

### **Identification of stakeholders, and organization of workshops**

Ultimately, 708 invitations were extended to knowledgeable individuals in the mining industry representing 480 companies. To identify individuals, the project team would a) examine conference registration lists and SME area membership lists; b) brainstorm names; c) reach out to others working in automation to generate ideas; and d) encourage invitees to nominate others with the goal of a deep and diverse pool.

Workshops were organized in conjunction with existing conferences with the feeling that it was easier and more cost-effective for attendees to travel, and it also allowed for a sector specific approach in most cases, except for the SME MINEXCHANGE Annual Conference which attracts a broad attendance.

### **Workshops and Data Collection**

A summary of workshop locations, conferences held in conjunction with, and attendees given in Workshops were generally scheduled for four to five hours, and efforts were made to attract themed expertise with approximately 10-20 attendees per workshop to allow for in-depth discussion by all participants. Every workshop started with introductions and an overview of the project. Next, we moved into a broad conversation about automation and the state of automation in the sector of the industry being addressed that day. We ultimately focused discussion based on the observations in the broader discussion and ended with an hour-long breakout session.

Breakout groups discussed motivation for automation, company practice in research and capital projects, and barriers and drivers. In the first workshop, the group organically reached a list of five barriers that we carried through the next eight workshops. These included regulation, economics, technology readiness, corporate willingness, and social license. It is clear that these five barriers are interconnected, but a general definition of each based on the group discussion follows:

**Regulation:** This barrier primarily refers to federal regulation in the U.S., MSHA regulations 30 C.F.R. Parts 1-199. Participants pointed most often to outdated regulation and sometimes to inconsistency in enforcement.

**Economics:** This barrier refers to the cost of automation, particularly since automating one area of the mine will necessitate changes to other systems. There is also risk associated with lost production and change management.

**Technology Readiness:** There is hesitancy to adopt technology that has not already been well proven at other sites, and a concern that technology is not mature enough.

**Corporate willingness:** This gets to corporate strategy and attitude along with appetite for risk.

**Social license:** This referred to the communities and associated workforces for some attendees. For others, social license included corporate ESG initiatives.

A brief description of each of the nine workshops is given below. Detailed notes are included in Appendix C. Workshop materials are included in Appendix D.

### **Workshop 1**

Workshop 1 was held in Tucson, Arizona in December 2022 with the SME Arizona Conference. It included major copper operators and OEMs. This group identified a need for a collaborative relationship between industry and regulators, and they cited the EMESR (Earth Moving Equipment Safety Roundtable) in Australia as a good example. They also felt strongly that small operators need the most assistance around automation from both NIOSH and MSHA. One key factor, especially for large open pit copper mines was that the brownfield nature of U.S. operations makes implementation more difficult. Many mines are quite old, complex, and were not designed for automation.

They saw key drivers in the U.S. for uptake of automation as lack of workforce and demand for low carbon technology. In this workshop and in all the others where the lack of workforce was seen as driver, there was acknowledgement that automation will not reduce the workforce considerably in the short to medium term, but it will allow for more diversity in hiring and flexibility for workers. There was also acknowledgment that a workforce for automation will require upskilling. Another impediment to technical innovation identified by the OEMs and suppliers was the lack of market size and potential to justify technology development. They identified economics as the primary barrier to automation.

## **Workshop 2**

Workshop 2 was held in Denver, Colorado in February 2023 in conjunction with the MINEXCHANGE 2023 Annual Meeting and Exhibit. This was the most diverse group of attendees, representing multiple commodities, sectors, and OEMs. In a discussion of regulation this group identified exposure-based regulation (e.g., dust rules) as driving automation, particularly the new silica rule in the metal/nonmetal industry. They also discussed workforce issues in detail and agreed that automation will not considerably reduce the workforce but will change the nature of skills required. There was a discussion of levels of automation. They deemed “level 7” (system runs in an automated mode with monitoring and opportunity for operator intervention) as currently attainable, but 8-9 (fully autonomous) as quite difficult legally and operationally. Finally, this group also identified economics as the primary barrier to automation.

## **Workshop 3**

Workshop 3 was held in Virginia, Minnesota in April 2023 with the SME Minnesota Conference. Attendees included mostly iron range operators along with one aggregate operator and one mining venture capital provider. The workshop was an outlier in terms of workforce. A strong union in the region and a strong workforce leaves operators less concerned about lack of workforce in this workshop. In fact, they are concerned about alienating the community with automation. They also felt that economics was the largest barrier to uptake of automation and indicated that capital budgets are fairly small for automation in this sector at this time; however, collision avoidance is a high priority, so some phased adoption is likely. There was extensive discussion about the nature of fully autonomous mining and the feeling that operators must choose an OEM. There was general concern about the level of control and access a single OEM can have over the business.

## **Workshop 4**

Workshop 4 was held in Boston, Massachusetts with the SME Rapid Excavation and Tunnelling Conference in June 2023. Attendees were mostly tunnelling and construction professionals who also indicated that labor shortages after COVID have driven the desire to adopt more automation. They felt that barriers to automation are iterative; and thus, it is difficult to identify one. They also indicated that dust and environmental exposure are key drivers for automation. Finally, they saw some gaps between U.S. uptake and other countries, including:

- Liability
- Zero harm mentality
- Compliance versus risk regulatory perspectives

Again, economics were identified as the primary barrier to automation.

## **Workshop 5**

Workshop 5 was held in Phoenix, AZ in August 2023 with Hydrometallurgy 2023. It consisted of processing plant and mill operators, OEMs, and other technical providers. The fixed plant nature of this part of the mining sector has allowed for early and long-time adoption of automation. However, there is still a need to mimic the highly experienced and skilled metallurgist with sensing and data science.

There was recognition that maintenance is often hazardous and difficult in fully automated systems (e.g., repair of a large crusher). There was recognition that there are many OEMs and technical companies at work in a single plant or mill. Connectivity and data access are substantial issues. One operator who just suffered a major cybersecurity breach indicated that these challenges may worsen. There was a general sense that standardization would be helpful. Again, economics were identified as the primary barrier to automation.

### **Workshop 6**

Workshop 6 was held in Canonsburg, Pennsylvania in October 2023 with the SME Pittsburgh/PCMIA (Pittsburgh Coal Mining Institute of America) joint meeting. This meeting was primarily with coal operators and OEMs. There is consistency in new technology across a single company's mines. They indicated that today's workforce is now more mobile (between shifts and operations) which allows technological innovation and safety innovation to move more rapidly. Conversely, Research and Development (R&D) departments are not as robust in industry and individual companies as they once were, and many simply do not have R&D departments or budgets. The attendees indicated that the coal industry will always share safety ideas within the industry, including new technology – there are no secrets in safety. This mentality is a source of pride in the industry. There was sentiment that there is no appetite in the federal government to incentivize new technology in coal because there is generally not an appreciation for the need to mine coal in the U.S. Workforce shortages are felt to be even more magnified in coal. Permissibility and MSHA approval are seen as a considerable barrier. However, economics were seen as a slightly larger barrier.

### **Workshop 7**

Workshop 7 was held in Nashville, Tennessee in March 2024 with the National Stone Sand and Gravel Association (NSSGA) Conference. It consisted of stone, sand and gravel operators and OEMs. Given that most aggregate operations have traditionally been family owned and operated and are locally significant in terms of employment and economic impact, social and community engagement are important considerations when making changes. Data ownership and security was communicated as key – the consensus being, “the machine owner owns the data.” Again, scarcity of skilled labor is driving automation. Careful integration of technology with the workforce is vital. It was emphasized that cost competitiveness is a major factor motivating technology. Yet once more, economics were seen as the primary barrier.

### **Workshop 8**

Workshop 8 was held in Triadelphia, West Virginia at the MSHA Approval and Certification Center (MSHA A&CC) following a NIOSH Mine Safety and Health Research Advisory Committee (MSHRAC) meeting in April 2024. Attendees included labor representatives, and coal operators, primarily from the MSHRAC members or their representatives, and MSHA personnel. Two barriers were identified for coal (versus metal and nonmetal): A) the small market stifles innovation, and B) the dynamic nature of the coal mine face also makes automation more difficult (as compared to a metal mine using block cave, for instance).

Technology *ratcheting* regulations were discussed and included communication and tracking, proximity detection, and potentially the new silica regulation versus other regulation. The group consensus was that it can be difficult to point to regulation as a barrier. However, prescriptive

regulations have the capacity to “chill” innovation. Labor is supportive of technology that improves safety, including automation, and also acknowledges that the nature of the workforce will change but reduction in workforce is unlikely in the short to medium term. MSHA, like all sectors of the industry, is very concerned about workforce. Additionally, it is difficult to maintain the A&CC and mine rescue equipment in light of rapid technology innovation. This group found it somewhat difficult to coalesce around a percentage assignment to each barrier and assigned 20% each to Regulation, Economics, Social License, Corporate Willingness, and Technology Readiness.

### **Workshop 9**

The last workshop was held in Elko, Nevada with the Elko Mining Expo and consisted of major gold operators and contractors, both underground and surface. A major theme was that the risk tolerance of the operator must increase with greater reliance on automation and autonomy. Further, systems must be properly designed for the specific mine environment. There was a feeling that OEMs are not always competent or interested in the specific factors influencing a particular operation. The availability of skilled labor is important and needs to be considered. Labor cost savings should not be part of the assessment, but availability is huge, particularly in some remote areas. Many companies are near-sighted with respect to labor costs, and do not understand the importance of upgrading labor skill sets with automation despite the increase in costs. This is seen as potentially disastrous for an operation.

There was also a considerable discussion of barriers posed by the limitations on communication frequency access and usage by Federal Communications Commission (FCC) regulations. There was a consensus that competitors in the industry would collaborate on technology to diminish risk or to address regulatory issues (e.g., the use of autonomous haul trucks and DPM). This group saw regulation as the major barrier to uptake of automation.

### **MSHA Meeting**

In addition to the nine workshops detailed previously, the project team held a meeting with MSHA leadership in Arlington in March 2024 with a total of nine people in attendance. This did not follow the standard workshop model but was a broad-ranging discussion of about two and a half hours. The following questions guided the discussion:

- What concerns does MSHA have regarding the development of automation relative to the current regulatory requirements and MSHA’s mission?
- How do MSHA and NIOSH collaborate on emerging issues resulting from increasing automation in the mining industry?
- In general, how long does it take to achieve certification for permissibility of a new technology in coal and gassy status mines? What is the relative cost of the process?
- What are your concerns about the implementation of technology?

MSHA is aware and acknowledged that technology is currently evolving at a rapid pace, and they recognize the need to increase their capability in approving and certifying technology. Furthermore, they understand that MSHA “must keep pace with technology to achieve their mission and remain relevant.” Unfortunately, MSHA is significantly hampered in facilitating the

needed changes due to shortfalls in labor and budget constraints. At present, the vast majority of their budget is allocated for enforcement as a requirement of the law.

They are attempting to be responsive to these changes in technology by reinterpreting existing regulations and promoting technology that supports the MSHA mission and addresses immediate health and safety priorities affecting miners. As a government entity, they are obligated to follow their congressional mandate.

It was noted on several occasions during our discussion that MSHA wants to change the perception to the industry that MSHA represents a barrier to the development and use of new technology in the mining industry. They want to promote and encourage technological improvements to make the mining industry safer and use the A&CC (Approval and Certification Center) to advance this cause. Furthermore, they emphasized the need to make the approval and certification process associated with permissibility more transparent and collaborative.

### **Summary Findings**

The following are some large take-aways from our research:

1. Research and Development (R&D) departments are not as robust in industry and individual companies as they once were, and many simply do not have R&D departments or budgets to advance automation in a timelier manner.
2. Almost everyone involved in this study felt that economics was the largest barrier to uptake of automation and indicated that capital budgets are fairly small for automation in this sector at this time; however, safety and health, along with collision avoidance is a high priority, so some phased adoption is likely. There was extensive discussion about the nature of fully autonomous mining and the feeling that operators must choose an OEM. There was general concern about the level of control and access a single OEM can have over any mine operation.
3. Permissibility and MSHA approval are seen as a considerable barrier.

In the first workshop participants coalesced quickly around a set of barriers affecting the uptake of automation in the U.S. mining industry *in addition to regulation*. There was consensus that these barriers are often greater contributors to a failure to automate. Subsequent workshop participants quickly agreed that these were the right barriers. In most workshops we were able to find some agreement around the percentage each barrier contributes to the uptake of automation. Although these categories are interrelated, even where the barriers presented by economics, social license, corporate willingness, and technology readiness were to be eliminated, the barriers to automation presented by the regulations in Appendix A would still remain.

These contributions are listed below in Table 1.

Table 1. Contributions of each of five identified barriers to the uptake of automation in the U.S. mining industry.

	<b>Workshops held jointly</b>	<b>Regulation</b>	<b>Economics</b>	<b>Social License</b>	<b>Corporate Willingness</b>	<b>Technology Readiness</b>
1	SME Arizona	5%	<b>55%</b>	10%	15%	15%
2	MINEXCHANGE	25%	<b>40%</b>	5%	5%	25%
3	SME Minnesota	25%	<b>50%</b>	5%	10%	10%
4	Rapid Excavation & Tunnelling	15%	<b>35%</b>	5%	20%	25%
5	Hydrometallurgy 2023	3%	<b>35%</b>	15%	15%	32%
6	SME PCMIA	33%	<b>35%</b>	17%	10%	5%
7	NSSGA Conference	10%	<b>40%</b>	28%	16%	6%
8	MSHA ACC	20%	20%	20%	20%	20%
9	Elko Mining Expo	25%	20%	20%	<b>30%</b>	5%

A participant weighted average of the nine workshops gives the following barrier contributions listed below in Table 2.

Table 2. participant weighted average of barriers to uptake of automation in the U.S. mining industry.

<b>Regulation</b>	<b>Economics</b>	<b>Social License</b>	<b>Corporate Willingness</b>	<b>Technology Readiness</b>
16.6%	<b>37.9%</b>	13.1%	14.9%	17.4%

A summary of key themes and findings that emerged from the nine workshops are:

- Regulation is not the primary barrier to automation in the U.S. Economics is generally seen as the primary barrier, and while regulatory barriers were identified, some technology ratcheting regulations were also identified.
- The issue is complex and commodity specific, but workforce challenges across commodities are likely to drive automation *and* drive additional training needs.
- There is recognition that an industry-led group needs to look at standards and technology integration with regulation in conjunction with other interested parties (regulators and labor), and that regulator-operator collaboration is key to moving forward in this area.
- U.S. regulation is highly prescriptive, and while not all sectors recognize it as a high barrier, it is likely a high barrier for underground coal. *Additionally* regional differences in enforcement and interpretation are a concern.
- There is an opportunity for NIOSH to consider the role of health and safety research in the other identified barriers. Potential specific opportunities are:
  - Examining the skills required for workers in autonomous and semi-autonomous mines. We know that upskilling is required but few studies or resources have detailed the skills required and best training approach - this is a key focus area.
  - Understanding the investments and long-term ROI from major automation projects. While financial details may be proprietary, NIOSH could better investigate what are

- the changes in worker safety and health via safety and health metrics and worker perceptions.
- Providing opportunities for industry to lead the creation of standardization around automation. In particular, addressing the challenges associated with multiple automated systems from multiple vendors in a single site. Specifically, how can this data be integrated and leveraged from systems engineering perspective? This was especially apparent in the Hydrometallurgy workshop in Phoenix.
  - Lack of workforce is seen as a driver for automation, but there was acknowledgement that automation will not reduce the workforce considerably in the short to medium term. It will, however, allow for more diversity in hiring and flexibility for workers. There was also acknowledgment that a workforce for automation will require upskilling.

#### **4. Conclusions and Recommendations**

Based on our research, workshops, and meetings, the MSHA regulatory framework has impediments to the deployment of autonomy, however, pilot operations have occurred within the United States. These pilot operations interacted very loosely with MSHA under experimental permissions or interpretations by individual inspectors and/or the varying levels of MSHA management. The risk generated by MSHA to operations adopting autonomy is the informality or instability of the relationship between MSHA, the operation, and the autonomy provider.

The biggest barriers are outdated science and technology, the long gap between the design of a project and its approval, (wherein technology may change), a lack of education and understanding among regulators and a need for improved (and non-adversarial) relationships between companies, regulators, and original equipment manufacturers (OEMs).

It is fully understood that amending the current regulations is too large of a task to solve the issue within a reasonable timeline based on constantly evolving technology, however, a publicly available guideline could be created and adopted by MSHA that provides a formalized interpretation of the regulations regarding autonomous operations. This guideline would need to provide clear criteria that must be met by technology. These criteria would likely be phased depending on the scope of the deployment, for example pilot, partial, or complete conversion of a mine's haulage fleet.

It is also the case that, unlike many other countries, and unlike OSHA, there is no "duty of care" standard in place under the mine act. The implementation of such a standard under the Mine Act would be problematic since the statute prescribes "strict liability" for any violation of a standard regardless of the cause. In other words, the statute commands MSHA to penalize mine operators for violations even if the operator is completely without fault. To impose such liability under such a broad standard would present enormous legal issues of notice as to what is expected of the operator, since there would be no defense that the operator was unaware of the duty of care it was supposed to adhere to.

Both Australia and Canada provide examples of guidelines and criteria for the adoption of autonomy. While the underlying regulations of those countries differ from the United States, many of the techniques could be utilized to provide a semi-quantitative approach to evaluating the proposed technology. (Please refer to Appendix B). Exposure to risk would need to be compared to the risk mitigants that are introduced by technology. While the prescriptive nature of current MSHA regulations does not include risk analysis, most mining companies and technology suppliers are comfortable undertaking risk assessments during operations.

During the development of the guideline, it is recommended that mining companies, equipment companies, technology companies, and labor representatives be included as stakeholders in the guideline development. Without buy-in from those stakeholders, adoption of the guideline will be difficult. Alberta's OH&S's creation of its AHS regulations utilized the stakeholder process. This distributed ownership to the stakeholders and increased the adoption rate of the regulations. The development of ISO17757: Earth-Moving Machinery and Mining – Autonomous and Semi-Autonomous Machine System Safety followed the same approach and had many of the same stakeholders as Alberta's process. The combination of Alberta OH&S regulations and ISO17757 provide a clear path to evaluating the safety of AHS and its approval for use within Alberta.

In addition to the creation of a publicly available guideline for autonomy, our research, workshops, and meetings revealed adjacent topics with the same profile as the adoption of autonomy.

- Electrification of mining equipment has become a significant topic within our industry. We witnessed during some of our MSHA sessions the complexity of the topic and roadblocks presented by MSHA regulations. Just like autonomy, the drafting of the MSHA regulations did not anticipate the battery technology now available in the market.
- The Federal Communication Commission (FCC) regulations were also discussed during our workshops and meetings. The interdependence of technology within mining requires the use of wireless technologies in providing functionality and safety.

Both electrification and communication warrant a similar investigation as Contract Number 75D30122C14149 and would likely result in a recommendation to create a publicly available guideline.

## References

1. Jong, E.C., Luxbacher, K.D., Kirsch, P.A., Mitra, R., Hebblewhite, B.K., Schafrik, S.J., and Conley, B.N. (2015). SME Annual Meeting Preprints 15-057. Society for Mining, Metallurgy, and Exploration, Denver, CO, 1-7.
2. Federal Mine Safety and Health Act of 1977.
3. Baiden, G., & Jämsä-Jounela, S. L. (2018). Computer Control in Mining and Extractive Metallurgy. In Instrument Engineers' Handbook, Volume 3 (pp. 907-917). CRC Press.
4. Bouchard, J., Sbarbaro, D., & Desbiens, A. (2018). Plant automation for energy-efficient mineral processing. In Energy Efficiency in the Minerals Industry (pp. 233-250). Springer, Cham.
5. Costner, K.M., Gunther, F., Brune, J., and Mischo, H. (2018). State of the art of the industrial internet of things and underground autonomous robots in the United States. SME Annual Meeting Preprints 19-147. Society for Mining, Metallurgy, and Exploration, Denver, CO, 1-3.
6. Tamers, S.L., Streit, J., Pana-Cryan, R., Ray, T. Syron, L, Flynn, M.A., Castillo, D., Roth, G., Geraci, C. Guerin, R., Schulte, P., Henn, S., Chang, C-C., Felknor, S., Howard, J. (2020). Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. American Journal of Industrial Medicine. Vol 63 (12): 1065-1084.  
<https://doi.org/10.1002/ajim.23183>
7. Olivier, L. E., & Craig, I. K. (2017). A survey on the degree of automation in the mineral processing industry. In 2017 IEEE AFRICON (pp. 404-409). IEEE.
8. Calder, W., Snyder, D.P., and Burr, J.F. (2018). Intrinsically Safe Systems: Equivalency of International Standards Compared to U.S. Mining Approval Criteria. IEEE Transactions on Industry Applications. Vol 54 (3): 2975-2980. DOI: 10.1109/TIA.2018.2804322
9. Rogers W.P., Kahraman M.M., Drews FA., Powell K., Haight J.M., Wang Y., Baxla K., Sobalkar M. (2019). Automation in the mining industry: review of technology, systems, human factors, and political risk. Mining, Metallurgy & Exploration. Vol. 36: 607–631.  
<https://doi.org/10.1007/s42461-019-0094-2>.
10. Burgess-Limerick, R. (2020). Human-Systems Integration for the Safe Implementation of Automation. Mining, Metallurgy & Exploration. Vol 37: 1799-1806.  
<https://doi.org/10.1007/s42461-020-00248-z> Miller, B. 2020, Ph.D. Thesis, Functional Safety Fault Tree Analysis of a Model Autonomous Haulage System, Colorado School of Mines, Mining Engineering Department, Mines-0052-12037.
11. Mining.com. (2022) Caterpillar autonomously hauls more than 1 billion tonnes of material with Cat Command for hauling in less than a year, March 16.  
<https://www.mining.com/web/caterpillar-autonomously-hauls-more-than-1-billion-tonnes-of-material-with-catcommand-for-hauling-in-less-than-a-year%E2%82%AC>

12. Goodbody, A. (2022). Komatsu emphasizes automation at MINExpo. Mining Magazine, September 15. <https://www.miningmagazine.com/fleet/news/1417764/komatsu-emphasises-automation-at-minexpo>
13. LaTourrette, Tom, Liam Regan, and Kristin Van Abel, (2023) Barriers to the Commercialization and Adoption of New Underground Coal Mining Technologies in the United States. Santa Monica, CA: RAND Corporation. [https://www.rand.org/pubs/research\\_reports/RRA1575-1.html](https://www.rand.org/pubs/research_reports/RRA1575-1.html).
14. Haight, Joel; Burgess-Limerick, Robin (2023). Automation Experience with a Global Perspective - An Assessment of the Automation Impact on Worker Safety and Health : Final report - November, 2023.

## **7. Appendix A**

### **Regulatory Report**

### **30 CFR Parts 1-199**

#### **Executive Summary:**

This report will detail the initial research on which the ongoing study is based. A comprehensive review of all MSHA regulations was conducted and a list compiled.<sup>1 2</sup> The potential effect of each regulation was examined and described. The conclusion was that there are almost 100 separate regulations that could act as potential barriers to automation in the industry. Next, an examination of the historic development of the regulations was conducted and the legal framework in which they are promulgated was examined. It was found that many of those regulations originate from long standing, historic mine safety practices and, as such, have become relatively embedded in industry safety culture and thus, are resistant to change. In addition, the statutory framework in which the regulations reside presents a barrier to regulatory evolution to address developing technology more effectively. Nonetheless, there appears to be a number of ways to mitigate the impacts of these potential barriers.

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<sup>1</sup> Attachment 1 to Appendix A

<sup>2</sup> International regulations are discussed separately in Appendix B

## Appendix A

### **The Regulations:**

MSHA regulations are broadly segregated by industry sector. 30 C.F.R. Parts 56 and 57 regulate surface and underground metal and nonmetal mines respectively while 30 C.F.R. Parts 75 and 77 regulate surface and underground coal mines respectively<sup>3</sup>. Those regulations were reviewed to determine if any of them had any possible effect on potential automation in the mining industry.

In addition to regulations discussed above, there are regulations governing the certification of a wide range of equipment for use beyond (“inby”) the last open crosscut in underground coal mines, considered by definition to have the possibility of containing an air-methane mixture, and in certain “gassy” metal and nonmetal mines. Those regulations are set out in 30 C.F.R. Parts 6 (Testing and Evaluation by Independent Laboratories), 7 (Testing by Applicants and Third Parties), 15 (Explosives), 18 (Electrical Motor Driven Mine Equipment and Accessories), 22 (Portable Methane Detectors), 23 (Telephones and Signaling Devices), 27 (Methane Monitoring Systems) and 36 (Diesel Powered Mobile Equipment). Collectively, these regulations are commonly referred to as the “Permissibility Regulations” and are not specifically addressed in this review. They are, however, discussed as a whole since a number of characteristics stemming from these regulations could have a substantive impact on the adoption of innovative or automated equipment<sup>4</sup>.

Finally, there are additional categories of regulations governing a wide range of subjects which cover matters that are not reasonably related to extraction operations. Those regulations encompass a diverse range of subjects such as training (Parts 46 and 48), appointment of a representative of miners (Part 40), mine rescue (Part 49) and accident reporting, which are not addressed in this paper.

Our examination of the regulations addressed four general types of potential barriers to automation. First, does the regulation require a “person” to conduct a certain activity that might otherwise be conducted through some other method? Second, does the regulation require that equipment be “attended” or operated by a person?<sup>5</sup> Third, does the regulation require that features (such as seat belts, for example) be installed in equipment that would not be necessary for safety if no human were operating it? Fourth, there is a “miscellaneous” category for regulations which could potentially create a barrier to automation, but which do not easily fit into another category.<sup>6 7</sup>

In addition to the specific regulations detailed in Attachment 1, there are broad categories of regulations which would likely require some adjustment or revision should automation become

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<sup>3</sup> There are several additional regulatory sections which cover all industry sectors including, for example, the newly promulgated Part 60, covering crystalline silica exposure at all mines.

<sup>4</sup> Given the potential impact of these regulations and the permissibility approval process, a workshop was held with representatives of MSHA, Labor and industry at the MSHA Approval and Certification Center in Triadelphia, WV

<sup>5</sup> See 56/57.2 defining the term “attended” as requiring the presence of a person.

<sup>6</sup> The “impediment category” associated with each regulation is noted in column D on Appendix 1

<sup>7</sup> Appendix 2

## Appendix A

widespread in the industry. Most prominent of these are the health regulations.<sup>8</sup> In a broad sense, all of the health regulations were promulgated to protect miners working full shifts in a wide variety of environmental hazards; ranging from heat and radiation to any number of airborne contaminants. Should aspects of the industry become fully or primarily automated, most miners would be involved in maintenance, rather than operations and would be exposed for shorter periods, but potentially to higher levels of contaminants and the regulations would then require a potentially different focus.

### **Discussion of Potential Regulatory Impediments to Automation**

Our review of the regulations dealing with extraction was intended to be inclusive, rather than exclusive, in order to provide as much information on potential issues as possible. As shown in Attachment 1, there are approximately 85 separate regulations dealing directly with extraction activities which were identified as presenting some potential barrier to automation or innovation. Sixty of the regulations explicitly require a “person” to conduct a required activity or function or at least be present for it. Six regulations explicitly require that equipment be “attended” when in use. Eight regulations explicitly require installation of features, such as seat belts or rollover protection, in equipment that is only necessary if a person is operating the equipment, while eleven regulations present potential barriers to automation or innovation that are not easily characterized by the other three categories.

As stated above, we have not done a regulation-by-regulation review of the permissibility regulations.<sup>9</sup> Instead, our examination of the regulations indicates a number of general impediments present throughout the regulations. These are presented below in order of which Section of the regulations they pertain to and not necessarily in order of importance.

First, the approval apparatus is relatively cumbersome. There is only one relatively small MSHA unit devoted to approval and testing of equipment. It was hoped that promulgation of rules allowing for third party testing a certification in 2003 (30 C.F.R. Part 6) would help to provide additional resources and generally speed up the process. However, those regulations allowed for the use of third- party testing and approval only if their criteria provided at least the same level of protection afforded by the MSHA approval requirements.<sup>10</sup> The same MSHA office that does review and certification of equipment also conducts that review. As of 2023, MSHA has approved only the International Electro-technical Commission (“IEC”) to conduct such evaluations but has required that certain of its criteria be modified in order to meet their standards. It is unknown at this writing whether those modifications have been made or whether any equipment has been certified under the IEC standards.

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<sup>8</sup> See Parts 56/57 Subpart D, Part 62, Part 70 and Part 71.

<sup>9</sup> 30 C.F.R. Parts 6,7,15,18,22,23, 27 and 36.

<sup>10</sup> 30 C.F.R. § 6.2

## Appendix A

30 C.F.R. Part 7, which contains detailed testing requirements for a number of different systems<sup>11</sup> was first promulgated in 1988. Various parts of it have been amended over the years with the latest amendments coming in 2008 for refuge alternatives. In other words, these regulations range from 16 to 36 years old. It is safe to conclude that during the periods between the promulgation of these regulations and today, much technology has changed. As discussed in more detail below, the relatively static nature of the regulations cannot but have a retardant effect on the adoption of new, more innovative and automated technologies.

The same is true of 30 C.F.R. Part 15 which covers approval of explosives and sheathed explosive units. Those regulations were also promulgated in 1988. There have been no substantive amendments to these regulations since then.

30 C.F.R. Part 18, which largely covers permissibility requirements for all electrically driven equipment and accessories, was promulgated over 50 years ago in 1968. Although some sections of Part 18 have been amended since then, the latest of the amendments to any of its substantive regulatory requirements was over 30 years ago in 1992. The latest amendments came at a time when CD-ROMs were the basis of computers and only 20% or so of U.S. households actually owned a computer. Digital cell phones first came on the market in 1991. By any measure, the Part 18 regulations were developed prior to the invention or adoption of most of the digital technology in use today. Given their age, these regulations present a significant barrier to the adoption of any newer technologies in areas where permissible equipment is required.

As a result of the obsolescence of these standards, permissible versions of many currently used pieces of equipment, such as survey instruments, Powered Air Purifying Respirators (PAPRs) and hand-held radios are not available. As a result, their use is only made possible through the Petition for Modification process (See 30 C.F.R. Part 46) which must be considered on an individual mine-by-mine basis. This results in significant inconsistencies between enforcement districts and generally hampers the adoption of these more advanced technologies.

30 C.F.R. Part 22, which governs approval of portable methane detectors essentially states that a portable methane monitor will be approved if it meets the requirements of Bureau of Mines Schedule 8c, which went into effect October 31, 1935, and was amended by a supplement issued in April 1955. While detector technology may or may not have changed significantly in the last 69 years, it is likely that the way in which the detected levels are communicated to and interact with mine equipment and personnel have changed significantly during that period.

30 C.F.R. Part 23, which covers approval of telephones and signaling devices is much the same as the other section discussed in this suite of regulations. It largely finds its source in 1955 and, although it has been amended over time, the last substantive amendment to that section appears

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<sup>11</sup> Brattice cloth, ventilation tubing, battery assemblies, multiple shot blasting units, and diesel engines intended for use in underground coal mines, including areas where permissible equipment is required, electric motor assemblies, electric cables, signaling cables, cable splice units and refuge alternatives.

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to have been in 1982, which, as discussed above, was almost 10 years prior to the introduction of the first digital cell phone.

The substantive criteria for approval of methane monitoring systems in 30 C.F.R. Part 27, appear to have originated in 1966 and do not appear to have been amended since then. Similarly, the substantive requirements for design and construction of permissible diesel-powered diesel transportation equipment in 30 C.F.R. Part 36 originated in 1961 and appear to have been last amended in 1996.

In addition to the age of the regulations, there are two additional factors which impede the approval of new or innovative equipment. As discussed briefly above, MSHA does not devote a great deal of its resources to approval and certification of new equipment. Because of that, approvals of new equipment are now well over a year on average. Since the approval process cannot take place until detailed design and material specifications have been developed, manufacturers are reticent to make an investment in design and specification absent some assurance that the equipment will eventually go to market.

Second, the amount of information required by MSHA for review makes it essentially impossible for the consumer of the equipment to seek approval. This means that the manufacturer must be the party interacting with MSHA to gain approval. The market for permissible mining equipment is quite small and thus it is generally not economical for a manufacturer of equipment primarily intended for a different market to spend the time, financial resources, and effort gaining approval for a product that is ultimately to be sold only to a handful of potential customers. This is especially true for equipment which has already been tested and deemed intrinsically safe by an independent third-party laboratory or other government authority. This issue inhibits the transfer of technology between industries at the expense of the mining sector.

### **History and Evolution of the Regulations:**

The history of comprehensive mine safety and health regulations begins with the Mine Safety Act of 1891.<sup>12</sup> While the substantive provisions of the statute itself have largely been replaced by more modern requirements, the statute is important because, rather than leaving detailed requirements to an administrative agency, the detailed mine safety requirements were included in the statute itself. Although the Bureau of Mines was created in 1910<sup>13</sup> the Bureau did not engage directly in regulatory activity until much later as the detailed requirements remained in the various statutes that succeeded the 1891 legislation.<sup>14</sup>

There were no formally promulgated regulations governing miner health and safety until 1946. At that time, those regulations were not promulgated by a government agency. Rather, those

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<sup>12</sup> “An Act for the Protection of Miners in the Territories” 55<sup>th</sup> Congress, 2<sup>nd</sup> Sess. March 3, 1891.

<sup>13</sup> “Organic Act of May 16, 1910” Public Law 179 (30 U.S.C. §§ 1,3, 5-7)

<sup>14</sup> The significant exception to that was the development of guidelines for governing safety in electrical equipment for use in potentially explosive atmosphere’s underground. The so-called “permissibility rules.”

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regulations were adopted as the result of an agreement between the Secretary of the Interior and the President of the United Mine Workers of America to resolve a labor dispute between the union and the federal government when the government took over operation of the coal mines during World War II.<sup>15</sup> Although the terms of the agreement were specifically limited to the period during which the mines were under government control, the safety rules remained in effect well beyond that time.<sup>16, 17</sup> As with the 1891 Act, much of the code has been replaced over time, but several fundamental aspects of the code, such as the requirement for preshift examinations has remained essentially unchanged.<sup>18, 19</sup>

The statute under which MSHA now operates is an amendment of the 1969 Coal Mine Health and Safety Act. Title III of that statute contained interim mandatory safety standards for coal mines. The statute was amended in 1977 to, among other things, create MSHA, include jurisdiction over non-coal mines and move the agency from the Department of the Interior to the Department of Labor. However, the amendment left the old “interim” mandatory standards from 1969 in place.

In addition to the interim standards, another section of the 1969 statute was carried over into the 1977 statute. Section 101(a)(9) of the statute states: “No mandatory health or safety standard promulgated under this title shall reduce the protection afforded miners under an existing mandatory health or safety standard.”<sup>20</sup>

This background is important for two reasons. First, the fact that mine safety regulations have historically been embedded in statute and that some current regulations remain there impedes MSHA’s ability to amend them as conditions and technology change, as changing the regulatory requirement would require amending the statute rather than simply promulgating new rules. Second, the historic nature of many of the regulations make them difficult to question.

This is especially important given the language of Section 101(a)(9) of the statute. It is always difficult to question historic practice, especially in the area of safety and health. That difficulty is only heightened when placed against the test that any new regulation may not “reduce the

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<sup>15</sup> The so-called Krug-Lewis agreement. The agreement called for the development of a “reasonable code” of safety practices within 30 days of the agreement. The agreement also established a standard miners’ vacation, the miners’ health and welfare fund and the miners’ retirement fund. While the government is no longer a party, most of the labor-related sections of the agreement remained in union contracts in the coal fields until the mid-1990’s when the health and welfare and retirement funds were incorporated into law.

<sup>16</sup> Federal Safety Code for Bituminous-Coal and Lignite Mines of the United States U.S. Government Printing Office 1946.

<sup>17</sup> The resulting code of safety rules was developed by a committee consisting of two representatives of the United Mine Workers, two representatives of the bituminous coal industry and one representative of the Coal Mine Administrator’s office.

<sup>18</sup> Compare Code Sections 10(b)-(n) with 30 U.S.C. Sections 863(d)-(g) and 30 C.F.R. Sections 75.360-75.364

<sup>19</sup> In fact, one patently obsolete relic of the 1891 Act has even made it into the current regulations. Among other things, the 1891 Act required a “metal speaking tube” to be installed between the surface and the shaft landing. The “speaking tube” requirement was carried over into the current statute and is still part of current underground coal regulations. See 30 C.F.R. § 75.1402.

<sup>20</sup> 30 U.S.C. 811(a)(9)

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protection” afforded by the prior standard<sup>21</sup>. All automated systems have some rate of failure. Of course, humans fail as well. The issue, then, that any new regulation allowing automation where humans are currently required is whether the failure rate of the automated system exceeds that of the humans. Absent closely documented, objectively observed experience with both approaches, that question is virtually impossible to answer, rendering any new or innovative regulatory approach particularly vulnerable to legal challenge.

### **Alternatives for addressing the issues presented:**

In spite of the difficulties outlined above, several paths could be taken to allow for more facile alignment of the regulatory environment with changing technology.

First, of course, the statute could be amended to remove the “interim” standards in Title III and adjust the existing language to allow for more regulatory flexibility.<sup>22</sup> That would, of course, literally take an act of the U.S. Congress. Although not likely, the obvious advantages of evolving technology could create a push to make it happen.

Second, MSHA could undertake to promulgate new regulations that would replace those most problematic to the adoption of automated systems. There are two potential approaches to this issue. One approach would be for MSHA to propose modifying the definition of “attended” and add a definition of “person” so as to embody the safety purpose of the regulations currently using those terms but without the physical presence of a person in certain, defined circumstances. At the same time, and in the same rulemaking, the MSHA could also provide an exception for automated equipment to those regulations requiring personal protective equipment such as seat belts. As discussed above, they could also develop a set of written criteria or guidelines that would formalize interpretations of the existing standards to account for automation. Of course, MSHA could engage in a regulation-by-regulation review for each of its regulations that might impede automation or innovation. The disadvantage to all of these approaches is that the promulgation process requires a large amount of agency resources and faced with a finite budget and rigid mandatory inspection requirements could put an unacceptable strain on agency operations. The other disadvantage to this approach is that virtually every major rulemaking that MSHA has engaged in over the last 20 years has faced legal challenges.<sup>23</sup> These challenges not only further strain agency resources but also require additional personnel for legal support.

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<sup>21</sup> This is compounded by the fact that, to the best of our knowledge, there has never been any objective data collected to measure the efficacy of any particular standard.

<sup>22</sup> This is not saying the current statute should be completely gutted or that protections should be removed. Statutes promulgated somewhat later anticipated that relevant technologies would evolve by including language that would require “best available control technology.” See, e.g., 42 U.S.C. § 7479(3) This language not only requires maximum protection, but also essentially requires the regulated entity to take advantage of it when it becomes available.

<sup>23</sup> It is possible that the threat of litigation could be reduced if MSHA were to switch from traditional “notice and comment” to negotiated rulemaking under 5 U.S.C. § 561 et seq. where all parties negotiate agreed upon language for proposed rules before they are published for public comment.

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Finally, section 101(c) of the statute allows interested parties (that is mine operators or miners' representatives) to petition MSHA to modify an existing regulation on one of two grounds:

- 1) An alternative method of achieving the result of the standard exists that will, at all times, guarantee no less than the same measure of protection afforded by the [existing] standard, or
- 2) Application of the [existing] standard will result in a diminution of safety to the miners<sup>24</sup>

Use of this provision would allow miners and mine operators to demonstrate to MSHA that certain automated systems would be as or more safe than existing systems and/or that use of existing systems when others are available would represent a diminution of safety to the miners.

While it may be the case that equipment manufacturers might be better positioned to present the kind of information necessary to meet these standards in regard to automation, the current regulations require that an application for modification may only be made by the mine operator of the affected mine or a representative of miners at such mine<sup>25</sup>. In addition, each application can only be made regarding a single, specified mine. Thus, the regulations would have to be amended in order to allow anyone other than a mine operator or representative of miners to apply and for the resulting modification to apply to more than one single mine.

In the interim, the current MSHA recognizes that its regulations could have an adverse impact on innovation or automation and is doing its best to interpret the regulations in such a way as to minimize any impact that they might have on the adoption of more automated mining systems. For instance, in one case, MSHA interpreted the regulation requiring that equipment be attended while in use to consider that it is "attended" by the remote operator or control room personnel. While that approach has served to allow a number of automation projects to go forward, it subjects the agency to a palpable threat of litigation by miners' groups should they choose to take that action. The problem is far more complicated when applied to equipment that must be classified as permissible. The current MSHA process and regulatory structure continues to present significant impediments to automation.

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<sup>24</sup> 30 U.S.C. § 811(c), 30 C.F.R. §§ 44.4(a)(1), (2)

<sup>25</sup> 30 C.F.R. § 44.10

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Impediment categories as used below:

Category 1: The regulation requires that a “person” conduct or be present for a particular regulatory function.

Category 2: The regulation requires that equipment be “attended.”

Category 3: The regulation requires that ancillary features such as seat belts or rollover protection be installed in equipment with no exception for fully automated equipment.

Category 4: Regulations which could be considered to impede automation but are not easily placed in one of the categories above.

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	Metal/Nonmetal Mines		
Surface			
56/57.2	<i>Attended</i> means presence of an individual or continuous monitoring to prevent unauthorized entry or access	The term "attended" is used in a number of other regulations and could present an issue depending on the nature of the process or equipment at issue.	For reference only
56/57.2	<i>Mobile equipment</i> means wheeled, skid-mounted, track-mounted, or rail-mounted equipment capable of moving or being moved.		For reference only
56/57.2	<i>Permissible</i> means a machine, material, apparatus, or device that has been investigated, tested, and approved by the Bureau of Mines or the Mine Safety and Health Administration and is maintained in permissible condition		For reference only
56/57.2	<i>Roll protection</i> means a framework, canopy or similar protection for the operator when equipment overturns.		For reference only
56.3401	Persons experienced in examining and testing for loose ground shall be designated by the mine operator. Appropriate supervisors or other designated persons shall examine		1

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	and, where applicable, test ground conditions in areas where work is to be performed prior to work commencing, after blasting, and, as ground conditions warrant during the work shift. Highwalls and banks adjoining travel ways shall be examined weekly or more often if changing ground conditions warrant.		
56.9101	Operators of self-propelled equipment shall maintain control of the equipment while it is in motion. Operator speeds shall be consistent with conditions of roadways, tracks, grades, clearance, visibility, and traffic, and the type of equipment used.	This becomes potentially problematic for fully automated equipment where there is no "operator."	2
56.12016	Power switches shall be locked out or other measures taken which shall prevent the equipment from being energized without knowledge of the individual working on it. Warning signs shall be posted and signed by the individuals who are to do that work. Such locks or preventive devices shall be removed only by the persons who installed them or by authorized personnel.	Note the reference to the word "individual." Also, there are certain PLC controlled systems where there may be no way to place a "lock" or "preventive device" on the equipment.	1
56.12017	Same as above	See above	1
56.14100(a)	Self-propelled mobile equipment shall be inspected by the equipment operator before being placed in operation on that shift		1
56.14100(b)	Defects on any equipment machinery or tool shall be corrected in a timely manner to prevent the creation of a hazard to persons	It is unclear how this standard would be applied to environments operated solely by automated equipment	1
56.14131(a)	Seat belts shall be provided and worn in haulage trucks	Note that the standard requiring ROPS (56.14130) specifically states that it does not apply to equipment that is "only operated by	3

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		remote control." While 56.14131 contains no such carveout.	
56.14131(b)	Seat belts shall be maintained in functional condition, and replaced when necessary to assure proper performance		3
56.14206(b)	When mobile equipment is unattended or not in use, dippers, buckets and scraper blades shall be lowered to the ground. Other movable parts, such as booms, shall be mechanically secured or positioned to prevent movement which would create a hazard to persons	The issue here is the requirement that movable parts be "mechanically secured." The language can be construed to prohibit the use of electronics to secure those parts.	4
56.14207	Mobile equipment shall not be left unattended unless the controls are placed in the park position and the parking brake, if provided, is set. When parked on a grade, the wheels or tracks of mobile equipment shall be either chocked or turned into a bank	MSHA has concluded, at least informally, that remotely controlled equipment is "attended" by the operator of the remote-control unit. To the best of our knowledge, MSHA has not taken a position on fully automated equipment where there is no "operator."	2
Underground			
57.3401	See 56.3401 except it adds "Underground haulageways and travelways and surface area highwalls and banks adjoining travelways shall be examined weekly or more often if changing ground conditions warrant."		1
57.4260	(a) Whenever self-propelled equipment is used underground, a fire extinguisher shall be on the equipment. This standard does not apply to compressed air powered equipment without inherent fire hazards. (b) A fire suppression system may be used as an alternative to fire extinguishers if the system can be manually actuated.		3

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57.9360	Shelter Holes.	It is unclear whether this standard applies independent of whether the area is operated solely by automated equipment	4
57.11050	Escapeways. It is unclear whether this standard applies independent of whether an area of a mine is operated solely by automated equipment		4
57.12016	See Section 56.12016		1
57.12017	See Section 56.12016		1
57.14100(a)	See 56.14100(a)		1
57.14100(b)	See 56.14100(b)		1
57.14130	Rollover protective structures (ROPS) and seat belts for surface equipment.	Unlike the analogous regulations under part 56, this regulation contains an exemption from both the ROPS and seat belt requirements for remotely operated equipment (57.14130(f)(3))	For reference only
57.14131	Seat belts for surface haulage equipment.	There is no exception for remotely operated equipment	1
57.14207	When parked on a grade unattended mobile equipment must either be chocked or turned in to the rib if unattended	The wheel chocking requirement would be difficult, if not impossible to comply with where equipment is fully automated or operated remotely	1
57.16002(c)	Where a person enters a bin, a lifeline shall be used, and a second person must be situated in a way so as to minimize any slack in the line	This appears to apply regardless of whether the harness system uses self-retracting pulleys	1
57.18010	An individual capable of providing first aid must be "available" on all shifts		1
57.19070	Each electric hoist shall be equipped with a "manually-operable" switch that will initiate braking...		1
57.19056	A competent hoist operator must be "readily available" when automatic hoists are used, and any person is underground.		1

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57.22226	Tests for methane shall be conducted by a competent person at least once per shift prior to starting work and upon initial release of gas into the mine atmosphere from boreholes		1
57.22280	Preshift examinations must be conducted by a competent person		1
	Coal Mines		
Underground			
75.2	Permissible: Equipment designed, constructed and installed in accordance with the specifications of the Secretary to assure that such equipment will not cause a mine explosion or a mine fire		For reference only
75.150	Subpart D of Part 75 and 75.1106 require that tests for methane be made by a qualified person		1
75.152	Tests for air flow must be made by a qualified person		1
75.211(a)	A visual examination of the roof, face and ribs shall be made immediately before any work is started in an area and thereafter as conditions warrant		1
75.211(b)	Where mining height permits, and visual examination does not show a hazard sound and vibration, or other equivalent tests shall be made		1
75.301	AMS Operator: The person(s) designated by the operator, who is located on the surface of the mine and monitors the malfunction, alert, and alarm signals of the AMS and notifies appropriate personnel of these signals		1
75.301	Appropriate personnel: The person or persons designated by the operator to perform specific tasks in response to AMS signals.		1

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75.310(a)(4)	Main fans must be equipped with a pressure recording device or system. ...If a device or system other than a circular pressure recorder of main mine fan pressure, the monitoring device shall provide a continuous graph or continuous chart of pressure as a function of time.	This regulation does not appear to allow fully electronic recordkeeping	1
75.312	Each main fan and associated recording devices must be examined by a trained person, the timing of such examinations ranges from every day to every 7 days, to every 31 days depending on the focus of the examination		1
75.320	Tests for methane and oxygen deficiency shall be made by a qualified person with MSHA approved detectors		1
75.324	Intentional changes in the ventilation system. (a) A person designated by the operator shall supervise any intentional change in ventilation that - (1) Alters the main air current or any split of the main air current in a manner that could materially affect the safety or health of persons in the mine; or...Affects section ventilation by 9,000 cubic feet per minute of air or more in bituminous...	Ventilation on demand cannot be utilized under these circumstances	1,4
75.336	A certified person shall monitor atmospheres of sealed areas at least every 24 hours		1
75.342	Methane Monitors. Methane monitors shall be maintained in permissible and proper operating condition and shall be calibrated with a known air-methane mixture at least once every 31 days. To assure that methane monitors are properly maintained and calibrated,	Does not allow for self-calibrating devices	1

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	the operator shall: Use persons properly trained in the maintenance, calibration, and permissibility of methane monitors to calibrate and maintain the devices.... Maintain a record...		
75.351	The operator must designate an AMS operator who must be on duty at the mine at a location where audible and visual signals from the AMS must be seen or heard	note the language "at the mine" which would seem to preclude any centralized or off-site monitoring	1
75.352	The AMS operator must notify appropriate personnel of any malfunction, alert or alarm from the AMS		1
75.360	A certified person must conduct a preshift examination within 3 hours of the beginning of any shift during which persons are scheduled to travel underground.		1
75.361	see 75.360 but for areas not examined in the preshift examination		1
75.362	A certified person must conduct onshift examinations when persons are underground and in any area where mechanized mining equipment is being installed or removed during the shift		1
75.364	A certified person must make examinations of all worked out areas every 7 days		1
75.500-506-1	Requirements for permissible electric face equipment		4
75.511	Repair of electrical equipment disconnecting devices must be locked out and suitably tagged by the person performing the work, where that is not possible, such devices shall be opened and tagged by the person doing the work		1

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75.512-1-512-2	Electrical equipment must be examined and tested by a qualified person at least weekly		1
75.523-2	Deenergization of self-propelled mobile equipment shall be provided by 1) mechanical actuation of an existing pushbutton emergency stop switch or 2) mechanical actuation of an existing lever emergency stop switch or 3) the addition of a separate electromechanical switch assembly. There are specific requirements for the size of the switch and the maximum pressure and movement needed to actuate it.	While no "person" is specifically required by this regulation, the specification of "mechanical actuation" and pressure requirements for the switches, etc. certainly appears to contemplate that a person must be actuating the specified controls.	4
75.523-3(b)(5)	Automatically actuated emergency park brakes may be released only by manual control that does not operate any other equipment function	The specification of "manual release only" implies that person must be present to operate the equipment	4
75.82	Before beginning troubleshooting or repair work on electrical equipment, a qualified person must 1) deenergize the circuit with a circuit interrupting device, 2) open the circuit disconnecting service, 3) lock out the disconnecting device with a padlock and 4) tag the disconnecting device to identify each person working on the circuit or equipment		1
75.821	At least once every 7 days, a qualified person must test and examine each high voltage longwall unit and associated circuits. Ground wire monitor and associated circuits must be examined and tested every 30 days. The person doing the tests must certify by signature and date that they have been completed.		1
75.829(b)	Tramming continuous mining machines... testing prior to tramming: A qualified person must activate the ground-fault and ground-wire test circuits of the		1

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	power source and where applicable a person must activate the test circuit for the grounded-phase detection circuit.		
75.832	Describes six separate tests and examinations that must be conducted by a qualified person and recordkeeping requirements for those tests.		1
75.1402	Two methods of communication must be available between shaft stations and hoist rooms one of which must be a telephone or a speaking tube	Communications is one of the most rapidly evolving areas of technology. Telephones, not to mention "speaking tubes", are both becoming outdated. Statutory Standard. Cannot be changed without amending the statute	4
75.1433	Visual examinations at least every 14 days are required for all hoist ropes		1
75.1710-1	Cab and canopy requirements for self-propelled mobile equipment.	No exceptions for automated equipment	
75.1715	Identification checks carried by miners underground must be made of rust resistant metal not less than 16 gauge.	Statutory Provision. Cannot be changed without amending the statute	4
75.1719	Illumination must be provided in every area of a mine in which self-propelled mobile equipment is operating.		3
75.1732	Continuous mining machines must be equipped with proximity detection systems.	No exception for fully automated equipment	3
75.1916(e)	Diesel-powered equipment shall not be operated unattended. Per 75.1908, "attended" means 1) any machine or device operated by a miner; or 2) any machine or device that is mounted in the direct line of sight of a job site located within 500 feet of such machine or device which job site is occupied by a miner	This provision could be used to argue that the term "attended" was never intended to include remote operators who are not in line of sight. From a legal perspective, this standard could present a real issue to informal interpretations of the term "attended" as it shows that MSHA has already considered the issue and defined the limits of	2

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		exception for attendance by a remote operator.	
Surface			
77.101	The provisions of Subparts C, P, R, and T require that tests for methane and oxygen deficiency be made by a qualified person		1
77.201-1	Tests for methane in structures, enclosures, or other facilities in which coal is handled or stored shall be conducted by a qualified person with a device approved by the Secretary at least once each operating shift or before repairs involving welding or open flame		1
77.309, 309-1	Frequent visual checks shall be made by the operator of the thermal dryer system control station, bypass dampers, air-tempering louvers, discharge mechanism and other dryer system equipment. The system controls must be installed at a location which gives the operator the widest field of visibility of the system and equipment		1
77.310	Control panels for thermal dryers must have a schematic diagram containing legends which show the location of each thermocouple, pressure tap, or other control or gaging instrument which must be posted on or near the control panel. Each instrument on the control panel must be identified by a nameplate or equivalent marker and a plan to control the operation of each system must be posted, showing startup, shutdown and emergency shutdown procedures.	While no "person" is specifically required by this regulation, the nameplate and legend requirements appear necessary only for persons engaged in operations or maintenance.	4
77.314	All dryer control instruments must be inspected at least every 3 months and a record signed by a trained		1

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	employee or servicing agent must be kept at the plant.		
77.403-1	All rubber tired or crawler mounted self-propelled scrapers, front end loaders, dozers, graders, loaders and tractors must be provided with roll over protective structures (ROPS)	There is no exception for fully automated equipment.	3
77.404(b)	Machinery and equipment shall only be operated by persons trained in the use of and authorized to operate such machinery or equipment		1
77.501	See 75.511		1
77.502	Electrical equipment must be frequently examined and tested by a qualified person		1
77.506-1	Short circuit and overcurrent protective devices must meet the requirements of the National Electric Code of 1968	Digital equipment was not present in 1968.	4
77.900-1	Circuit breakers protecting low and medium voltage circuits must be inspected monthly by a qualified person		1
77.1007	Drilling equipment to be used during a shift must be inspected by a competent person		1
77.1009	Drills must be voltage attended at all times while in operation		2
77.1302(j)	When vehicles containing explosives are parked, they shall be blocked securely against rolling	There is no alternative, such as turning the wheels into a bank or berm. It is difficult to imagine how an automated or remotely operated piece of equipment could be physically blocked against rolling without a person being present to do so.	1
77.1433	Hoist ropes must be visually examined every 14 days and more frequently if there are signs of any condition that might affect the rope strength. Such ropes are also	While not specifically required in the examination section of the regulation, it is apparent from the language of Section 75.1433(d) and	1

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<b>Attachment 1</b>	<b>As of May 22, 2023</b>		
<b>Regulation Number</b>	<b>Regulation Text</b>	<b>Comment</b>	<b>Impediment Category</b>
	required to undergo nondestructive testing and diameter measurement if there is evidence of wear or corrosion.	(e) that all such examinations must be made by a person	
77.1504	The operator of auger equipment shall not leave the controls of such equipment while the auger is in operation		1
77.1606(a) and(b)	Mobile equipment must be inspected before being placed into operation. Aerial tramways must be inspected each shift		1
77.1607(m)	Electrically powered mobile equipment shall not be left unattended unless the master switch is off, all operating controls are in neutral, and the brakes are set		2
77.1607(n)	Mobile equipment may not be left unattended unless the brakes are set and wheels turned into a bank or berm or blocked when on a grade		2
77.1710	Seat belts must be installed in vehicles where there is a danger of overturning and roll protection is provided	There is no exception for fully automated equipment or equipment without cabs	3
77.1713	Surface mines must be inspected at least once during each working shift, hazards noted and recorded in a book in ink or indelible pencil and countersigned by a designated official	There is no provision for electronic recordkeeping.	1
77.1901	Slopes and shafts must be examined at least 90 minutes prior to each shift. Results of the examination must be recorded in a book approved by the Secretary		1
77.1908-1	Hoists shall be operated by a qualified hoistman when miners are in the slope or shaft		1

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**Attachment 2 Sorted in order by Impediment Category**

<b>Attachment 2</b>	<b>As of May 22, 2023</b>		
<b>Regulation Number</b>	<b>Regulation Text</b>	<b>Comment</b>	<b>Impediment Category</b>
56.3401	Persons experienced in examining and testing for loose ground shall be designated by the mine operator. Appropriate supervisors or other designated persons shall examine and, where applicable, test ground conditions in areas where work is to be performed prior to work commencing, after blasting, and, as ground conditions warrant during the work shift. Highwalls and banks adjoining travel ways shall be examined weekly or more often if changing ground conditions warrant.		1
56.12016	Power switches shall be locked out or other measures taken which shall prevent the equipment from being energized without knowledge of the individual working on it. Warning signs shall be posted and signed by the individuals who are to do that work. Such locks or preventive devices shall be removed only by the persons who installed them or by authorized personnel.	Note the reference to the word "individual." Also, there are certain PLC controlled systems where there may be no way to place a "lock" or "preventive device" on the equipment.	1
56.12017	Same as above	See above	1
56.14100(a)	Self-propelled mobile equipment shall be inspected by the equipment operator before being placed in operation on that shift		1
56.14100(b)	Defects on any equipment machinery or tool shall be corrected in a timely manner to prevent the creation of a hazard to persons	It is unclear how this standard would be applied to environments operated solely by automated equipment	1
57.3401	See 56.3401 except it adds "Underground haulageways and travelways and surface area highwalls and banks adjoining travelways shall be examined weekly or more often if changing ground conditions warrant."		1
57.12016	See Section 56.12016		1
57.12017	See Section 56.12016		1

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<b>Attachment 2</b>	<b>As of May 22, 2023</b>		
<b>Regulation Number</b>	<b>Regulation Text</b>	<b>Comment</b>	<b>Impediment Category</b>
57.14100(a)	See 56.14100(a)		1
57.14100(b)	See 56.14100(b)		1
57.14131	Seat belts for surface haulage equipment.	There is no exception for remotely operated equipment	1
57.14207	When parked on a grade unattended mobile equipment must either be chocked or turned in to the rib if unattended	The wheel chocking requirement would be difficult, if not impossible to comply with where equipment is fully automated or operated remotely	1
57.16002(c)	Where a person enters a bin, a lifeline shall be used, and a second person must be situated in a way so as to minimize any slack in the line	This appears to apply regardless of whether the harness system uses self-retracting pulleys	1
57.18010	An individual capable of providing first aid must be "available" on all shifts		1
57.19070	Each electric hoist shall be equipped with a "manually-operable" switch that will initiate braking...		1
57.19056	A competent hoist operator must be "readily available" when automatic hoists are used, and any person is underground.		1
57.22226	Tests for methane shall be conducted by a competent person at least once per shift prior to starting work and upon initial release of gas into the mine atmosphere from boreholes		1
57.22280	Preshift examinations must be conducted by a competent person		1
75.150	Subpart D of Part 75 and 75.1106 require that tests for methane be made by a qualified person		1
75.152	Tests for air flow must be made by a qualified person		1
75.211(a)	A visual examination of the roof, face and ribs shall be made immediately before any work is		1

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<b>Attachment 2</b>	<b>As of May 22, 2023</b>		
<b>Regulation Number</b>	<b>Regulation Text</b>	<b>Comment</b>	<b>Impediment Category</b>
	started in an area and thereafter as conditions warrant		
75.211(b)	Where mining height permits and visual examination does not show a hazard sound and vibration or other equivalent tests shall be made		1
75.301	AMS Operator: The person(s) designated by the operator, who is located on the surface of the mine and monitors the malfunction, alert, and alarm signals of the AMS and notifies appropriate personnel of these signals		1
75.301	Appropriate personnel: The person or persons designated by the operator to perform specific tasks in response to AMS signals.		1
75.310(a)(4)	Main fans must be equipped with a pressure recording device or system. ...If a device or system other than a circular pressure recorder of main mine fan pressure, the monitoring device shall provide a continuous graph or continuous chart of pressure as a function of time.	This regulation does not appear to allow fully electronic recordkeeping	1
75.312	Each main fan and associated recording devices must be examined by trained persons, the timing of such examinations ranges from every day to every 7 days, to every 31 days depending on the focus of the examination		1
75.320	Tests for methane and oxygen deficiency shall be made by a qualified person with MSHA approved detectors		1
75.336	A certified person shall monitor atmospheres of sealed areas at least every 24 hours		1

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Attachment 2	As of May 22, 2023		
Regulation Number	Regulation Text	Comment	Impediment Category
75.342	Methane Monitors. Methane monitors shall be maintained in permissible and proper operating condition and shall be calibrated with a known air-methane mixture at least once every 31 days. To assure that methane monitors are properly maintained and calibrated, the operator shall: Use persons properly trained in the maintenance, calibration, and permissibility of methane monitors to calibrate and maintain the devices. Maintain a record.	Does not allow for self-calibrating devices	1
75.351	The operator must designate an AMS operator who must be on duty at the mine at a location where audible and visual signals from the AMS must be seen or heard	note the language "at the mine" which would seem to preclude any centralized or off-site monitoring	1
75.352	The AMS operator must notify appropriate personnel of any malfunction, alert or alarm from the AMS		1
75.360	A certified person must conduct a preshift examination within 3 hours of the beginning of any shift during which persons are scheduled to travel underground.		1
75.361	see 75.360 but for areas not examined in the preshift examination		1
75.362	A certified person must conduct onshift examinations when persons are underground and in any area where mechanized mining equipment is being installed or removed during the shift		1
75.364	A certified person must make examinations of all worked out areas every 7 days		1
75.511	Repair of electrical equipment ... disconnecting devices must be locked out and suitably tagged by the person performing the work, where that is not possible, such devices shall be opened and tagged by the person doing the work		1

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Attachment 2	As of May 22, 2023		
Regulation Number	Regulation Text	Comment	Impediment Category
75.512-1-512-2	Electrical equipment must be examined and tested by a qualified person at least weekly		1
75.82	Before beginning troubleshooting or repair work on electrical equipment, a qualified person must 1) deenergize the circuit with a circuit interrupting device, 2) open the circuit disconnecting service, 3) lock out the disconnecting device with a padlock and 4) tag the disconnecting device to identify each person working on the circuit or equipment		1
75.821	At least once every 7 days, a qualified person must test and examine each high voltage longwall unit and associated circuits. Ground wire monitor and associated circuits must be examined and tested every 30 days. The person doing the tests must certify by signature and date that they have been completed.		1
75.829(b)	Tramming continuous mining machines... testing prior to tramming: A qualified person must activate the ground-fault and ground-wire test circuits of the power source and where applicable a person must activate the test circuit for the grounded-phase detection circuit.		1
75.832	Describes six separate tests and examinations that must be conducted by a qualified person and recordkeeping requirements for those tests.		1
75.1433	Visual examinations at least every 14 days are required for all hoist ropes		1
77.101	The provisions of Subparts C, P, R, and T require that tests for methane and oxygen deficiency be made by a qualified person		1
77.201-1	Tests for methane in structures, enclosures, or other facilities in which coal is handled or stored shall be conducted by a qualified person with a device approved by the Secretary at least once each operating shift or		1

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<b>Attachment 2</b>	<b>As of May 22, 2023</b>		
<b>Regulation Number</b>	<b>Regulation Text</b>	<b>Comment</b>	<b>Impediment Category</b>
	before repairs involving welding or open flame		
77.309, 309-1	Frequent visual checks shall be made by the operator of the thermal dryer system control station, bypass dampers, air-tempering louvers, discharge mechanism and other dryer system equipment. The system controls must be installed at a location which gives the operator the widest field of visibility of the system and equipment.		1
77.314	All dryer control instruments must be inspected at least every 3 months and a record signed by a trained employee or servicing agent must be kept at the plant.		1
77.404(b)	Machinery and equipment shall only be operated by persons trained in the use of and authorized to operate such machinery or equipment		1
77.501	See 75.511		1
77.502	Electrical equipment must be frequently examined and tested by a qualified person		1
77.900-1	Circuit breakers protecting low and medium voltage circuits must be inspected monthly by a qualified person		1
77.1007	Drilling equipment to be used during a shift must be inspected by a competent person		1
77.1302(j)	When vehicles containing explosives are parked, they shall be blocked securely against rolling	There is no alternative, such as turning the wheels into a bank or berm. It is difficult to imagine how an automated or remotely operated piece of equipment could be physically blocked against rolling without a person being present to do so.	1

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<b>Attachment 2</b>	<b>As of May 22, 2023</b>		
<b>Regulation Number</b>	<b>Regulation Text</b>	<b>Comment</b>	<b>Impediment Category</b>
77.1433	Hoist ropes must be visually examined every 14 days and more frequently if there are signs of any condition that might affect the rope strength. Such ropes are also required to undergo nondestructive testing and diameter measurement if there is evidence of wear or corrosion.	While not specifically required in the examination section of the regulation, it is apparent from the language of Section 75.1433(d) and (e) that all such examinations must be made by a person	1
77.1504	The operator of auger equipment shall not leave the controls of such equipment while the auger is in operation		1
77.1606(a) and(b)	Mobile equipment must be inspected before being placed into operation. Aerial tramways must be inspected each shift		1
77.1713	Surface mines must be inspected at least once during each working shift, hazards noted and recorded in a book in ink or indelible pencil and countersigned by a designated official	There is no provision for electronic recordkeeping.	1
77.1901	Slopes and shafts must be examined at least 90 minutes prior to each shift. Results of the examination must be recorded in a book approved by the Secretary		1
77.1908-1	Hoists shall be operated by a qualified hoistman when miners are in the slope or shaft		1
56.9101	Operators of self-propelled equipment shall maintain control of the equipment while it is in motion. Operator speeds shall be consistent with conditions of roadways, tracks, grades, clearance, visibility, and traffic, and the type of equipment used.	This becomes potentially problematic for fully automated equipment where there is no "operator."	2
56.14207	Mobile equipment shall not be left unattended unless the controls are placed in the park position and the parking brake, if provided, is set. When parked on a grade, the wheels or tracks of mobile equipment shall be either chocked or turned into a bank	MSHA has concluded, at least informally, that remotely controlled equipment is "attended" by the operator of the remote-control unit. To the	2

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Attachment 2	As of May 22, 2023		
Regulation Number	Regulation Text	Comment	Impediment Category
		best of our knowledge, MSHA has not taken a position on fully automated equipment where there is no "operator."	
75.1916(e)	Diesel-powered equipment shall not be operated unattended. Per 75.1908, "attended" means 1) any machine or device operated by a miner; or 2) any machine or device that is mounted in the direct line of sight of a job site located within 500 feet of such machine or device which job site is occupied by a miner	This provision could be used to argue that the term "attended" was never intended to include remote operators who are not in line of sight. From a legal perspective, this standard could present a real issue to informal interpretations of the term "attended" as it shows that MSHA has already considered the issue and defined the limits of exception for attendance by a remote operator.	2
77.1009	Drills must be attendance attended at all times while in operation		2
77.1607(m)	Electrically powered mobile equipment shall not be left unattended unless the master switch is off, all operating controls are in neutral, and the brakes are set		2
77.1607(n)	Mobile equipment may not be left unattended unless the brakes are set and wheels turned into a bank or berm or blocked when on a grade		2
56.14131(a)	Seat belts shall be provided and worn in haulage trucks	Note that the standard requiring ROPS (56.14130) specifically states that it does not apply to equipment that is "only operated by remote control." While	3

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<b>Attachment 2</b>	<b>As of May 22, 2023</b>		
<b>Regulation Number</b>	<b>Regulation Text</b>	<b>Comment</b>	<b>Impediment Category</b>
		56.14131 contains no such carveout.	
56.14131(b)	Seat belts shall be maintained in functional condition, and replaced when necessary to assure proper performance		3
57.4260	(a) Whenever self-propelled equipment is used underground, a fire extinguisher shall be on the equipment. This standard does not apply to compressed air powered equipment without inherent fire hazards. (b) A fire suppression system may be used as an alternative to fire extinguishers if the system can be manually actuated.		3
75.1719	Illumination must be provided in every area of a mine in which self-propelled mobile equipment is operating.		3
75.1732	Continuous mining machines must be equipped with proximity detection systems.	No exception for fully automated equipment	3
77.403-1	All rubber tired or crawler mounted self-propelled scrapers, front end loaders, dozers, graders, loaders and tractors must be provided with roll over protective structures (ROPS)	There is no exception for fully automated equipment.	3
77.1710	Seat belts must be installed in vehicles where there is a danger of overturning and roll protection is provided	There is no exception for fully automated equipment or equipment without cabs	3
75.1710-1	Cab and canopy requirements for self-propelled mobile equipment.	No exceptions for automated equipment	3
56.14206(b)	When mobile equipment is unattended or not in use, dippers, buckets and scraper blades shall be lowered to the ground. Other movable parts, such as booms, shall be mechanically secured or positioned to prevent movement which would create a hazard to persons	The issue here is the requirement that movable parts be "mechanically secured." The language can be construed to prohibit the use of electronics to secure those parts.	4

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Attachment 2	As of May 22, 2023		
Regulation Number	Regulation Text	Comment	Impediment Category
57.9360	Shelter Holes.	It is unclear whether this standard applies independent of whether the area is operated solely by automated equipment	4
57.11050	Escapeways. It is unclear whether this standard applies independent of whether an area of a mine is operated solely by automated equipment		4
75.500-506-1	Requirements for permissible electric face equipment		4
75.523-2	Deenergization of self-propelled mobile equipment shall be provided by 1) mechanical actuation of an existing pushbutton emergency stop switch or 2) mechanical actuation of an existing lever emergency stop switch or 3) the addition of a separate electromechanical switch assembly. There are specific requirements for the size of the switch and the maximum pressure and movement needed to actuate it.	While no "person" is specifically required by this regulation, the specification of "mechanical actuation" and pressure requirements for the switches, etc. certainly appears to contemplate that a person must be actuating the specified controls.	4
75.523-3(b)(5)	Automatically actuated emergency park brakes may be released only by manual control that does not operate any other equipment function	The specification of "manual release only" implies that person must be present to operate the equipment	4
75.1402	Two methods of communication must be available between shaft stations and hoist rooms one of which must be a telephone or a speaking tube	Communications is one of the most rapidly evolving areas of technology. Telephones, not to mention "speaking tubes", are both becoming outdated. Statutory Standard. Cannot be changed without amending the statute	4

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Attachment 2	As of May 22, 2023		
Regulation Number	Regulation Text	Comment	Impediment Category
75.1715	Identification checks carried by miners underground must be made of rust resistant metal not less than 16 gauge.	Statutory Provision. Cannot be changed without amending the statute	4
77.310	Control panels for thermal dryers must have a schematic diagram containing legends which show the location of each thermocouple, pressure tap, or other control or gaging instrument which must be posted on or near the control panel. Each instrument on the control panel must be identified by a nameplate or equivalent marker and a plan to control the operation of each system must be posted, showing startup, shutdown and emergency shutdown procedures.	While no "person" is specifically required by this regulation, the nameplate and legend requirements appear necessary only for persons engaged in operations or maintenance.	4
77.506-1	Short circuit and overcurrent protective devices must meet the requirements of the National Electric Code of 1968	Digital equipment was not present in 1968.	4
75.324	Intentional changes in the ventilation system. (a) A person designated by the operator shall supervise any intentional change in ventilation that - (1) Alters the main air current or any split of the main air current in a manner that could materially affect the safety or health of persons in the mine; or...Affects section ventilation by 9,000 cubic feet per minute of air or more in bituminous...	Ventilation on demand cannot be utilized under these circumstances	4
56/57.2	<i>Attended</i> means presence of an individual or continuous monitoring to prevent unauthorized entry or access	The term "attended" is used in a number of other regulations and could present an issue depending on the nature of the process or equipment at issue	For reference only
56/57.2	<i>Mobile equipment</i> means wheeled, skid-mounted, track-mounted, or rail-mounted equipment capable of moving or being moved		For reference only
56/57.2	<i>Permissible</i> means a machine, material, apparatus, or device that has been investigated, tested, and approved by the		For reference only

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Attachment 2	As of May 22, 2023		
Regulation Number	Regulation Text	Comment	Impediment Category
	Bureau of Mines or the Mine Safety and Health Administration and is maintained in permissible condition		
56/57.2	<i>Roll protection</i> means a framework, canopy or similar protection for the operator when equipment overturns.		For reference only
57.14130	Rollover protective structures (ROPS) and seat belts for surface equipment.	Unlike the analogous regulations under part 56, this regulation contains an exemption from both the ROPS and seat belt requirements for remotely operated equipment (57.14130(f)(3))	For reference only
75.2	Permissible: Equipment designed, constructed and installed in accordance with the specifications of the Secretary to assure that such equipment will not cause a mine explosion or a mine fire		For reference only

## **8. Appendix B**

### **International Approaches Comparison**

#### **Executive Summary:**

The international approach to autonomous safety regulations can be most easily seen in Autonomous Haulage Systems (AHS) because they represent the largest conversion of mining activities to autonomous operations. Australia, Chile, and Canada have the largest concentrations of commercial-scale AHS deployments in the world, Figure 1 and Figure 2. Unlike the United States, mine safety in those countries are governed by state or provincial level regulations. Western Australia has approximately 80% of the worldwide AHS deployments. The Department of Mines, Industry Relations, and Safety (DMIRS) only provides a guideline for compliance rather than enforceable regulations (DMIRS, 2014). This is due to the structure of their regulatory framework which places a much larger burden on the mine managers. Australia is considered to have a “duty of care” standard in place. As mentioned in the final report, implementation of a “duty of care” standard under the Mine Act would be problematic, since the statute prescribes “strict liability” for any violation even if the operator is completely without fault. Australian guidelines have been utilized as a basis for many of the other countries’ approaches to regulation.

Alberta Canada’s Occupational Health and Safety (OHS) regulations are the first enforceable regulations for AHS and reference international standards. Worldwide pressure from industry groups like Global Mining Group (GMG) have begun pressing for the adoption of international standards such as Functional Safety to analyze AHSs. With the roll-out of the Alberta OHS regulations, international standards are becoming an enforceable document. Those standards already govern many of the aspects of the base haul trucks. The addition of functional safety into the enforceable standards is enabling a quantitative or semi-quantitative process to evaluate a very complex system’s safety. The path to complying with those standards is presented in this appendix.

Appendix B

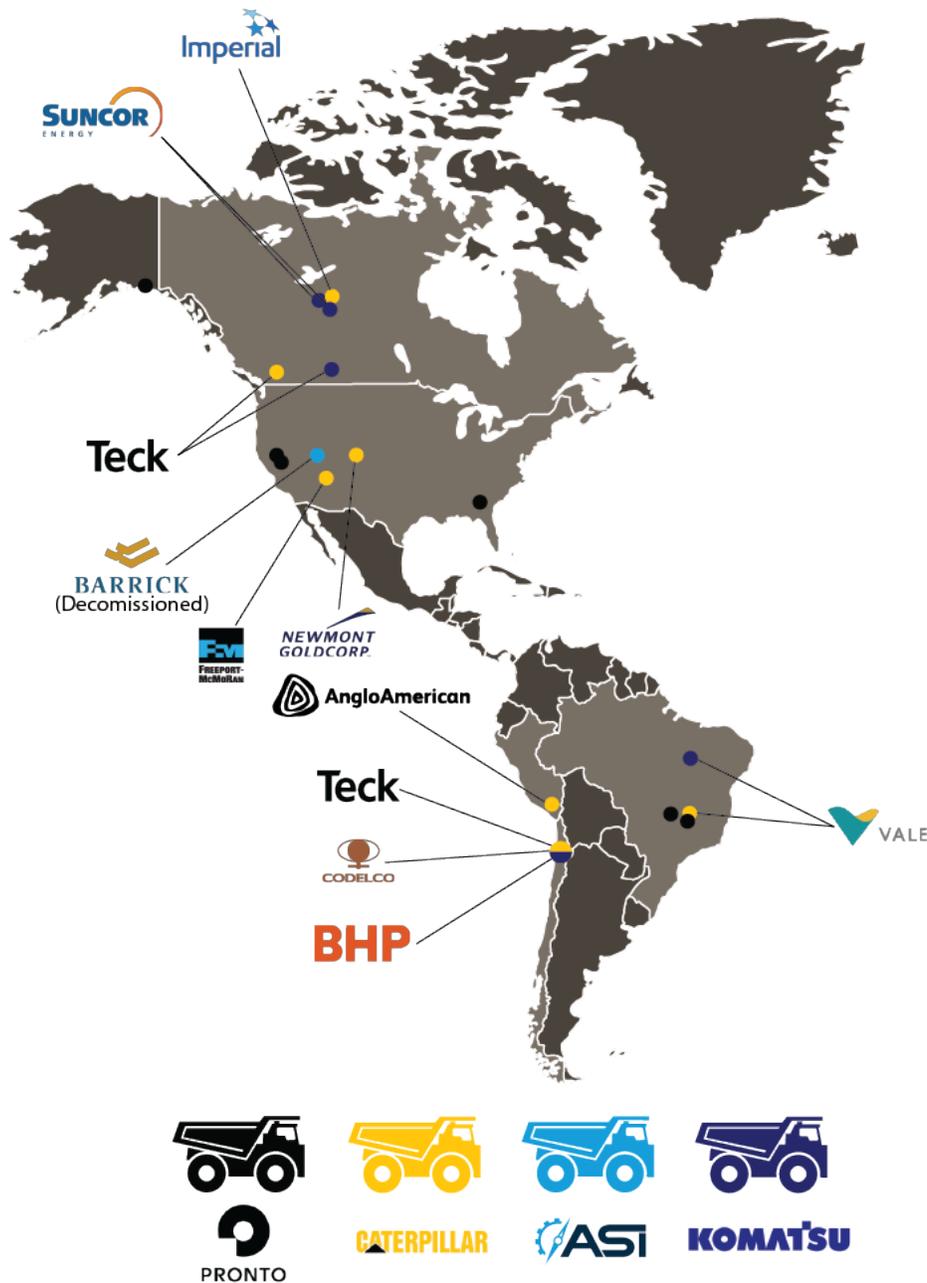


Figure 1. North & South American AHS Deployments. Figure 1 shows a grayscale map of North and South America pinpointing the deployment of Autonomous Haulage Systems (AHS) made by the following companies: Pronto, (7 black dots), Caterpillar, (7 yellow dots) ASI, (1 blue dot) and Komatsu (5 purple dots) and deployed by the following companies: Imperial, Suncore, Teck, Barrick, Freeport-McMoRan, Newmont Goldcorp, and AngloAmerican.

Codelco, BHP, and Vale. Imperial, Suncore, and Teck show deployments in Canada; Barrick (decommissioned), Newmont Goldcorp, and Freeport-McMoRan in the U.S.; and AngloAmerican in Peru; Teck, Codelco, and BHP in Chile; and Vale with several locations in Brazil.

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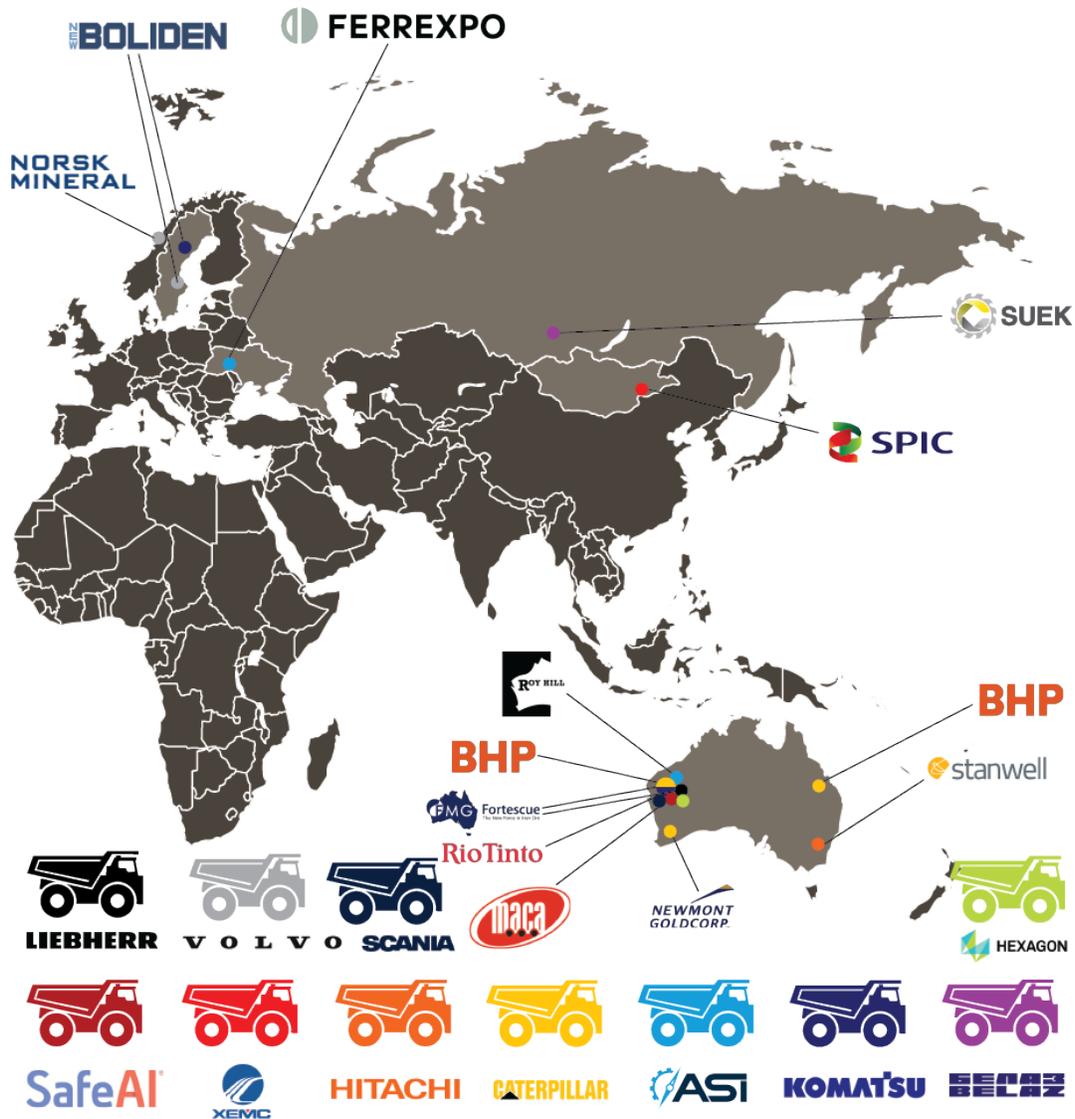


Figure 2. European, African, and Australasia AHS Deployments. Figure 2 shows a grayscale map of Europe, Africa and Australasia pinpointing the deployment of Autonomous Haulage Systems (AHS) made by the following companies: Liebherr, (2 black dots) Volvo, (2 gray dots), Scania, (1 navy blue dot), SafeAI, (1 dark red dot), XEMC, (1 light red dot), Hitachi, (1 orange dot), Caterpillar, (3 yellow dots) AST, (2 light blue dots), Komatsu (dark purple, no dots shown), Belaz, (1 light purple dot), and Hexagon (1 green dot) and deployed by the following companies: Ferrexpo, New Boliden, Norsk Mineral, SUEK, Spic, BHP, Stanwell, Newmont Goldcorp, Maca, Rio Tinto, and Fortescue.

Companies are deployed in the following countries: Boliden in Sweden, Norsk Mineral in Norway, Ferrexpo in Ukraine, SUEK in Russia, Spic in Mongolia, and BHP, Stanwell, Newmont Goldcorp, Maca, RioTinto, Fortescue, BHP and Roy Hill in Australia.

## Appendix B

### **DMIRS Code of Practice**

The Western Australia Mines Safety and Inspection Act 1994 (the Act) (State of Western Australia, 1994) governs mining within the state. A code of practice, as issued by the Department of Mines, Industry Relations and Safety (DMIRS), is a practical guide to achieving the health and safety standards of the Act (DMIRS, 2014). The code applies to those with a duty of care in the circumstances described in the code. Western Australia's maturity of mining regulations has influenced the other states to adopt the Western Australia's regulations and certifications as their own or to slightly modify those regulations to fit their specific jurisdiction.

Following the code of practice, in most cases, would achieve compliance with the regulations. "Safe mobile autonomous mining in Western Australia" (the Code) is designed to provide guidance on: mobile autonomous and semi-autonomous systems used in surface and underground mines; developing and evaluation safe work procedures for those systems; the control of autonomous loaders, trucks and other mobile equipment, such as drills and dozers; and identifying the unique risk profiles in relation to mobile autonomous mining systems.

Rather than the prescriptive rules applied by the Mine Safety and Health Administration (MSHA), the DMIRS utilizes risk management techniques as required by Work Health and Safety (Mines) Regulations 2022. Risk assessments define risk as the probability and consequence of occurrence of loss, injury, or illness. Analysis performed a risk assessment analyzes the frequency of the risk, as well as the consequences of the risk.

### **Alberta OHS Approval Process of AHS**

In January 2020, Alberta OHS issued their approval process for AHS (Government of Alberta, 2019) based on OHS Act Section 56. This standard was developed through cooperation with Western Australian AHS sites and specifically calls out ISO 17757: Earth-moving machinery and mining - Autonomous and semi-autonomous machine system safety. The approval process is site specific and may vary based on specifics of the mine site, technology, systems, and site operator's experience with AHS system. It should be noted that this regulation was not developed until after many of the oil sands mines had already implemented AHS.

Unlike the DMIRS Guide, the OHS process is a set of specific regulations rather than a guide. Within these regulations are prescriptive requirements for international standards that must be met. A required portion of the application is a compliance letter either from the manufacturer of the equipment being used or an Alberta Professional Engineer indicating that the applicable requirements of ISO 17757 are met.

## Appendix B

### Layers of Protection

Woven into an AHS operation are several safety systems or controls arranged in the Hierarchy of Controls format Figure 3. This hierarchy concept assumes that the control methods at the top of the figure are potentially more effective and protective than those at the bottom which are more reliant on human behavior rather than systematic controls.

In the case of AHS, elimination of risks associated with human error is one of the greatest benefits. Through the removal of truck operators, the risk to those operators is eliminated. However, loading unit operators, ancillary unit operators, drilling operators, and technical services staff still remain within the Autonomous Operation Zone (AOZ). Impacts to the maintenance/workshop employees do not change within the maintenance workshop. However, field repairs will expose them to the AOZ risks. Therefore, it is recommended by the Australian DMIRS that additional primary controls, such as elimination and substitution, be put in place to reduce risks to these employees (Department of Mines and Petroleum, 2014). Typical controls may include:

- Remove the risk by isolating or providing alternative access for personnel not directly involved with the autonomous activity;
- Reduce the likelihood of the risk by restricting functions and activities to authorized personnel; and
- Additional technology.

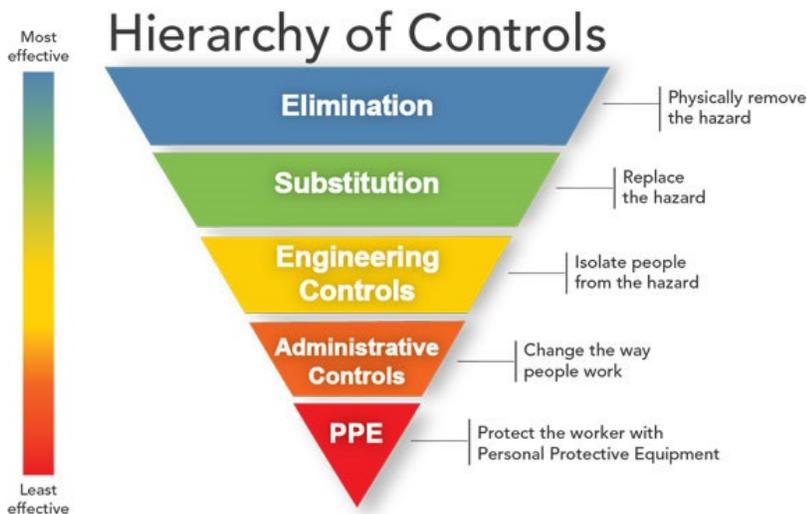


Figure 1. NIOSH Hierarchy of Controls (NIOSH, 2016) Figure 3 depicts an inverted triangle diagram measuring the most effective to the least effective controls and in the following order from most effective to least effective: Elimination: Physically remove the hazard; Substitution: Replace the hazard; Engineering Controls: Isolate people from the hazard; Administrative Controls: Change the way people work; PPE: Protect the worker with Personal Protective Equipment.

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Engineering controls remain the second control tier to mitigate risk. Engineering controls are arranged as layers of protection from most effective to least effective as perceived by system designers. Current AHS implementations utilize the layers of protection shown in Figure 4. An AHS provides protection via object detection systems (ODS) on each Automated Haul Truck (AHT). The situational awareness that those systems provide includes positional information of all machines within the AOZ, and the ability to stop some or all the machines within an AOZ. If a hazard is not mitigated by site procedures that eliminate the risk, additional layers of protection provided by AOZ access control systems, situational awareness, object detection systems, and All-Stop systems should provide an acceptable level of risk. If those layers do not provide sufficient risk reduction, administrative controls such as site procedures or PPE in the form of the remote stop system should be added. A remote stop system is a button either within a manually operated machine or a handheld device that allows for the emergency stopping of all autonomous vehicles within the area.

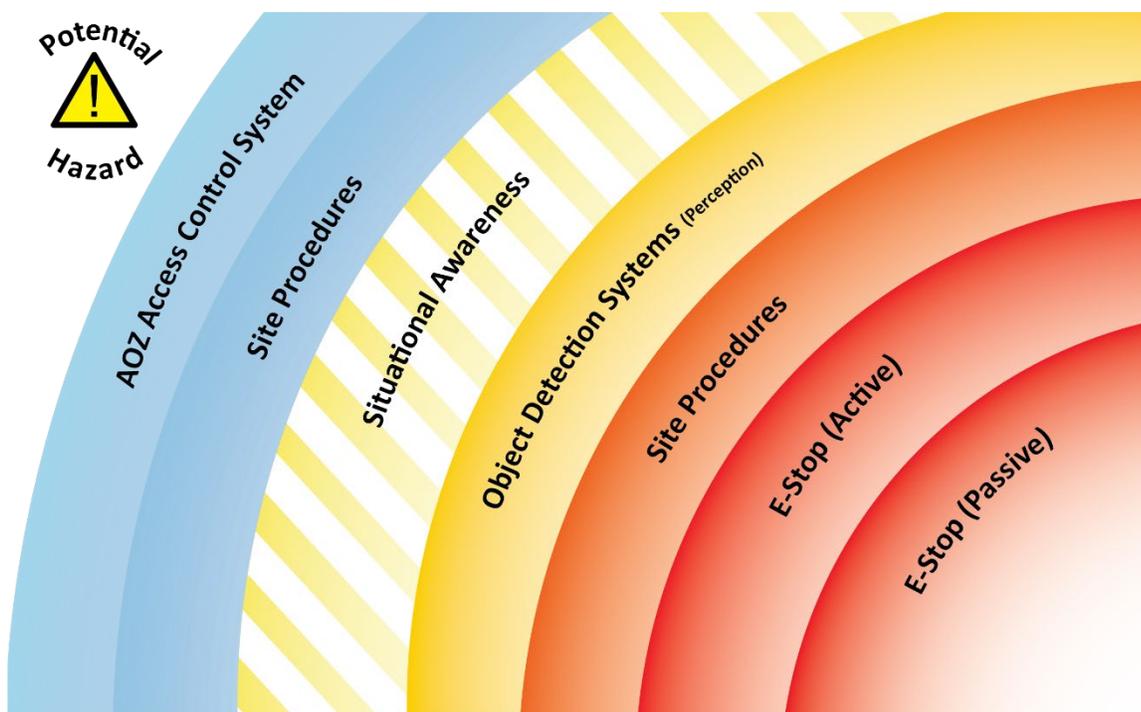


Figure 2. AHS Layers of Protection increasing left to right. Situational Awareness may be considered a basic process control system, not a safety system. (Miller, 2020). Figure 4 depicts a rainbow chart with the following layers listed as potential hazards in colors ranging from left to right in shades of blue, yellow, orange, and red. From left to right the layers are: AOZ Access Control System, Site Procedures, Situational Awareness, Object Detection Systems (Perception), Site Procedures, E-Stop (Active), and E-Stop (Passive).

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### Relevant International Standards

Standards are generally not mandatory in comparison to regulations unless that standard is referenced in a regulation, such as ISO 17757 in the Alberta OHS Regulation. Additional standards required for manned operations will also be required for AHS sites. An example of a required standard for manned sites that would also be required for an AHS is European Standard (EN) ISO 12100 Standard “Safety of Machinery – General Principles for Design – Risk Assessment and Risk Reduction” which describes the requirements safe design principles.

ISO and IEC standards follow a hierarchical system, where the tip of the pyramid (Type A standards) represents the basic design and analysis principles. Figure 5 is a graphical representation of the hierarchy of standards that is often utilized by ISO and IEC. The middle of the pyramid is built from group safety standards (Type B standards) that provide standards for general safety aspects and special protective devices. The base of the pyramid is built from specialist standards (Type C standards) that specify safety features for individual machine families. Standards are developed by a committee often made up of consortium of national and regional regulators, business within a marketplace, and non-governmental agencies (AusIMM, SME, etc.). The definition of a standard from ISO is a document established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context (ISO, 2020).

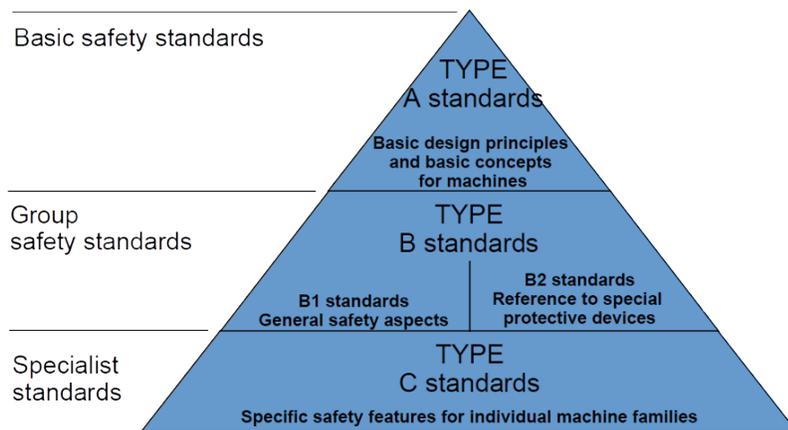


Figure 3. Hierarchical Organization of the IEC, ISO, EN Standards. Adapted from common sources. Figure 5 depicts a pyramid figure in blue with the following from the bottom up: First Level is Specialist Standards: Type C Standards, Specific safety features for Individual machine families; Second Level is Group Safety Standards: Type B Standards- B1 standards-General safety aspects and B2 standards-Reference to special protective devices; Top Level is Basic safety standards: Type A standards-Basic design principles and basic concepts for machines.

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Table 1 lists some of the standards that would apply to an AHS. They are relevant to risk analysis required for the deployment of AHS at a mine site, but it is not an exhaustive list. Additional standards are also applied to manned and AHS sites.

*Table 1. Commonly Accepted Standards.*

<b>Standard</b>	<b>Title</b>	<b>Type</b>
ISO 31000	Risk Management Package	A
IEC 60204	Safety of Machinery – Electrical Equipment of Machines	B1
IEC 61025	Fault Tree Analysis	A
IEC 61310	Safety of Machinery – Indication, Marking and Actuation	B1
IEC 61508	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems	A
IEC 61511	Functional Safety – Safety Instrumented Systems for the Process Industry Sector	B
IEC 62061	Safety of Machinery – Functional Safety of Safety-Related Electrical, Electronic and Programmable Electronic Systems	C
ISO 9001	Quality Management Systems – Requirements	A
ISO 12100	Safety of Machinery – General Principles for Design – Risk Assessment and Risk Reduction	A
ISO 13849	Safety of Machinery – Safety-Related Parts of Control Systems	B1
ISO 14121	Safety of Machinery – Principles for Risk Assessment	A
ISO 15998	Earth-Moving Machinery – Machine-Control Systems (MCS) Using Electronic Components – Performance Criteria and Tests for Functional Safety	B1
ISO 16001	Earth-Moving Machinery – Object Detection Systems and Visibility Aids – Performance Requirements and Tests	C
ISO 17757	Earth-Moving Machinery and Mining – Autonomous and Semi-Autonomous Machine System Safety	C
ISO 19014	Earth-Moving Machinery – Functional Safety	C
ISO 19296	Mining – Mobile Machines Working Underground – Machine Safety	B1
ISO 20474-1	Earth-Moving Machinery – Safety – Part 1: General Requirements	B1
ISO 21815	Earth-Moving Machinery – Collision Warning and Avoidance	C
ISO 26262	Road Vehicles – Functional Safety	A

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### **ISO 17757: Autonomous Machine System Safety**

ISO 17757 – Earth-moving Machinery and Mining: Autonomous and Semi-Autonomous Machine System Safety formalizes the definitions and requirements of an autonomous mining machine. This standard is explicitly referenced in the Alberta OHS regulations for AHS. ISO 17757 requires a risk assessment process for Autonomous and Semi-Autonomous Machine System (ASAMS), which conforms to the principals of ISO 12100. All identified risks shall be mitigated to acceptable risk levels as part of the risk assessment process. ISO 17757 also requires that safety-related parts of control systems shall comply with the appropriate functional safety performance level. Examples include ISO 13849 Standard “Safety of Machinery – Safety-Related Parts of Control Systems,” ISO 19014 Standard “Earth-Moving Machinery – Functional Safety,” IEC 62061 Standard “Safety of Machinery – Functional Safety of Safety-Related Electrical, Electronic and Programmable Electronic Systems,” or IEC 61508.

### **IEC 61508 Functional Safety Standard**

Functional Safety is defined by IEC 61508 as ‘the safety parameters control systems provide to an overall process or plant.’ Functional safety standards were developed to improve confidence in safety systems. This requirement is due to complexity in modern safety systems that are now predominantly electrical, electronic, or programmable systems. The process plant environment bred many of the development standards used today in autonomous systems. This approach to reducing risk deviates from previous standards that were prescriptive in nature by focusing on quantitative risk reduction. The functional safety approach greatly differs from the prescriptive approach taken by MSHA regulators with the mandate of no allowable risk.

Functional safety engineering seeks to identify specific hazardous failures that can lead to serious consequences. It then establishes a maximum tolerable frequency target for each mode of failure. If the failure of a piece of equipment contributes to the identified hazards, it is referred to as “safety related.” A “safety function” is further defined as the function of safety related equipment which maintains a safe state or brings it to a safe state in response to a hazard.

Functional safety addresses both random hardware failures and systematic failures. The former is often quantified and assessed in terms of failure rates while the latter cannot be easily quantified and must rely on conformance to acceptable development standards. Systematic failures most often occur when software is involved in the safety related function.

### **Basic Process Control System**

IEC 61511: Functional safety - Safety instrumented systems for the process industry sector’ defines a basic process control system (BPCS) as the system that continuously monitors and controls the

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process in a day-to-day plant operation. A BPCS is typically considered as an independent protection layer (IPL) preceding the Safety Instrumented System (SIS).

IEC 61511 Part F.9 states the criteria to qualify a Protection Layer (PL) as an IPL are: the protection provided reduces the identified risk by a large amount, for instance  $10^{-1}$ ; the protective function is provided with a high degree of availability (90% or greater). An IPL should be designed solely to prevent or to mitigate the consequences of one potentially hazardous event (i.e., a runaway reaction, release of toxic material, a loss of containment, or a fire). Multiple causes may lead to the same hazardous event; therefore, multiple event scenarios may initiate action of one IPL. An IPL must also be designed to facilitate regular validation of the protective functions also known as auditability. Only those protection layers that meet the tests of availability, specificity, independence, dependability, and auditability are classified as independent protection layers.

Typically, a BPCS is a relatively weak IPL due to limited redundancy in components, limited built-in testing capability, and limited security against unauthorized changes to internal programming. The latter of these may have the greatest impact to effectiveness due to human error. IEC 61511 limits the combined probability of failure on demand (PFD) to not less than  $1 \times 10^{-1}$  for all the BPCS IPLs that can be applied to a unique initiating event-consequence pair. However, some companies use a PFD equal to  $1 \times 10^{-1}$  for each BPCS IPL if analysis indicates that the configuration, maintenance, and regular testing of the BPCS ensures that each IPL BPCS is truly independent. For the analysis presented in this study the PFD of the BPCS has been assumed to be  $10^0$  due to the complexity of the system.

### **Safety Instrumented System**

A safety system provides functional safety if the safety system, including logic solvers, sensors, and actuators, achieves a tolerable level. IEC defines tolerable risk (International Electrotechnical Commission, 2016) as, “The aim of functional safety is to bring risk down to a tolerable level and to reduce its negative impact; however, there is no such thing as zero risk. Functional safety measures risk by how likely it is that a given event will occur and how severe it would be; in other words: how much harm it could cause.”

A Safety Instrumented System (SIS) is a system designed to prevent or mitigate hazardous events by taking the process to a safe state when specific conditions are violated. An SIS is comprised of at least one Safety Instrumented Function (SIF) composed of various combinations of logic solvers, sensors, and actuators. SIFs must be functionally independent from the BPCS. Signals can be shared between the SIF and the BPCS only if the PFD is not affected. Typically, SISs utilize logic solvers with multiple redundant processors, power supplies, signal paths, sensors, and actuators. Ideally, this redundancy is achieved by more than one or duplicate components. An example of non-duplicate redundant sensors is Caterpillar’s use of Radar and LiDAR in their perception system. Additionally, each SIS will use self-diagnostics to detect and communicate sensor, logic solver, and final control element faults.

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Each SIF will have a Safety Integrity Level (SIL) rating. An SIL rating is a ranking of safety systems performance. It is rated as PFD and can be expressed in terms such as 1 in 1,000. The SIL rating system has four discrete levels: SIL 1, SIL 2, SIL 3, and SIL 4 as seen in Table 2.

*Table 2: SIL Level, Risk Reduction Factor, Probability of Failure on Demand. Annotated from (International Electrotechnical Commission, 2016).*

<b>SIL Level</b>	<b>Risk Reduction Factor</b>	<b>PFD</b>	<b>Rigor</b>
<b>SIL 4</b>	100,000 to 10,000	$10^{-5}$ to $10^{-4}$	State of the art and usually avoided.
<b>SIL 3</b>	10,000 to 1,000	$10^{-4}$ to $10^{-3}$	Less rigorous than SIL 4 but still requiring sophisticated techniques.
<b>SIL 2</b>	1,000 to 100	$10^{-3}$ to $10^{-2}$	Requires good design and operating practice such as in ISO 9001 Standard “Quality Management Systems – Requirements.”
<b>SIL 1</b>	100 to 10	$10^{-2}$ to $10^{-1}$	The minimum level requires good design and practice.

The higher the SIL rating, the higher the safety level or the lower the probability of failure on demand. Individual components do not have SIL ratings; instead, components are determined to be suitable for different SIL environments. Use of components suitable to a SIL rating does not ensure that a system has that SIL rating. The actual SIL rating is dependent on the implementation of SIL appropriate logic solvers, sensors, and actuators.

The selection of an SIL rating for an SIS utilized in a process is based on risk analysis of the situation. This risk analysis follows the same process as that described in the Australian DMIRS’s code. Risk analysis will result in a risk profile for the process. If that risk is too high, a risk reduction and mitigation plan must be prepared that could include SISs. The SIL ratings of the SISs would be dependent on the desired risk reduction factor. For example, a process industry company may only accept SIS designs up to SIL 2. If the risk analysis indicated a requirement for a SIL 3 SIS, a redesign of the process to lower the intrinsic risk would occur rather than implementing a SIL 3 SIS. This change in process would be in the elimination or substitution step of the hierarchy of controls.

A typical SIS/SIF/SIL example case is a pressure vessel containing a flammable liquid. If this pressure vessel’s process control system fails and allows the vessel to be subjected to an overpressure condition, the SIS will act to prevent or mitigate the hazardous condition resulting from the overpressure event. The SIS may include a pressure transducer, a logic solver to control the system behavior, and a solenoid valve to vent the vessel into a safe location. If the risk reduction factor required by the risk analysis is a factor of 100, then a SIL 2 level SIF would be specified.

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This one SIF may constitute the entire SIS, or the SIS may be composed of multiple SIFs to mitigate additional unacceptable process risks.

### Human Independent Protection Layers

Human IPLs rely on operators to take action to prevent an undesired consequence in response to an event. It is worth noting that most well-known major incidents, such as Three Mile Island and Chernobyl, involved complex systems interacting with humans. The effectiveness of humans in performing routine tasks under low or high stress conditions is limited. Overall, human performance is less reliable than engineering controls. The Center for Chemical Processes and Safety has extensively studied human failure rates. Routine tasks typically have PFDs in the  $10^{-2}$  to  $10^{-3}$  range, while complicated non-routine tasks under timing limitations have PFDs approaching  $10^0$  (Center for Chemical Process Safety, 2001).

### Maximum Tolerable Risk

Counter to many of the catch phrases used in the mine health and safety community, there is no such thing as zero risk. Public perception and those involved in the health and safety of mines often call for zero risk; however, this is not practical. Table 3 demonstrates the everyday risk of death from various causes. Data is compiled from Center for Disease Control (CDC), DMIRS, and MSHA. Probability units are in risk of death per year per worker.

Table 3: Probability of Risk of Death. Adapted from CDC, MSHA, and DMIRS data sources.

Cause	Probability	Source
All causes (mid-life including medical)	$7 \times 10^{-3}$	(CDC, 2020)
Unintentional Injuries	$5 \times 10^{-4}$	(CDC, 2020)
Traffic Accidents	$1 \times 10^{-4}$	(CDC, 2020)
Working at a USA Coal Mine (2018)	$1 \times 10^{-4}$	(MSHA, 2019)
Work at a USA mine (2018)	$8 \times 10^{-5}$	(MSHA, 2019)
Working at a Western Australia mine (2018)	$3 \times 10^{-5}$	(DMIRS, 2019)
Natural disasters	$6 \times 10^{-6}$	(CDC, 2020)

The tolerable degree of risk varies based on the degree of control of the circumstances, the voluntary or involuntary nature of risk, and the number of persons at risk. However,  $10^{-5}$  per annum

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(pa) is often considered a broadly acceptable level of risk within mining and industrial activities such as oil & gas. Tolerable risks in the  $10^{-6}$  pa range are typically only utilized for scenarios that present a risk to communities outside of an operational area.

**Maximum Tolerable Failure Rate**

For simple systems, the maximum tolerable failure rate is calculated by dividing the maximum tolerable risk by external IPLs. Typically, most of these IPLs reduce the exposure rate of an individual. Reduction in staffing, AOZ access control, and site procedures are the reducing factors specific to AHS. For example, factors that might be experienced at an AHS site are show in Table 4.

Table 4: Factors used to calculate maximum tolerable failure rate. (Miller, 2020)

Factor	Value	Source
Portion of time system can offer risk.	80%	7000 operating hours/ 8760 total hours per year
Person at risk	23%	2000 working hours/8760 total hours per year
Probability of Fatality from Incident	80%	Judgement
Daily exposure to an AHT (<30m separation)	5%	Estimated exposure based on operational conditions

Based on Table 4, a requirement of a maximum  $1.4 \times 10^{-3}$  pa PFD is calculated in the equation below. The calculated PFD results in a safety integrity level requirement of SIL 3. This means that a single SIL 3 safety system is required to meet the tolerable degree of risk for an AHT. However, a single SIL 3 system is not a preferred solution due to the difficulty in creating those individual systems; however, a combination of SIL 1 and SIL 2 systems can achieve the risk reduction factor of a SIL 3 system. All current AHS implementations have numerous layers of protection to reach an acceptable level of risk reduction.

$$\frac{1 \times 10^{-5} \text{pa}}{(0.80 \times 0.23 \times 0.75 \times 0.05)} = 1.4 \times 10^{-3} \text{ pa}$$

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### As Low As Reasonably Possible (ALARP)

It is insufficient to end functional safety analysis at the determination of an SIL target based on an acceptable level of risk. It is also necessary to establish if further improvements to the system can be undertaken to reach ALARP risk target. Ideally, a system would reach a state of safety where the risk lies below the broadly acceptable risk limit of  $10^{-6}$ .

The principal of ALARP is rooted in the way risk is treated legally. Reasonable measures will be taken to reduce the risk until further risk reduction is disproportionate to the benefit. This is most often measured financially, which leads to the concept of cost per life saved. The cost per life saved is multiplied by gross disproportionality factor depending on how close the predicted risk is to the target. For predicted risks approaching the maximum tolerable risk, a factor of 10 is used.

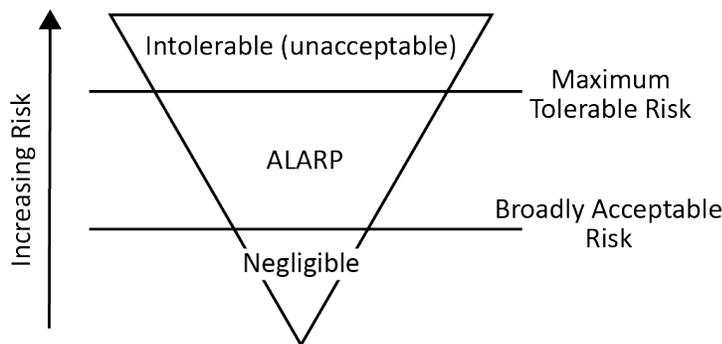


Figure 4. ALARP Triangle adapted from IEC 61508. Figure 6 depicts an inverted pyramid graph. An arrow labeled increasing risk points up to the left of the pyramid. The top layer is labeled Intolerable (unacceptable); the top and middle layer is divided by a line labeled: Maximum Tolerable Risk; the middle layer is labeled ALARP; the middle and bottom layer are divided by a line labeled Broadly Acceptable Risk; the bottom layer is labeled Negligible.

An example created for this report of an ALARP calculation is presented below:

- A \$2,000,000.00 USD cost per life saved target is used in a particular industry; (this is typical)
- A maximum tolerable risk target of  $10^{-4}$  pa was set for a particular hazard that is likely to cause two fatalities;
- The proposed system was assessed and a predicted risk of  $8 \times 10^{-5}$  pa obtained. Given that the negligible risk is taken as  $10^{-6}$  pa, the application of ALARP is required;
- For a cost of \$6,000.00 USD, additional instrumentation and redundancy will reduce the risk to just above the negligible region ( $2 \times 10^{-6}$  pa);

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- The plant life is 30 years;
- A gross disproportionality factor of 10 is used;
- The cost per life saved criteria is becomes  $10 \times \$2,000,000 \text{ USD} = \$20 \text{ M USD}$ ;
- The cost per life saved is calculated by the cost of the proposal divided by the number of lives saved of the plant life, as follows:  $\$6,000 / [(8 \times 10^{-5} - 2 \times 10^{-6}) \times 2 \times 30] = \$1.3 \text{ M USD}$
- Based on this calculation, the cost per life saved is less than the cost per life saved criteria; therefore, the safety improvement should be implemented.

The application of ALARP to a mine model should evaluate more than just the cost of the system. The cost of additional IPLs is negligible to the cost per human life; however, the process interruptions due to false positives do have a significant impact. Typical operating costs of a large haul truck vary between \$500/hr. and \$800/hr. (USD). Typically, process interruptions from a loss of communications or a false detection of the object detection system results in a chain reaction across the fleet shutting down the fleet until the interruption is resolved. In a small fleet of 20 trucks, process interruption would cost \$10,000-\$16,000 USD per hour. In more common sized fleet of 50 trucks, process interruption would cost \$25,000-\$40,000 USD per hour.

### **Meeting the Requirements of IEC 61508**

Based on the Alberta OHS regulations on AHS and movement within the regulatory environment of Western Australia, it is likely that AHSs will at some point be required to demonstrate conformance to the requirements of IEC 61508. An active topic within the Global Mining Guidelines Group focuses on the application of Functional Safety to AHS (GMG, 2019). Their problem statement, “The industry is not aligned. Available international standards applicable for mine autonomy are not clearly defined and the requirements for managing functional safety are therefore unclear,” demonstrates the lack of clarity on the application of the standard; however, Alberta OHS has already included ISO 17757 in their regulations for AHS.

Certification under IEC 61508 takes two forms: certification of the organization creating the product or system and certification of the system. It is not credible to expect certification of a product without verification of the organization producing the product. Many of the companies associated with AHS cleared or could clear the burden of ISO 9001. However, the situation with IEC 61508 is different and less well developed. Self-certification is not precluded in IEC 61508.

IEC 61508 includes a provision for a system to be “Proven in Use.” As an alternative to the rigorous process of Parts 1 and 2, statistical data from field applications may be used to satisfy IEC 61508.

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Due to their large number of trucks, Caterpillar and Komatsu could argue that their AHSs achieved a ‘proven in use’ demonstration.

In November 2018, Caterpillar announced they hauled one billion tonnes and traveled 35 million kilometers (Caterpillar, 2018). Assuming the average speed of their trucks is 20 km/hr., the result is 1.75 million hours of operation. AHS trucks operate approximately 7,000 hours per year, which means that Caterpillar has approximately 250 years of operation without a lost time incident (LTI) or fatality. Because truck numbers have climbed to over 500 and annual movements are approaching a half billion tons, it is likely that Caterpillar could claim a SIL 3 rating under the “Proven in Use” path.

While a majority of the requirements to meet IEC 61508 are the responsibility of the manufacturer, the implementation strategy and supporting documentation are critical to the success of the deployment as well as the potential certification of the system. Implementation philosophies, restrictions, and limitations will contribute to an effective and practical implementation of AHS and are also critical in the certification of a system under IEC 61508. An adaptation of a Functional Safety “V” diagram presented in ISO 26262 Standard “Road Vehicles Functional Safety” shows the stages of the Functional Safety process that should be the sole or shared responsibility of the mine site Figure 7. Functional Safety “V” Diagram Adapted from ISO 26262.

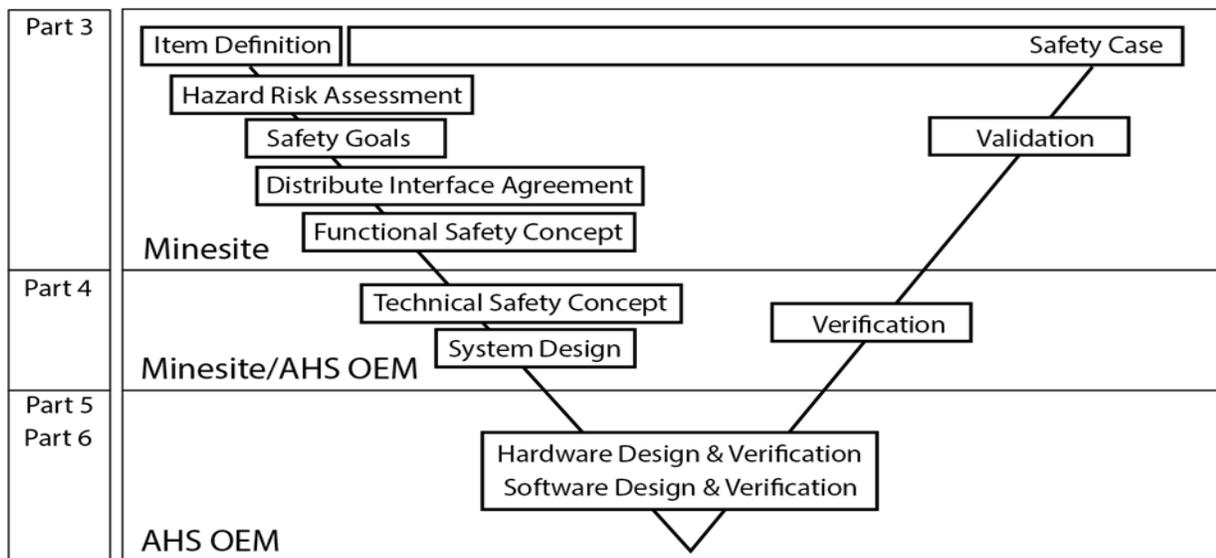


Figure 5. Functional Safety “V” Diagram Adapted from ISO 26262. Figure 7 depicts a 3 layered graph with the following layers from the top layer down. Top Layer - Part 3: Minesite: Item Definition- Safety Case, Hazard Risk Assessment, Safety Goals, Distribute Interface Agreement, and Functional Safety Concept; Middle Layer- Part 4-Minesite/AHS OEM: Technical Safety Concept, System Design and Verification; Bottom Layer- Part 5 and Part 6: AHS OEM: Hardware design & Verification and Software Design & Verification.

## **DMIRS Incident Data**

The DMIRS logs all accident and incident data for various categories of events (Department of Mines and Petroleum, 2017). AHS incidents fall into two categories: “Potentially serious occurrence” and “Loss of control, failure of braking or steering heavy earth moving equipment.”

### **Potentially Serious Occurrence**

A potentially serious occurrence is any event at a mine or exploration site considered by the manager to have potential to cause serious injury or harm to health, even if no injury or harm occurred. Sixteen potentially serious incidents related to AHS equipment occurred during approximately 20 years of commercial operations of AHS in the Pilbara region.

Of these incidents, one was a mechanical failure of a braking component where the truck’s control software did not correctly identify the fault. Another was an AHT that was struck by lightning. A third incident was a complicated semi-teleoperated event where the control room attempted to remotely control an AHT and nearly tipped it over by backing it over a stockpile. A loss of communications followed by a failure to follow procedure results in a collision of two AHTs. The remainder of the incidents were manned breaches of site procedures. Specifically, manned equipment failed to adhere to the hierarchy of vehicles. At many mine sites, the larger/heavier vehicle has the right of way. When this procedure is utilized, all AHTs are located at the top of the hierarchy regardless of their actual size. Included in this type of traffic management plan is a minimum distance that machines must maintain from each other with the exclusion of passing each other in opposite directions.

Luckily, only three of these breaches resulted in a metal-on-metal incident. Two incidents were collisions between an AHT and a manned water truck/cart, where the water truck/cart operator failed to yield to the AHT. Another incident was a collision of a manned wheel dozer into a parked AHT. The remaining incidents are made up of exclusively manned vehicles failing to yield to an AHT. In these cases, the AHT utilized its object detection and object avoidance systems to prevent the collisions.

### **Loss of Control, Failure of Braking, or Steering of HME**

Twenty-three loss of control incidents were recorded by the DMIRS involving AHTs during approximately 20 years of operations. Of the twenty-three logged incidents, eight were loss of control incidents due to wet driving conditions caused by heavy rain events or over watering of roadways. One of these incidents resulted in a metal-on-metal contact. Traditionally, simple manned slides due to wet conditions rarely are reported to the DMIRS at active mine sites. Any slip or perceived loss of control by the AHT is directly reported to DMIRS; even slips that would be considered non-events in manned vehicles.

It should also be noted that due to the travel lane restrictions of an AHT, any breaches of its travel lane triggers an abrupt emergency stop. Understandably, in slick conditions this results in a more severe slide than a manned machine would experience. Two loss of control incidents were

due to abrupt emergency braking that caused a skid. These two incidents were tied to a loss of communications and a positioning error that triggered a hard stop. Two more incidents occurred due to loss of traction from road conditions and grade where abrupt emergency braking caused the AHT to slide.

Additional incidents are accounted as follows. Two were due to mechanical failures outside the autonomous system. One incident was due to a geotechnical issue on the dump. One incident was due to a detection error during edge dumping operations. Two other incidents were likely due to software or operational procedural issues. The first of these was a windrow strike that occurred due to a complex dynamic lane assignment. The second is still under investigation but, based on the author's private conversations with site personnel, a communications issue is believed to have temporarily stopped operations.

Four incidents included manned vehicles where the responsible party was operating the manned vehicle. In three of these cases, the manned vehicles were AHT that were intentionally, in two instances, and accidentally, in one instance, switched into manual mode. The last incident occurred due to a hierarchy failure, where a manned vehicle did not yield to the AHT. This event occurred in 2012 near the initial date of AHT deployment for the operation. Once operations resumed, an AHT backed into a parked AHT. It is worth noting that the incident involved a Caterpillar system that did not implement rear-facing object detection.

## **Conclusion**

The international approach to regulating autonomous haulage systems (AHS) in mining demonstrates a marked contrast to the MSHA's prescriptive methods created by the "strict liability statute" within the Mine Act. While jurisdictions like Western Australia and Alberta have embraced risk-based frameworks and functional safety standards, their implementations have yielded demonstrably positive safety outcomes. The success of these regulatory approaches is evidenced by several key findings:

1. Western Australia's maturity in AHS regulation, with its "duty of care" standard and risk management techniques, has influenced other jurisdictions globally. The DMIRS guidelines, while not prescriptive, have provided an effective framework for safe AHS implementation. This approach aligns more closely with OSHA's general duty clause than with MSHA's strict liability framework, highlighting a fundamental difference in regulatory philosophy between U.S. mining and general industry safety regulation.
2. The contrast between MSHA's strict liability approach and the duty of care standard used in other jurisdictions is particularly relevant for autonomous systems. While OSHA's general duty clause allows employers to demonstrate reasonable care and implement evolving safety technologies, MSHA's framework poses unique challenges for implementing new autonomous technologies due to its prescriptive nature and absence of a duty of care standard.
3. Alberta's OHS regulations represent an evolution in regulatory approach, incorporating specific international standards like ISO 17757 while maintaining flexibility for site-

specific considerations. This hybrid model demonstrates how prescriptive elements can be effectively combined with risk-based frameworks, potentially offering insights for future MSHA regulatory development.

4. Incident data from DMIRS over approximately 20 years of commercial AHS operations show that while incidents do occur, they are largely due to human factors or environmental conditions rather than autonomous system failures.

The evidence suggests that risk-based regulatory frameworks, when properly implemented with appropriate safety systems and procedures, can achieve superior safety outcomes compared to traditional prescriptive approaches. The success of international AHS deployments, operating under duty of care standards similar to OSHA's general duty clause, provides valuable lessons for future regulatory development in the United States.

## References

- Caterpillar. (2018, November). *CAT® AUTONOMOUS MINING TRUCKS HAUL ONE BILLION TONNES*. Retrieved from Caterpillar.com:  
[https://www.cat.com/en\\_US/news/machine-press-releases/cat-autonomous-mining-trucks-haul-one-billion-tonnes.html](https://www.cat.com/en_US/news/machine-press-releases/cat-autonomous-mining-trucks-haul-one-billion-tonnes.html)
- CDC. (2020). *Mortality in the United States, 2018*. Washington, DC: U.S. Department of Health and Human Services Centers for Disease Control and Prevention.
- Center for Chemical Process Safety. (2001). *Layer of Protection Analysis - Simplified Process Risk Assessment*. New York, NY: American Institute of Chemical Engineers.
- Department of Mines and Petroleum. (2014). *Code of Practice for Safe Mobile Autonomous Mining in Western Australia*. Perth: State of Western Australia.
- Department of Mines and Petroleum. (2017, March 10). *Safety Regulation System - Summary for Industry Awareness*. Retrieved from Government of Western Australia - DMP:  
<https://srs.dmp.wa.gov.au/SRS/Public/PublicationSearch?publicationTypeEnum=SummaryIndustryAwareness>
- DMIRS. (2014). *Code of Practice for Safe Mobile Autonomous Mining in Western Australia*. Perth: State of Western Australia.
- DMIRS. (2019). *Safety Performance in Western Australia Mineral Industry 2017-18*. Perth: DMIRS.
- EMESRT. (2016, April 5). *EMESRT PR – 5A Vehicle Interaction Systems*. Retrieved from Earth Moving Equipment Safety Round Table: <https://emesrt.org/wp-content/uploads/2017/01/EMESRT-PR-5A-Vehicle-Interactions-2.pdf>

GMG. (2019, April 12). *Understanding the importance of functional safety for autonomous equipment*. Retrieved from Global Mining Guidelines Group:  
<https://gmgroup.org/importance-functional-safety-autonomous-equipment/>

Government of Alberta. (2019). *Applying for Occupational Health and Safety Autonomous Haulage System Approval*. Edmonton: Government of Alberta.

International Electrotechnical Commission. (2016). *Functional Safety*. Geneva, Switzerland: IEC.

ISO. (2019). *ISO 17757:2019*. ISO.

ISO. (2020, February 23). *Consumers and Standards: Partnership for a Better World*. Retrieved from ISO.org: [https://www.iso.org/sites/ConsumersStandards/1\\_standards.html](https://www.iso.org/sites/ConsumersStandards/1_standards.html)

Miller, B. (2020). *Ph.D. Thesis, Functional Safety Fault Tree Analysis of a Model Autonomous Haulage System*. Golden: Colorado School of Mines, Mining Engineering Department.

MSHA. (2019, January 10). *MSHA Reports 27 Miners Dies in 2018*. Retrieved from OH&S Online: <https://ohsonline.com/articles/2019/01/10/msha-reports-27-miners-died-in-2018.aspx?m=1>

NIOSH. (2016, July 18). *Hierarchy of Controls*. Retrieved from Centers for Disease Control and Prevention: <https://www.cdc.gov/niosh/topics/hierarchy/>

State of Western Australia. (1994). *Mines Safety and Inspections Act 1994*. Perth: State of Western Australia.

Appendix C

## 9. Appendix C Workshop Notes

<b>Workshop</b>	<b>Location</b>	<b>Date</b>	<b>Workshop held in conjunction with these conferences</b>	<b>Attendees</b>
1	Tucson, AZ	December 2022	SME Arizona Conference	21
2	Denver, CO	February 2023	MINEXCHANGE 2023 SME Annual Conference	17
3	Virginia, MN	April 2023	SME Minnesota Conference	15
4	Boston, MA	June 2023	Rapid Excavation and Tunneling Conference	16
5	Phoenix, AZ	August 2023	Hydrometallurgy 2023	24
6	Canonsburg, PA	October 2023	SME PCMIA Conference	17
7	Nashville, TN	March 2024	NSSGA Conference	12
8	Triadelphia, WV	March 2024	MSHA ACC	14
9	Elko, NV	March 2024	Elko Mining Expo	10
<b>Total</b>				<b>146</b>

Appendix C

# Workshop 1

1	Tucson, AZ	December 2022	SME Arizona Conference	21
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## Opening discussion

Regulation is wide open, so automation is the operators' problem.

Does not really address automation, e.g., you have to chock a truck with no driver.

Seems like the regulator is just waiting for the operator to make a mistake with automation.

### 2 areas of autonomy to discuss:

1. Operator assisted autonomy – not perfect but will save lives, changes risk profile.
2. Full automation – difficult for OEM to introduce to the US.

Consider the [Earth Moving Safety Roundtables in Australia \(EMESRT\)](#)

### 9 levels of safety

1-6. people and process

7. technology awareness

8. collision awareness

9. complete autonomy (how do we get here?) – the technological challenge is costly.

Perhaps parse into operator vs. no operator

MSHA is selective (not consistent) in terms of autonomy and enforcement.

Technology must be a partnership (OEM, operator, regulator)

For example, with autonomous pit monitoring you may be shut down too early, even though the system knows when safe shutdown should occur → any knowledge = liability

Autonomy and safety – regulation are two separate issues in the US.

This is why many of the top tier companies chose not to operate in the U.S.

In Australia, the burden is on the operator to manage risk, different in US.

## Appendix C

### Questions:

- ➔ What does collaboration look like?
- ➔ How do we develop autonomy alongside enforcement?
- ➔ How do we ensure consistent enforcement?
- ➔ In other regulation active involvement has been required (e.g., dust)

Autonomous drills are a good example of systems widely adopted in the U.S. with relatively few issues.

In autonomy risk factors are related to

- Speed/mass
- Operator (assist or not)
- Comparative size (light trucks, biggest haul trucks)

### Dynamics of the problem with regulation:

- Is there technological capacity and know how in MSHA?  
Tech support capacity is needed in MSHA.
- No cooperative nature or opportunity
- USBOM lost the federal tech assistance – NIOSH has the narrower H&S mandate.
- There is a need to educate MSHA.
- Could there be some sort of external tech assistance arm?

New technology is, by nature, disruptive. US companies tend toward lean brownfield projects. (example, trolley assist).

US operators do not mind “leading edge,” DO mind “bleeding edge.”

Workforce is already a problem → this makes autonomy less of a threat to workers because there are not enough workers.

U.S. factors driving autonomy

- Proven autonomy solutions

## Appendix C

- Decarbonization
- Lack of workforce

The relationship between operators and MSHA is not constructive – significant transformation is needed, along with operators collaborating towards technology. (WHERE do we (operators/OEM) want to be most strongly aligned?)

How do we build a collaborative and constructive relationship – OEM – Operator – MSHA?

Why does the US lag much of the developed world in mining autonomy?

- The workforce is relatively stable now.
- Cost

These factors are changing rapidly.

Also, the U.S. is already highly productive with cost relatively optimized which is why US is not leading edge in autonomy.

Is NEPA an issue as well as the 30 CFR?

General agreement, yes

Design is not long term and not aligned with a technology roadmap.

Decarbonization-automation do present new opportunities to raise investment in mining, but brownfield remains challenging.

### Barriers to automation:

- It just does not work.
- Too many units for the system
- FCC radio frequency issues (some disagreement here, also dependent on population of area of operation)
- The hardest part of the system is haulage, specifically haul trucks.
- Automated haulage systems work but not economically feasible – fundamentally problematic for brownfield operations – the economics are NOT trivial.

### Discussion of haulage fleets

- In large companies it is about optimizing fleet replacement – e.g.,
- Company with 500 haul trucks
- Old trucks cannot run automation.
- Generally, long term rebuild programs are used.
- To replace 400 trucks → \$2 billion in capital IF you can get them.

## Appendix C

- Hard to introduce in a hybrid way.

*Rest of the world is really impacted by China.*

China has doubled fleet – new trucks so automation introduced more rapidly.

### Consideration of Geopolitics

- ➔ US culture is about relationships with employees, labor relations, we will upskill small groups of people now.
- ➔ Other countries → industry organizations work through issues with regulators (we need this!)

**Breakout group – Question 2** – much discussion of how different companies fund and manage R&D (very differently – for some R&D is specific, for others it is carved out of capital and operating at specific operations).

### What is driving autonomy?

- ➔ Customer demand (not enough workers)
- ➔ Looking ahead, companies will invest in new technology with promise.
- ➔ OEMs will prioritize based on financial impact to the customer and willingness to partner.

### Cyclical nature of mining

High return, high potential, but even then, may not come to fruition in a down cycle.

### R&D in mining companies

- ➔ Different depending on site.
- ➔ Must have high TRL.
- ➔ Must have value proposition across the portfolio.
- ➔ How much \$ can we afford to spend just learning? Versus reasonably expected return on investment
- ➔ Sites have to be convinced of value (they bear the real cost in some companies, and they always bear the disruption cost)
- ➔ This requires leadership and culture shift → advances strategy based on future gains (somewhat new to mining)

## Appendix C

- ➔ In North America this will be driven by decarbonization demand and critical supply chain
- ➔ Still, uncertainty on how U.S. policy will develop around CO2 emissions, especially CO2 tax.
- ➔ Government incentives around CO2 would drive investment in automation.
- ➔ Allocating capital is otherwise difficult.
- ➔ Decarbonization WILL reframe autonomy.

Partnerships are needed – change how we work as a modern industry.

- ➔ Common direction to solve common problems.

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De-carbonization = Electrification. Autonomy is the key to making electrification acceptable over other energy sources.

What have your experiences regarding barriers and regulations?

- 90% of the agencies will view it as punitive if the safety system is not complete. Related to 56.1400 safety defects which have not been updated since 1972. Thus, automated safety systems raise our negligence exposure.
- Example – camera systems watch operators for tiredness. The operator unplugs the camera. This could lead to a MSHE violation. The operator did not want evidence that he took hard hat off which violated corporate policy.
- Some companies do not want to take non-mandated actions because it takes on risk.
- Regulators will not specify anything, so they cannot be blamed.
  - Example: How do you chuck the tires on a truck if there is no driver? Regulators will not answer. Instead, they wait for you to screw up and then fine.
- Automation versus Operator Safety Systems:
  - U.S. – No defects. 100% correct, all the time, every time
  - Other countries – Not perfect, but overall saves lives
  - Some companies will not sell certain operator systems in the U.S. but will in other countries.
- Automation for Hauling: No regulations. Work with regulators.
- The U.S. mining industry should be more involved in the EMSR (Earth Moving Safety Roundtable)
- Operator vs. non-operator haul truck.
  - Operator is harder in U.S. non-operator is easier. One non-operator truck at Barrick. Non-operator is safer.
- Selectively enforcement on chucking (trucks vs. wheels)
- U.S. Law is about legal liability. “This doesn’t change what we do.”

## Appendix C

- Collision avoidance has been available for 30 years. Aggressively being implemented now through partnership with operator and developer.
  - Most companies focus on need to save lives.
  - If systems are not maintained, citations should be issued, shame on us.
  - Radar can detect problems earlier – better than in the past – focus on stopping “too early.”
- Two issues
  - Automations in safety
  - Regulations in safety – Some companies do not want to operate in U.S. because of this)
- Behavior based on safety works.
  - Compliance based safety does not.
- In Australia, safety/risk assessment by company before a decision

What systems run here vs. other countries?

- Full automation in the U.S. is not a problem.
  - The decision is economic.
- NIOSH/MSHA relationship with mining companies
  - Concerns about getting the agencies involved too early.

What is the collaboration relationship between regulators and U.S. operators?

- Regulators have a lack of education on automation.
  - It takes weeks/months to mitigate issues.
  - Maybe they should be involved earlier?
- With full automation by one company, regulators were brought in early.
  - Regulator – show me what you want, not a partner, then regulate after screw up occurs.
- Bingham Canyon Case Study
  - Landslide
  - 103K Order - run everything by MSHA and cleared by them.
  - Autonomous drills, excavators, etc. to clear unsafe areas
  - Not a regulation concern from that case.
- MSHA is not an issue, just not part of the development process.
- Education is the key for regulators at D.C., then local.

What has worked?

- Systems are now rolling out in the U.S.
- Tier one operators represented at this workshop. Thus, not looking for help from MSHA or NIOSH

## Appendix C

- Smaller operators will seek advice from NIOSH/MSHA
- Discussion about automation is too broad. Different answers for drills, truck, car, etc.
- Risk related to if an operator on-board, speed and size of equipment.
- Tier 1 operators are different than Tier 2 or 3
- The company stated that at some times in the past, automation technology did not work, and this is why it was not implemented.

### Difference between U.S. and Other Countries

- U.S. less mandated and more litigated than other countries
- U.S. operators are o.k. with this. Some international firms are not.
- See COVID response as an example to differences in government approaches.
- MSHA needs training from Industry.
- MSHA is an enforcement agency.
  - Enforcement is different by district.
- U.S. has no “bureau of mines” to help. Australia has that.
  - No one to partner with inside the U.S. government
  -

### General Comments

- Industry is going through a transformation (de-carbonization). This will be expensive. More cost-effective solutions are needed.
- Industry needs to align with what are the fundamentals.
  - Suppliers/OEM think they understand their customers.
    - This is not always true.
    - Need relationships between operators and vendors.
- A list of technological innovations of what worked and what did not work would be useful.
  - DOT for autonomous cars could be examined for haul trucks.
  - Western Australian guidelines could be considered as best practices.
  - MSHA’s vagueness gives flexibility.
  - Prescriptive rules should be avoided.
    - Example -MSHA Boiler Code from 1975. New materials cannot be used because they were not invented in 1975.
- Regulation is not causing the U.S. to lag in mining automation.
  - A mining equipment provider – U.S. will be last.
    - U.S. workforce does not change.
    - Already really productive – hence less economic drives.
    - U.S. mining not growing.
      - No new mines, Greenfield sites help with adoption.

## Appendix C

- New technology is disruptive and can lead to reduced production.
- Brownfield sites are already lean and hard to justify.
- Only so much improvement, implementation, or disruption
- Mine is not designed for automation technology.
- Rest of the world was impacted by “Mine by China” leading to many greenfield mines.
  - U.S. not impacted due to large domestic consumption.
    - Some U.S. companies are not leaders/ they are followers.
  - Need new technologies designed specifically for brownfield sites.
- Regulations/Permitting to start new mines is hindering automation.
  - Mine permitting process started 10-30 years ago before automation technology existed.
  - Mine plan will not be changed to delay process.
- Iron Range has implemented some technologies due to favored economics
- U.S. now cannot hire enough workers. This has changed the economic considerations.
- Drivers for U.S. Operations
  - Technology has been proven elsewhere.
  - Carbon-free (ESG)
  - Cannot hire people post-COVID.
    - Idle trucks are a big economic driver.
- Location matters in the implementation of technology.
  - Nevada mining mostly on public land – mine plans are very detailed.
  - Arizona can be on private land – this allows more flexibility with the mine plan.
  - Mining on public lands causes significant risks if a mine plan is changed.
- Automation decisions are limited to certain points in time.
  - Make a decision, then you cannot go back, wait for re-capitalization.
- Financing is not a barrier to mining automation.
  - See South America where automated mining was successfully financed.
  - Greenfield mining will be automated everywhere (open pit?)
    - It depends on where the mine is in the permitting process.
- Everyone agrees that automation for drills and dozers work. Trucks are harder, but they work.
  - Retrofitting brownfield sites are technically feasible in most cases, but the economics are very difficult
  - Retrofitting also related to mine manager decision and negligence liability.
- Haul trucks have 15 yr life + rebuilds.
  - Some older models cannot be retrofitted with autonomy.
  - One company has 500 trucks worldwide.
    - A \$5 million/truck = \$2.5 billion capitalization

Appendix C

- Not enough truck building capacity in the world
  - Fleet replacement must be examined at the “right time.”
- U.S. operators are concerned that autonomy will replace operators.
  - May Impact Labor Relations
  - Need very strong trust and collaboration with workforce and company.
  - Need to communicate that automation will not eliminate jobs, upscaling of current employees, cannot hire enough replacements.
    - These conversations have not started.
- U.S. does not have industry/regulator education system.
  - Australia does and they system works. Collaboration and proactive solutions occur.
  - South Africa does not, system does not work.

<b>Successful technology</b>
Fatigue Monitoring
Fleet management
Drones
INSAR
RADAR/LIDAR
Dynamic ERPs (Enterprise Resource Planning)
Electronic delay in blasting
Automated guards on belts

- Fear of being sued is a barrier.
  - Liability under the 1977 Mining Safety Act
  - View on OEM liability
    - Very different than 10 years ago
    - One company will not put their system on their competitor’s equipment due to potential liability.
- Technology rollout slowed down to make sure industry was ready.
  - This had a bigger impact than liability concern.
  - Automation forced change management aspects.
    - A lot more playbooks are available now.
      - You will implement these or have no sale.
    - Not sold to everyone
    - Are we behind in plug and play systems?
      - Systems are complex.
      - Bluetooth cannot be trusted.
        - Can fail during critical alert.

## Appendix C

- Technology that did not work – “Dispatch System.”
  - Terrible management change
  - Now OEM personnel on onsite in response to previous failure
  - Some sites are not ready for technology.
    - Example – no fatigue education, no fatigue management, fatigue cameras will not work.
- A change management playbook for the mining industry would help remove barriers for automation.

Was MSHA involved in technology implementation?

- Fatigue monitoring – MSHA was involved.
- MSHA is not really involved in technology implementation.
- Drones – FAA involved.
  - Implemented from other industries.
  - MSHA is going to ask about training, policy, and standards.
    - This is why change management training and playbook are needed.

More General Comments

- Barriers may be different for smaller companies.
- Industry standards
  - See GMG (Global Mining Guidelines) efforts as an example.
  - EMSR provides one voice by industry.
    - Many involved
    - Define and describe the problem, not the solution.
  - Industry is very good about sharing on safety.
- Autonomous truck was presented at MineExpo in 1996
  - There was no business case then.
- Data is really important in implementing autonomy.
- MINESTAR
  - Failure when first available, but you could see the value.
  - Investment needed to create a system.
  - Now a “kick-ass” system
  - 20–25-year product
- Software is always oversold.
- Technology success comes from working with a mining company from the beginning.
- By 2030, 2X autonomous fleet is needed.
  - Scale issue
  - Very difficult to achieve.
    - Lack of supply of equipment

## Appendix C

- Lack of technicians and trade schools
- Lack of workforce development
- Automation technician training is a barrier.

### Terms of Timeframe

- 5-7 years acceptable payback – depends on size of investment.
- Entire haul fleet (big investment, production disruption)
- It depends on the risk.
  - ROI lower than smaller site
- For single technology piece – less than 12 months

### Safety vs. Economics

- Look at data – frequency and magnitude of incidents.
- Fatigue Monitoring Example
  - # of vehicles (frequency)
  - Haul trucks (magnitude)
    - Falling asleep #1 cause
- Collision avoidance
  - Cannot find a system that works.
- Barrier historically was data collection to confirm improvement.
  - Now KPI's provide feedback.
- Slope stability
  - Could not control error on side of safety.
  - lead to increased production by automating radar.
  - RADAR, Airborne/satellite scans lead to prevention.

### Debt Financing

- Limited U.S. data on financing new large automated haulage
  - No greenfield sites
- Financing foci
  - On time, On cost, Full capacity
- Engineering firms have no incentive to implement new technology.
  - Liability issues if capacity is not achieved.

Appendix C

## Workshop 2

2	Denver, CO	February 2023	MINEXCHANGE 2023 SME Annual Conference	17
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- Drivers that are encouraging mine automation
  - Shortages of skilled labor and sometime difficult to utilize foreign labor due to visa and related regulatory challenges.
  - Environmental and dust exposures
  - Operational delays and loss of productivity between shifts (particularly in UG Mines)
  - Cycle times (unit operations and haulage)
  - Challenging and unstable ground conditions, including backfill.
  - Vein Mining (Narrow-vein)
    - Dilution
    - MMW and access constraints
    - Faster and more rapid development and mining processes
    - More efficient energy and resource consumption
    - Selective mining
  - Automated drilling systems
  - Environmental monitoring
    - Ventilation & dewatering
    - Evacuation of blasting gases
  - Information to support autonomy and other innovations
    - Real-time and validation
- Covid significantly changed the operational view of many companies. Greater emphasis on sensors and equipment reliance on productivity. Less dependence on human interaction/reliance.
- Safety by itself, is no longer a sole motivator for technical innovation. Must be aligned with economic and productivity. Cost is the driver (CAPEX vs OPEX)?
- How to quantify the impact of automation relative to corporate goals? Economics & productivity. Maintenance & repair (costs - labor and inventory), and mechanical availabilities key considerations
- Companies must evaluate their own systems and processes.
  - Impacts corporate priorities.
  - Internal barriers often exist.
  - Often iterative; solve one constraint/barrier and a new one appears. Hard to forecast and to predict.

## Appendix C

- Social and Workforce Barriers
  - Some operators are reluctant to share technology and data.
  - The current mentality of many operators is more than a decade behind other industries.
- Different countries have different standards and regulatory environments.
  - No Global Standards – lack of consistency complicates technology integration.
- Zero net change in labor requirements between operations utilizing autonomy and conventional truck haulage. Worker relocation and training utilizing alternative skill development. To what employment role or categories do these workers take? Need to investigate this statement.
- Global Perspective
  - For many operators, it might be more efficient to improve unit operations, equipment utilization, and production scheduling.
  - In general, most mining companies have difficulties in adapting to change.
  - Eliminating human operators may increase truck productivity while reducing operating costs and increasing predictability. In these situations, human operators represent a risk. However, it is often difficult to make that argument.
  - While prescriptive regulations are a deterrent to automation, it may not be any specific regulation. Cumulative impact and mentality
  - There are well defined reasons that discourage mining operations from being early adopters of technology.
    - Permitting, Financing, Lack of supply chain & OEM support, operating risk
    - Rule of “5”
  - Continuous & automated maintenance activities on equipment while in operation (e.g., conveyor systems). Interesting concept, particularly relevant to high-cost equipment and infrastructure
- How do companies prioritize investments in technology (what types of systems and kinds of innovation)?
  - Differences in risk assessment creates large gaps between comparable US and foreign operations (why?)
    - Liabilities, including personal.
    - Strict liability derived from the 1977 Act and administered through 30 CFR will penalize companies for deviating from established regs, even if there is a better alternative for a given situation.
    - Compliance vs. risk-based regulatory frameworks
    - Zero harm mentality rather than focus on incremental improvements

## Appendix C

- The structure of the US regulatory system is a problem, not individual regulations.
  - Given the rapid pace of technical change, MSHA may need to make significant structural changes and regulatory reforms.
  - Applied research relative to innovation is intimately tied to company priorities. Different drivers. Sometimes may be added by tax incentives (Australia).
  - Can insurance be utilized effectively to circumvent some of this liability? Only Civil applications.
- Group Consensus  
Assessment of Barriers to Automation:

Regulation	20%
Economics	45%
Technology Readiness	20%
Corporate Willingness	10%
Social License	5%

Drivers of automation

Labor shortages are important.

Removing workers from exposure to particulates

Inter-shift delay

Cycle time... challenging ground conditions. Get in and out faster.

Controlling dilution

Savings...rapid deployment

Potential reduction in development time

At Leeville, new zones are set up for autonomous systems which improves productivity.

Visa issues are keeping some tech folks out of international mine sites.

Safety alone is not a motivator. Productivity improvement. No one will innovate solely to innovate.... Cost is the differentiating factors for new entrants to automation.

Internal constraints on data handling are a barrier. Individual operators are unwilling to contribute data to an anonymized cloud-based AI training protocol.

Global regulatory inconsistencies. No global vehicle to vehicle frequencies. So, communication is an issue.

## Appendix C

Iterative barriers...as soon as one hurdle is cleared, industry has another hurdle, then cost... etc. etc. because these issues are raised serially, they end up requiring repeated re-design in order meet the latest objection.

Lower maintenance and tire costs are now a driver... lower maximum load per lift but steadier maintenance and lower overall maintenance costs.

Shifts planning from daily to more strategic....Autonomous will not solve all your problems, it will just help you find them faster.

Mixing manual equipment and autonomous can actually reduce productivity.

Elimination of break and shift changes times could increase productivity hours by 5600-7000.

ISO/Canadian/Australian reg. systems. Core principal is how risk is defined... other systems have risk reduction tolerance... U.S. system looks at zero risk.

Any regulation hindering adoption...need historical context.

Architecture of regs. is a barrier to automation not necessarily individual regulation.

4 drivers to staff a truck 24/7 in autonomous deployments...it is reduced to 3.5/truck. Net increase in cashflow into community because of increase in job skill. [does the 4 include maintenance? Is it not really around 6 when maintenance included].

Conveyor maintenance generally requires that equipment be shut down... issue is maintenance while running.

The total environmental cost of building a truck will not beat the cost of a conveyor overall. So, there is pressure to move to hybrid conveyor/small truck system.

Surge loading will decouple loading from shovel dipper size.

Priorities as far as innovation... capital budgets, etc. how do they prioritize?

Komatsu... safety first, productivity second, profit third.

Productivity has to be connected to safety.

CEMA will not implement anything that would hurt a member company. It limits what the north American product array looks like.

OEM conveyors do some research on their own. but may look for an industrial partner depending on the cost.

Some are regulatory forced, some are not. Gains made with an industry partner are perhaps more valuable than without as they are generally more applicable than just trying to guess what the future holds.

## Appendix C

First Majestic mostly works on metallurgical aspect. Corporate investment is considered a separate fund from site capital. So, it does not affect the site performance.

What are the barriers?

Regulation, Economics, Social License, Tech Readiness, Corporate Willingness.

First Majestic starting ventilation on demand. Then asset tracking. Wifi and leaky feeder on all levels. No significant rock stress issues at their Mexico mine.

Ore sorting systems are needed when hoist limited. Lucky Friday is coming close.

What drives companies to try any innovative systems? There are water and emissions regulations. Getting ahead of regulation... you force yourself to get ahead of it (like DPM) because you know it is coming.

In the absence of regulation, what motivates you? Tailings for instance Global (GST) recommendations. It will be needed for insurance and social license.

Most innovations are coming from Tier One operators.

Biggest barriers ranked:

- |                          |     |
|--------------------------|-----|
| 1. Economic              | 40% |
| 2. Regulation            | 25% |
| 3. Tech Readiness        | 25% |
| 4. Corporate Willingness | 5%  |
| 5. Social License        | 5%  |

Operating/safety regulation prescriptive.... Environmental regulation; forward looking emissions/discharge/conservation.

Tech Readiness not only depends on the mine as well as the tech itself. For instance, trying to create infrastructure for autonomous systems in a large old mine is a much more significant investment than it would be for a newer, smaller mine.

What is the payback period for investment in new tech? Minimum IRR of 15% but time is not that important. Next answer IRR of 20%-25% also time not so important. For OEMs... the key is that they are in the parts business...for conveyors, it was time to market.

Is financing resistance an impediment to innovation? R&D costs are reimbursed dollar for dollar by Canadian Gov't. Australia gets a 3-dollar tax saving for R&D.

Appendix C

## Workshop 3

3	Virginia, MN	April 2023	SME Minnesota Conference	15
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### General Discussion

Most participants feel that solutions are technically ready for process plant automation and surface mining applications, with the exception of barriers associated with mixed fleets (infrastructure, training, etc.). They generally feel they have to unify the fleet to achieve autonomy.

Cost of entry is a barrier, and different sites are at different levels of technical readiness.

Social license is seen as a barrier, particularly around workforce. The mining operations drive the economy in this area. Participants acknowledge that autonomy might not result in net job loss BUT would require new skills and upskilling – individuals would be out of work. Additionally, the mines are unionized (United Steelworkers), and efforts toward full autonomy would be fraught and potentially jeopardize social license. In this area, the operator workforce is not a challenge (salary engineering workforce is somewhat challenging). Also, in Minnesota, mining does not enjoy public support, but the workforce benefits are seen as very positive.

Ultimately, the participants do not see a return on investment for full autonomy in the Iron Range Mines. First, there is no shortage of workers. Next, both Cleveland Cliffs and US Steel are steel companies – the cost of mining is seen as relatively small (~25%) compared to the rest of the business, so gains in efficiency and productivity in mining may not be prioritized. Likewise, the positive carbon benefits associated with automation and social license are seen as relatively small in this part of the business.

One additional challenge is the nature of operations in the Iron Range – old brownfield sites that are more difficult to retrofit.

One operator said their strategy is to upscale workers and they will do it (not in the Iron Range).

There is substantial concern around the two major mining OEMs and their perceived market control and share; operator concerns include:

1. By choosing an OEM for a fully autonomous solution they have lost the leverage needed to keep costs down and service quality high (e.g., as they do with mixed fleets, and new purchases). A full solution “locks in” an operation.
2. There are concerns that any new regulation will be driven almost entirely by the two major OEMs and leave little room for innovation, and market share for others. (See Alberta, CAN regs).

## Appendix C

3. One barrier for smaller OEMs to join is patenting strategy. One example was a Sandvik patent around charging of mining equipment – not a novel invention, and when applied to mining, still mundane.
4. Data ownership and access was also discussed. The OEM full solution provider now has access to data that will allow them a more complete understanding of how their solutions impact the business and give unfair advantage in setting costs. There is also a feeling that the data may be leveraged against operators. One operator indicated that they were trying to understand why tire wear and costs were high but could not easily access their own truck data, so instead they installed scales (not as accurate/precise and additional cost, but easier).
5. There was concern about infrastructure and the specialized nature of infrastructure required for full turnkey solutions. The need for standard architecture was stressed, but also acknowledgement that it may be too late – manufacturers have already made substantial investment in their own infrastructure.

Quote from discussion: “Automation doesn’t result in headcount reduction, but better, more innovative approaches from skilled workers.”

### **Regulatory Issues**

There was some discussion of permissibility from one person who works in coal. This includes long wait times, cost, and inability to update technology easily in the MSHA approval process.

Iron Range operators have not really pushed regulation because they are not at the leading edge of automation.

There are disparities in terms of enforcement from MSHA. Regional control of enforcement is problematic, e.g., in Texas line of site is needed for remote drilling (but not actually written in the law). There is a need for some more non-biased interaction with the regulator, it will be interesting if more automation comes to construction sites and becomes regulated. Most participants believe the construction industry lags mining considerably in terms of automation.

If there was regulation that incentivized autonomy it would drive it here, because there just is not economic case yet. Participants compared it to the push on emissions in the automotive industry. One solution might be to require some features on haulage (automatic stopping, proximity detection, situational awareness, etc.), but not full autonomy.

ISO standards are pretty good...they are risk assessment based which is problematic in the U.S. context where often the only acceptable risk allowed is zero (i.e., unattainable).

From the standpoint of these operators the regulatory risk is the risk of the unknown. It is possible that insurance costs could drive some technology.

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There was some discussion of funding models with consideration of: a) autonomous as a service and b) venture capital projects within a mining company.

### Capital priorities identified by participants.

1. Maintain production.
2. Safety/regulation (sometimes 1 depending on the issue)
3. New technologies are what is left over (not much)

Contractual models do not work well at union operations (seen as work union members can do).

Data collection and storage → unused data actually creates a liability.

At one company projects <\$250,000 in AI are eligible for strategic investment, requires business case.

One example of incentivization – drilling, can specially make the case around shift change, productivity gains are very clear in autonomous drilling, and can allow for less rigs to run 24-7.

This OEM is collaborating with customers on site to develop technology. Generally, there is a high financial incentive for the company, but they must tolerate the development process.

If you make huge improvement to one machine but it is not the critical component, then there is no business case. Every site for this this company in the Iron Range is truck limited. The ROI process is a barrier. Multiple components of the operation (and multiple automation processes) must be considered and integrated.

Participants indicate a very small capital budget for any automation on the mining side (not sure about steel side of the business).

One company is investing in data, especially data digestion, so it can be utilized.

### **Breakout Group (B Miller, A Schaum, B Atkinson, T.)**

1. No, not an important component. Currently, the mine is just a cost center. The decision is made on a short-term basis. The strategic advantage, however, is that both companies make their own pellets. Automation either has to save a lot of money or be forced on them. There is major investment in environmental improvements that will positively affect permitting.
2. Discussed this question at length in prior discussion. Sulphate regulations are so low it is almost impossible to permit new mine. Any technology that would require re-permitting or permit review would not be considered at all.
3. Short, not confident proposing anything with more than 2-year payback. Some even less. On company is putting in HPGR (\$10-\$20 million), expecting immediate payback (Y1).
4. Depends on how you fund big projects – use bonds a lot, try to use ABL as much, there is a lot of funding. Financing does not seem problematic.

## Appendix C

	<u>KL Group</u>	<u>HM Group*</u>	<u>Final Consensus</u>
Regulation	10	5	<b>see KL</b>
Economics	50	20	
Tech Readiness	5	50	
Corporate Willingness	20	5	
Social License	15	10	

*\*HM group also had “coal” column (90, 5, 10, 5, 10)*

There was a discussion of how to create new regulations. Participants do not want to have a monopoly driven by the two major OEMs. They believe there should be an open protocol that all trucks run on. This was the principle of GMG.

Interoperability by OSDU, especially on petroleum side, would be very interesting to look at. Data interpretation is sold as a service.

Participants recommend that as part of the regulation, just like right to repair, operators should have the right to data.

There was more discussion of how difficult it is to integrate various trucks (training, stock parts, infrastructure), participants say operators feel forced to go between two OEMs to keep prices down.

Between the two Iron Range Operators there were no recent major accidents/fatalities that were identified; however, there was general discussion of some near misses:

- Metal on metal, metal on high wall, especially at dawn
- Light vehicles flattened.
- Berm surfing – tire damage, etc.
- Jostling the operator, back and neck issues, because of large chunks

Finally, there was further discussion of how to drive automation. These participants think that a phased process is key; companies will likely phase in driver assist technologies to begin. The safety case can be made, and safety money is considerably more discretionary.

### **Automation General Discussion**

- Most of the operators felt that the technology associated with autonomous Hal truck was sufficiently advanced to integrate into mines, but not most other pieces of equipment and infrastructure.

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- Mixed Fleets (mines using both autonomous and manually driven trucks) represent a problem both from a perspective of operations and safety.
- Capital costs are considered to be the most significant barrier to entry for innovation.
- Politics is an issue, primarily from Organized Labor and Internally within the companies.
- Smaller Trucks utilize more people (Union considerations), where the initial capital expenditure (CAPEX) is more amenable to the companies.
- The CAPEX of automation is a barrier to investment.
- The Iron Ore Mining Companies are all now owned/operated by Steel Companies. Investment for innovations generally goes to processing facilities and steel production units, and not to the mines. The mines are viewed solely as a supplier of ore and represent a small percentage of the overall cost, where the benefits for investment are directed towards higher value-added processes. The research budgets for the mines have been slashed over the last decade.
- Drills are capable of autonomy but have not been implemented for a number of reasons. The perceived costs are too high.
- COVID has a large impact on the types of innovation that has occurred at the mines.
- In terms of growth, investment capital and budget allocation has been directed towards the acquisition of other properties instead of technology. Believed to have higher growth potential and less risk (bigger impact) than technology.
- Technology integration has numerous social repercussions, including employment transitions. It is important to understand social issues around the operations and the labor history.
- Unions are devoted to the preservation of jobs. Anything that threatens this, including technology, will find resistance. From a cost perspective, labor is one of the few economic drivers that a company can control. Given the history of labor/employment losses in the area due to automation, innovation has a poor perception by the work force and unions.
- In terms of the labor force, most hourly workers at the mines have high school education and are considered locals. Workers from outside the area generally have a very high attrition rate, it is hard to adapt to the harsh climate. As such, labor shortages can be serious, where the mines are in competition for workers from the local communities.
- That said, there are currently no labor shortages.
- Application of new technology is usually driven by the need to achieve compliance with new regulations or to address challenges that threaten the economic survival of the operation.
- All operations are watching what new technologies and processes are being used by competitors.
- Equipment OEMs generally will not support collaborations on new technologies unless it is extremely economically lucrative, and they maintain IP. Terms vary from OEM to OEM.
- There is a belief that if a company aligns with a specific OEM to integrate new technology, they will lose leverage in negotiating with other companies.

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- The question becomes how a company justifies change. Varies significantly from one company to the next.
- Successes of working with OEMs and Suppliers has been in communications, software, and data collection.
- Technology implementation by companies is heavily dependent upon presenting a business case.
- Safety alone is usually not a motivating factor without economic argument. Combination of factors, but economics are crucial.
- Assessment of the total benefits derived from automation and autonomy helps operations justify the expense and necessary commitment.
- The age of the operations on the Iron Range serves as a major deterrent to integrating new technology. Difficult to adapt to changes.
- The impact of technology assessment
  - Scalability
  - Factors governing success.
  - Key factors are independent of technology itself.
- While there was some disagreement between the two iron ore companies, most of the participants believed that the biggest barriers to technology were Economics and Corporate Willingness. It was assumed that if technology were advanced enough, it would never make it through the corporate decision-making processes.

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## Workshop 4

4	Boston, MA	June 2023	Rapid Excavation and Tunneling Conference	16
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### Drivers Encouraging Automation

- Labor Shortages
- Employee/Worker Dust and Environmental Exposures
- Labor Efficiency (Delays between Shifts), particularly in Underground Mines
- Faster Cycle Times – Impacts labor productivity and Production Capacities
- Challenging Ground Conditions – includes Backfill.
- Narrow Vein Mining (Challenges that New Technologies can Address)
  - Dilution
  - Minimum Mining Widths and Heights
  - Faster (Rapid) Development
  - Selective Excavation and Mining Systems
  - Automated Unit Operations, particularly Drilling Systems
  - Environmental Monitoring
    - Work Areas Inspections and Safety
    - Control of Ventilation, Blasting Gases, Heat, and Dewatering
    - Equipment Monitoring and Rock Support
- Infrastructure to Support Autonomy and other Innovations/Automation
- COVID significantly changed managerial perspective concerning the operating environment and dependence on skilled labor.
  - Greater emphasis on automation, greater use of more sensors and data collection, greater reliance on equipment capabilities in support of production and ancillary activities, less reliance on human productivity and judgement (less truly skilled workers)
- Safety Improvements are Critical and Must Include Considerations Associated with Economics and Production. This also must comply (Be Consistent) with potential goals of the company.
- Major consideration should be given to Equipment and Infrastructure Maintenance and Repair
  - Discussion/Analysis should include Equipment Availabilities, Economics, and Capex
  - All new Innovations must undergo a review of this type, plus potential hazards.

### Barrier Discussion

- Companies Must Evaluate their Own Systems and Processes

## Appendix C

- Familiarity with all the Factors and Characteristics Involved
- Impact on their Priorities
- Internal Barriers often Exist.
- Iterative Barriers Often Exist; where if a Company Overcomes one, others will subsequently Appear. Often Iterative process
- Social and Workforce Barriers often Exist.
  - Some Operations are Reluctant to Share Technology and Data
  - Current Mentality is Responsible for Delaying some Innovations by up to a decade.
- Different Countries have Distinct Standards and Different Regulatory Environments
  - No Global Standards and Lack of Consistency
- Zero Net Change in Labor Requirements Between Truck Autonomy and Conventional Methods
- Worker Relocation Alternatives and Required New Skill Development

### **Global Perspective**

- Better to focus on Mining Operations and Scheduling Operations (biggest bang for the buck)
- In general, many companies have difficulty adapting to change.
- Eliminating Human Operators May Increase Truck Productivity, while Reducing Operating Costs.
- Automation also Increases Predictability (Important), where Humans are Highly Unpredictable
- Prescriptive Regulations are a Deterrent; this does not apply to any specific regulation.
- There are Well Defined Reasons that Discourage Many Operators from Being Early Adoptors to New Innovations and Technology:
  - Permitting & Financing
  - Risk vs Benefits.
- Continuous Maintenance of Mobile Equipment, like Shovels, is an important concept. Similar to the Conveyor Discussion that was raised in the Workshop in Denver.
- How do Companies Prioritize Investments regarding the type of innovation:
  - Differences in how Risk is Assessed
  - Large Gap between US Mining Companies and Countries. Why?
    - Liabilities
    - Zero Harm Mentalities
    - Compliance vs. Risk Based Regulatory Structures
  - Priorities Towards Innovation
    - Applied Research Focused on the Company Needs and Challenges. What could impact their Ability to be Safe and Economic.

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Engage in research? What are the considerations in selecting operational systems and trying to improve them through software and hardware? Sometimes try to utilize systems for unconventional purposes. Buy TBMs and try to learn how they work and figure out how to modify them to make them better.... Work closely with manufacturers. Cost is a concern as well as time. Also try to find folks competent in the technologies and a lot is from out of the U.S. and it is expensive and logistically problematic getting those folks in. But it would be better if they could have come from the U.S. It would be better to train their own folks as that would be better suited to the uses they engage in.

Learn about different technologies from a variety of sources including conferences, OEMs, shared information among various companies.

As a design company, they work for owners and contractors. Uses data collected from prior jobs to fine tune designs. Cooperation on equipment among all stakeholders is important. Mostly young folks run models, but it requires a P.E. so sometimes they run models and sometimes just review what has already been done.

There are a lot of stakeholders so it is important to get everyone on board on the production level. That is often the challenge. Specs prohibit or do not allow for innovative techniques, and it is too late in the game to change them. How do we define who takes risks from new techniques or equipment? It depends a lot on the procurement process. Sharing risk and reward can push innovation forward. The risk sharing process generally starts at the outset of the procurement process.

First question is who has used this before and the answer can be a deal killer. As far as going into other industries is difficult as well. How much does someone really “like” what is being presented. Selling new ideas is harder than simply improving existing systems.

Case studies presented at conferences can help with that but sometimes the company does not want to share all the information without an NDA or another sort of agreement.

How knowledgeable and savvy is the owner’s staff. If the contractor cannot get a response in a month or two it is too late. Currently there are more prescriptive specs which place more responsibility on the contractor. Go through bidding and get selected and then the contractor has to build to a set of prescriptive specs. That then complicates the process.

Public entities are not going to take big risks. Debate about how the project gets built. Does designer think they are smarter than the contractor, etc.?

Most crossover between the mining world and the tunneling world is on the material extraction side.

The biggest barrier is owners not being savvy enough to realize the impracticalities of what they are asking for.

## Appendix C

The biggest innovation in tunneling is the size of the tbms. The tunnels are getting bigger and shallower, so ground movement monitoring has developed quickly to deal with that. Seattle project. The machine got stuck and had to be rebuilt but once done, there was much less settlement than was predicted.

Progressive design-build involves hiring a contractor based on qualifications and then getting the concept finalized and the contractor comes up with a price. If the price does not work, then it has to be re-bid. Most of that risk of that method is with the owner. The contractor does get paid for the work that was done but can then take an offramp out of the deal if the price does not work out. But that is not always attractive to the contractor because most of the profit is in construction and not the design. The size of the contract makes a big difference. If the owner tries to treat a \$25MM contract like a Billion-dollar contract that generally will not work out.

Regulatory barrier. Ontario wants a “hoistway” in each shaft to the surface.

Internal cooperation is a growing trend in moving decisions forward. Designers are moving towards 3d so that would be a direction in terms of innovation budgets. Is the data gathered by TBM operations gathered and analyzed? Yes, the data is valuable as far as establishing trends and explaining what may happen in certain grounds and operating conditions. Also useful for training the field and TBM engineers on how to cope with those conditions. Each separate contractor has an individual effort. Collecting real time data helps react to changes in conditions or problems like subsidence as soon as possible.

There is a fair amount of information sharing among companies, but some information is held confidential. They have to concentrate on safety based on their visibility among other things. But safety is good economics. But there are other regulations that impact them.

They need more and more people to keep up with the administrative requirements that are imposed on them. It is an ever-growing burden. The cost of doing the work continues to grow. More complaints etc. if you work in an urban environment. A lot more dealing with the mayor’s office.

Safety is generally the key. Most owners these days make it a requirement to use certain types (or even brands) of equipment.

Ever have issues with CO2 emissions? Some states are more restrictive than others about idle time, etc. but generally not much of an issue. Not a growing problem.

### **Barriers to automation**

Economics	35%
Technology Readiness	20%
Corporate Willingness	20%
Regulations	15%
Social License	5%

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## Workshop 5

5	Phoenix, AZ	August 2023	Hydrometallurgy 2023	24
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### **Part I: Discussion led by Mike Moats**

Where have we been successful in automating processing plants? Discussion was wide-ranging and included mineral processing and mining.

- Load IQ, sensing of ball strikes, allows for optimization of performance.
- Expert control of flotation circuits
- Underground automation has substantially improved productivity and safety.
- Automation of online control to examine grades in the coal industry (e.g., ash concentration)
- LIBS and DRS are good examples of optical technologies for sensing grades.
- A big challenge is the online analysis of precious metals at low concentrations.
- One example is a plant in another country where they wanted to put in automation (plant with thousands of I/O loops) - there was initial reluctance in an area where labor was inexpensive, but afterwards they requested similar installations at other operations.

How do you replace highly experienced and skilled metallurgists with sensor technology, i.e., the person who could walk into the plant pick up a handful of concentrate and understand many different issues nearly instantaneously?

Flotation remains a challenge, we understand the froth and the reagents, but the AI systems cannot match experienced operator performance. On the other hand, we have successfully automated other things such as grinding. There has been tremendous automation around flow between cells, and measurement of froth thickness.

What about automated crusher maintenance? The mechanics who do the maintenance make experienced decisions and they use very precise tools, dexterity, and strength for crusher maintenance (operator). From an OEM perspective, wear-sensors still require more development but have not reached maturity.

Laboratory automation and robotics, including continuous flow of samples, pulp splits and digestion, etc. The gathering of these data into material balances, metallurgical spreadsheets, and control input. Standardization of these systems is desirable. The LIMS (Laboratory Information Management System) is key.

Mill liner changeout is now far more automated. In terms of safety, there has been high safety improvement in confined space jobs in plants.

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There remains substantial work to be accomplished in upstream-downstream knowledge exchange (what mineralogy is coming to the plant or mill from the pit?)

One commentor indicated that we cannot discuss plant automation improvement without adequate sensors. While we are still struggling with sensing technology, we cannot assess the process conditions without it. For instance, in SAG mills we now better measure load charge profile and liner wear.

On the mining side, we now see the ability to really assess and respond to machine health, and perform maintenance on demand? Is the same true on the processing side? Getting sensors that can do the job is part of the problem – the other piece is sensing that is ruggedized enough to survive the process.

On the OEM side, connectivity is a huge challenge. OEM are machine experts but struggle to connect to monitor for health and efficiency. The difference is that in a plant there may be 15+ OEMS, and there is no standardization of connectivity → looking at OSIP. The barrier of cross communication is IP and trade secret divulgement, this (along with cybersecurity) will certainly make companies leery. We must ensure that OEMs only get data from their own machines. The OEM perspective is that the operators will have to demand it, in order for this to happen.

Why is data harder to get out of the plants to OEM versus the mine fleets? One operator says they have processes in place on the mining side. Because the fleets have not gone completely autonomous it is ok – there is still an operator – that is not true of a plant. A recent major cybersecurity incident at a major mining company highlighted this difference. Some mining systems were affected while plants were not. The level of automation in the plant is higher so cybersecurity risks are higher; protection is becoming key. This will also change the way operators view fleet and dispatch technology soon. There may be an approach that allows data storage on site with highly controlled sharing going forward. The OEM perspective is that standardized protocol would improve security. The operators in the room agree.

What are the barriers around sensing? Cross belt analysis, downhole probes. Issues are particle size (e.g., boulders), hostile environments, liability. One of the largest barriers was workforce acceptance. Also, no one wants to be first; mining companies tend to be reticent to be on the bleeding edge.

There have been step changes in equipment and process design; automation is high – are we limited by computing abilities? Consensus seems to be that as long as cloud computing is tenable from a cybersecurity perspective we are not limited.

What about inspection and enforcement concerns? MSHA does not present particular barriers, now that one company is moving to fully autonomous fleets, they do anticipate issues but believe that they can work through them. They do not identify issues in the plant.

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Are there concerns around data that are collected, especially for environmental regulation? There was relatively little response to this question.

What is inherent around processing plants that allowed for more rapid uptake of autonomy?

Simple - processing plants do not move – fixed plant. Corporate level often wants to purchase automation, while operators often feel they are more proficient, and cannot get over the hurdle. Trust is the biggest problem, human factors around automation require more study.

What is the next best thing in process automation? It is definitely AI, which is data driven.

OEMs must have connectivity and data access in order to fully leverage AI. One barrier is lack of interest in proper data or lack of conviction that it is needed. Manual sampling not following protocol is still common, automatic samplers are not being maintained. The management team does not always see the cost-benefit case, especially in brownfield plants which are costly to retrofit. Most of the U.S. is brownfield.

What about the people and workforce? One barrier among operators and the community is the concern about job loss. We still require experienced operators in plants, and there is some trepidation about automation. However, there are other benefits; it is hard to optimize process while dealing with unplanned problems and maintenance – the system can respond. Production bonuses may follow. Humans must stay in the loop, especially at failure points (failsafe states).

**Part II: Kray Luxbacher led the next section of the discussion (no notes).**

**Part III: Small group discussion - 2 project personnel + OEM processing (1), OEM underground (1), high-tech consultant (1), and mine operator (1)**

Applied research and technical innovations are an important component in the company's operating strategy. In particular, zero emissions are an important piece of strategy. One OEM strategy is always around safety, and when they produce an idea, they take it to a nearby operation. They agree and the machine goes underground, but then troubleshooting and change actually becomes difficult because the machine is in production. Occasionally, the customer makes recommendations. One OEM is looking at improving performance – in particular, new technology for the flotation process, but they went back to equipment longevity and maintenance, so they are now adding additional wear sensing. Another company says safety drives all of their development, and then they come in with a solution based on what the mine asks. On critical processes, the mine operation does not want to be on the leading (or bleeding!) edge – they do want to innovate in areas where they control risk and reap benefit (e.g., leaching, but not haul trucks).

Priorities depend on several different things, but immediate needs matter – are we struggling in a critical process to meet targets? For instance, in the area of autonomous haulage – the interest was future haulage requirements, battery assist and trolley, but now (post-pandemic) the driver is

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manpower – how to retain and house people, for instance. So, they look at strategic future needs, but then immediate needs trump strategy.

For OEMs and high-tech consulting, safety, and competitors both drive priorities. The high-tech consultant is trying to stay ahead of competitors. From a budgeting standpoint, they want to minimize machine cost and stay competitive in the market. Some investment aims to improve safety and life cycle cost – can we show the customer that we are minimizing their cost? On the other hand, with respect to policy and regulation there is a big focus on global warming policy, especially if the parent company is European. The consultant says they will take big risks on capital investment, and they try not to be the only early adopter – their business is predicated on assuming the early risk. GHG reduction is a long-term strategy for capital investment. Financial decisions around GHG reduction are evolving rapidly. GHG emissions reductions are causing increased engine costs for OEM – the commodity market drives the path. OEM permissibility is a problem with coal, and the cost for permissibility is quite high.

For the OEM immediate payback is generally required, selling the technology to the customer at a discounted rate, they just cover the cost, and then hope to gain in the long run. The high-tech consultant needs ROI in year one, other processing OEM hopes for 2-3 years, testing in the field prior to pushing out to other customers is 1-1.5 years. More advanced technologies may take even longer. One off 2 years or less, but longer term might be 5-6 years Just finished an acquisition of technology. An example around acquisition of HPGR (high pressure rolling mill) technology was given, which can hopefully help to meet zero emission goals (reduced water consumption, in this case) – can use to replace a SAG mill. Evolving ESG concerns are really changing mindsets, and even the 2-year mindset is changing. Additionally, several mine commodities markets look quite healthy in the long term, so companies tend to be more comfortable with longer ROI.

There was little discussion around conventional debt financing, other than to say that current high interest rates are not encouraging investment in technology.

This led to discussion of permitting, specifically that so much money is spent permitting the mine, that there is little money left to actually innovate in terms of automation, this permitting cost does not result in value gains to the community, workers, or company. Permissibility guidelines, etc. by MSHA are quite cumbersome – these rules were written decades ago. One participant's perspective was that many citations written do not have considerable impact on safety and health. Another observed that field modifications at MSHA take many months.

FAA regulation is also becoming problematic, although two positives are the 1000' vertical airspace for mines (that benefit is dependent on pit depth), and the use of Nevada mines as a testbed.

The group determined the following constraints are barriers to automation with final consensus from the whole room included.

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<b>Constraint</b>	<b>Group 1 (process)</b>	<b>Group 2 (coal perspective)</b>	<b>Group 2 (process)</b>	<b>Group 3 (process)</b>	<b>Final consensus</b>
Regulations	5%	95%	2%	0%	<b>3%</b>
Economics	35%	0%	40%	35%	<b>35%</b>
Technology Readiness	20%	5%	43%	35%	<b>32%</b>
Corporate Willingness	15%	0%	5%	25%	<b>15%</b>
Social License (workforce impact)	20%	0%	10%	5%	<b>15%</b>

**Participant’s initial thoughts on innovation and potential barriers to technology implementation**

- Free range of exchanges of ideas and technologies that possess knowledge gaps (research areas)
  - Given that most of the participants had a technical background related to mineral processing, much of the discussion focused on hardrock extractive metallurgy with applications related to copper and gold.
  - Areas identified in need of innovation include:
    - Control and operating systems related to material flow, floatation, material consumption, energy, and water use.
    - SAG Mill operations related to ball optimization, such as Load IQ (tracking ball strikes and energy efficiency of grinding media)
    - Underground Mining Equipment- focused on productivity and safety.
    - On-line Process Controls and Integrated Sensors that utilize analytical tools for measuring PH., ore grades and densities, and etc., such as SRX.
    - There are large challenges associated with metal processing that extend to energy consumption, low grades, and documentation.
- New Focus Areas:
  - Robotics applicable to production
  - Sensor development and camera (vision) technology in adverse operating environments
  - Sensor technology with capabilities and physical characteristics to potentially replace human senses, such as smell, touch, temperature, and sound/hearing.
  - Floatation advances related to automation and assaying. Capable of analyzing conditions and making real-time adjustments.

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- Maintenance usually requires human experience and judgement – how does one transfer this to a machine or control system.
- Thickeners; ability to measure and control settling rate, turbidity, density - requiring new sampling systems and sensors.
- Filtration technology
- Automated feed and adjustments: cells vs. leaching. This extends to pretreatment technologies.
- Conveyance and slurry systems; more reliable and efficient. Improved maintenance and greater availability
- Maintenance coordination between different equipment is always a challenge.
- Many of the OEMs cater to larger processing facilities, not sole mining. For small to medium plants, it is difficult to work with them directly in terms of innovation. Small part of the overall market.
- Processing technologies and machine processes are not generally standardized or consistent.
- Technology needs to be operator driven, not by OEMs.
- Ownership of collected data is a challenge, OEMs, or the Mining Company. There are significant concerns related to data security and the control of new technology.
- Requires data sharing agreements, where OEMs can access the data through standardized agreements. Data security is a paramount issue, as is ownership and approved uses.

### Sensor Technology

- The challenge for suppliers has been that operators have a need for new types of reliable sensors but are reluctant to share data or to participate in research.
- The biggest constraint is that companies do not want to be engaged in this type of research, they just want proven technology that they can use. The expectation is that this equipment will be developed and vetted by others, where the company can just purchase it as needed. This makes it incredibly difficult for suppliers and OEMs to find research partners.
- 
- There are significant limitations related to the collection of lab information, its analysis, and the execution of processes that can help guide commercialization. This includes pilot plant testing. Requires internal capacity by the OEMs and suppliers, and an understanding of the supply chain. Significant financial risk, particularly given the relatively small market size. That said, many companies are not limited by this potential risk (not true 20 years ago).
- Are there any concerns related to regulatory barriers or compliance issues?
  - From an operator's perspective, the company works with the supplier or OEM, and not with MSHA. As such, it is not an issue. Furthermore, many of these processing facilities are under the jurisdiction of OSHA.

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- In many of these companies, Corporate Management focuses on the review and implementation of new technologies and expects that the operators will accept them, even if it is inconsistent with the established operating goals and interests.
- OEMs and suppliers are an important source of information on new technologies.
- Since most processing facilities are capital intensive, have long lives, and “don’t move,” the process for innovation is believed to be different than mining equipment.
- One of the driving innovations for the future is AI and how large datasets will be collected, analyzed, and used. (Detailed algorithms)
  - Lack of commitment/trust in the collected data is a major concern and requires significant investment. For example, auto samplers have proven to be highly inaccurate)
  - The quality of data is not there. Goes back to the need for reliable sensor technology.
  - It is difficult to know how good your data really is.
- Labor concerns associated with autonomous equipment and processes.
  - Not really a concern at this point.
  - Online collection of data and control (where there is a reduction in the need for workers in a facility) is currently influenced by the best industry practice and is often mandated by company management. Plants need people for maintenance, and what happens if things fail? The focus should be on semi-autonomy. There are current limits to labor dependency, and it is accepted by management.
- Technology is often driven by a false economy.
  - If a technology company develops a new widget (like something related to autonomy), mining companies (as end-users or clients) will often look at short-term benefits and economics. There is generally a reluctance to evaluate or compare technologies on a long- term basis. The process of forming a justification for companies to invest in new technologies is often fraught with challenges (very short-time horizons).
- Regulatory Compliance as a Technology Barrier?
  - Regulations are not a barrier to adopting technology in mineral processing.
  - The drivers do not have sufficient funding, and the financial risk is associated with implementation.
  - Corporate Buy-in and approvals are major drivers.
- End-users often push/drive OEMs back to standards (making sure technology conforms to best industry practices). Each company prescribes to its own set of control standards. Often requires a corporate mandate to move from this.

## Appendix C

- Industry engaged in autonomous control standards should solicit federal resources to advance technology and standardization. Hard to do otherwise.
- Mine to Mill is a very old concept, but the integration of AI to assist control optimization has an interesting potential. Concerns over changes in orebody composition and muck characteristics might represent a challenge (or an opportunity).
- Unfortunately, there is a lack of two-way communication and dialog between companies and OEMs on innovation and technology priorities. No trust and opposing economic objectives/perspectives.
- Discussion Group III
  - Regulations: 0%
  - Economics: 35%
  - Technology Readiness: 35%
  - Corporate Considerations: 25% (Important consideration: change management)
  - Social: 5%

- 
- Environmental regulation led to automation in emissions control and monitoring.
  - Automation leads to more steady state for processes, preventative maintenance, and improved safety.
  - Automated laboratory auto samplers and analysis are safer and better for waste control.
  - Need for continuous monitoring of discharge effluents leads to automation.
  - Barriers – mining – drones crashed – all drones banned; underground drones not allowed for coal mining.
  - Big barriers for automation – ROI, risk aversion, culture; not regulation
  - Standardization of connectivity between OEMs would help.
    - Each company has its own standards, providing funding from government to incentivize.
  - Mine-to-mill automation is in its infancy, but it is coming.
    - Generic algorithms are more powerful than previously.
    - AI can be used to monitor asset health.
    - Lack of measurements is hurting the process.
  - The permitting process leads to delays in automation implementation.
    - Once a permit is submitted, the process of development is frozen.
    - Slowing the adoption of ore soring and dry stacking

## Appendix C

- Vendor analyzes need and decides on product development. Innovation is needed for survival. R&D provides the ability to stay ahead of the curve. Ideas come from user/operator.
- Large companies perform their own innovation. Small companies rely on suppliers. Regardless, they need a champion on site.
- Automation projects are hard to quantify economics ahead of time. Decisions based on ROI, payback period, miner safety and familiarity.
- Liquid/solid separation – tailings, paste technology, dry stacking – regulation challenges due to regulations associated with wastes.
- Acceptable payback period varies by organization. 3-5 years. 2 years.
- Greenfields more skittish about automated labs. Brownfields more likely to consider.

Appendix C

## Workshop 6

6	Canonsburg, PA	October 2023	SME PCMIA Conference	17
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### Exploring Automation and Soliciting Input on Experiences, Thoughts, and Insights

- Within the region, the greatest need for automation in underground coal applications stem from low coal environments (less than 60 inches to as low as 38 inches) in order to reduce hazards and risk to miners, roof/rib falls, and material handling.
- Operators have expectations that the OEMs should be intimately involved in terms of equipment and system innovation and automation.
- In these operating environments (based on economics, size of mines, and other constraints), there are not a lot of alternatives for driving technology other than OEMs. Operators do not have much capacity to facilitate automation on their own.
- While significant hazards exist in these mining environments, the economic incentives for OEMs to engage in R&D are fairly limited since there are very few customers to warrant the amount of time and investment required. Often dependent upon the OEM.
- The current state of the technology is such that operators still require Miners at the face.
- The technology is not sufficiently advanced to fully automate the mining process. Even if it were, it might not be prudent to do so (human judgement is important)
- Beyond the financial expense, the biggest impediment is the time required to achieve permissibility. The process of determining permissibility in itself is also problematic and often results in equipment “packages” (???) that are often not practical in underground applications. (Note: this statement needs to be clarified)
- In small markets, particularly like underground coal, OEMs are reluctant to advance technologies to the market due to internal costs. Furthermore, end-users have a limited capacity to pay for it and the market is comprised of numerous potential small customers.
- Even when mining companies are willing to participate in the development of new technology/automation, it sometimes also results in complications associated with IP and questions regarding liabilities.
- In the past, Dragger has used NMA to assist in interfacing with MSHA to introduce new technologies and solicit support and cooperation from mining companies (end-users).
- From experience, it takes 3-6 years and costs a significant amount of resources in order to gain regulatory approval. This process needs to be much faster and is far slower than other mining countries.

## Appendix C

- If the technology is already being used in another country, there should be a way to fast track the approval process in the U.S.
- Examples include remote gas monitoring systems and new battery charging systems.
- In general, automation often requires electrification which forces companies to be innovative but often creates other downstream challenges. This is particularly true for technologies developed outside the US, this sometimes means that operators cannot meet specific MSHA requirements. An example includes some innovative associated with underground communication systems.
- Similarly, certain technologies have been adopted by OSHA for gassy or explosive environments, like gas monitoring, but not by MSHA.
- Most companies (including mining and equipment OEMS and suppliers) find it difficult to work inside the current system to achieve permissibility certification/approvals. It is simply too costly and far too difficult to navigate the process. A great case study is associated with the use of drones.
- As discussed previously, vendors and OEMs are reluctant to engage in this regulatory approval process because of the cost associated with it and the relatively small market potential once it gets approved. Not enough potential to amortize the cost of going through the process. Another good example is total stations, which have not been approved.
- In addition, any changes in a given technology often requires it to proceed through new regulatory approval.
- Given the current state of this approval process, it is difficult to adopt advanced equipment setups and networks utilizing sensor technologies for remote system operations. The challenge is only compounded by the fact that the approval process takes far longer than the current pace of technologic development. Once a sensor or electronic piece of equipment is approved, it may be obsolete.
- Standards are necessary for infrastructure that guides new technology.
- Given these realities, adapting technologies from other industries is extremely difficult without significant corporate investment.
- For example, imagine using YouTube videos for training or as instructional guides for equipment or infrastructure maintenance. It is common in other industries but is not applicable to UG Coal due to constraints associated with tablets.
- Networks currently exist but just cannot be adapted or used to make substantive improvements, without going through the approval process again. (Note: We need to verify whether this is a true statement).
- Relative to its mandates, MSHA has no incentive to approve any given technology. Companies struggle with getting MSHA cooperation. Presumably, this is particularly evident if technology does not have a direct contribution or proven outcome with safety.
- There was consensus of many of the participants in the group that MSHA needs to have a mandate which encourages the adoption of new technology for the benefit of the industry. Unfortunately, it appears that MSHA has no appetite for any shift or change in policy.

## Appendix C

- The challenges associated with soliciting the approval of electronic surveying equipment is an excellent example. It needed a loophole in the regulations.
- The introduction of new mining technologies may facilitate problems related to the acceptance by skilled labor. Sometimes it requires different skill sets and ways of doing things (outside of the traditional norm). How technology is introduced and marketed to the labor force appears to be important. This also represents an indirect cost incurred by the mining companies as they adopt new technologies.
- Consol provides additional training for miners to go to school and acquire new skills.
- The group believed that there are deficiencies in the total number of skilled miners and mining engineers available and interested in working in coal.
- In terms of trends, there will be a continued desire by companies and regulators to displace workers from hazardous environments and duties, including longwalls.
- The adoption of technology in places like South Africa maybe easier because of financial and regulatory considerations. However, once perfected, it will be difficult to adapt this technology back in the US.
- State agencies represent another challenge for operators seeking to adopt new technologies.
- In terms of research, shareholders do not have any input for most coal companies. No premium given for companies utilizing advanced equipment and systems.
- Technology is often viewed as a value-added process and is assessed relative to KPIs and budgetary considerations.
- Safety is an important component in company operating strategies and will drive technical innovation. Economics is a much more complicated analysis and the justifications for pursuing a given technology are obviously different and more complex. Regulatory and safety concerns represent the primary drivers for adopting technology.

### I. Break-out Sessions.

#### **Determination of Barriers by the full group:**

Regulation	33%
Economics	35%
Technology Readiness	17%
Corporate Willingness	10%
Social	5%

Introductions were made, and

Dave Kanagy gave an overview of the project.

#### **General Discussion of Automation in Underground Coal (facilitated by Kray Luxbacher)**

## Appendix C

One attendee indicated that his company runs low coal mines, between 38-60”, and that the height and associated equipment profile limit the technologies they can apply.

Longwall automation is one example of a higher level of automation adopted in underground coal. Arch Leer Mines (no representatives) were pointed to as two of the most advanced examples. One participant indicated that the camera technology for this level of automation required almost four years in MSHA approval. Additionally, the Alliance Tunnel Ridge Mine has moved the tail shearer operator to an underground control room (at the longwall). The operator is often in the face when the shearer is moving in the tail direction but is removed from the dust and in the control room when the shearer is moving to the head. Additionally, they have instituted landmark and face automation technology for steering face shields.

Other participants mentioned the critical importance of communication. First, because the underground coal market is small, and the U.S. does not recognize the existing global standards around permissibility/explosibility it is difficult to join the market (too expensive), and it is difficult to maintain systems. One attendee indicated that they use Kenwood radios for wireless communication underground, but that Kenwood no longer sees their manufacture and approval as viable, so supply is highly problematic. Further, nearly every company wants to utilize tablet and cell phone technologies for record keeping, maintenance communication and reference, and training underground, but the need for an enclosure that can contain explosion (not *just* withstand explosion) is a high barrier to use.

An OEM representative indicated that the MSHA approvals for underground coal are highly specialized and very expensive. There was substantial discussion about the MSHA approval process in the U.S. contrasted against the processes in South Africa and Australia. Attendees find that South African and Australian processes are still quite strict and guarantee a safe product but are far more efficient. There was high frustration around this process with the following issues identified:

- a) The process is long and there is no real timeline expectation offered.
- b) Operators and OEMS are regularly encouraged to use the 101C petition to “loophole” the law and find approval for technology (e.g., total stations and PAPRs) that will actually make the mines safer – it is sending a poor message that there is no appetite to change regulation to positively health and safety. The 101C also leaves companies who develop technology for use under the 101C at higher risk, since it must be renewed on a case-by-case basis.
- c) Every part of a new piece of technology requires approval so an entity entering the market needs to identify parts with 10–15-year life, the actual life of parts (before redesign) in high tech is closer to 9 months. Many entities then find they must manufacture their own parts to guarantee supply.

## Appendix C

- d) Highly portable new technology (such as through-the-earth (TTE) often becomes untenable after meeting approval criteria. In the TTE example the participant said that a technology that was backpack wearable ultimately had to be moved by scoop.

Overall, the sentiment was that the structure of regulation absolutely stifles innovation.

One attendee indicated that working with NIOSH can be helpful with new technologies, but others indicated that the loss of IP can be a concern. This might just be an area for improved communication with technology developers.

The funding from NIOSH to wireless companies (e.g., IWT) was identified as an excellent technology driver.

Safety and health – or efficiency – are the major drivers for investment in new technology in coal.

Around fixed gas monitoring there is a real need to monitor for different gases (e.g., hydrogen fluoride around batteries, CO, and CO<sub>2</sub> for diesel, etc.).

Network infrastructure is a huge problem, and standardization here would also be helpful. Redundancy and reliability are required for automation and again, approval processes are a high barrier.

Mines wanting to incorporate drone technology for inspection, monitoring, and emergency preparedness have found it extremely difficult.

There was sentiment that there is no appetite in federal government to incentivize new technology in coal because there is generally not an appreciation for the need to mine coal in the U.S. and that all federal agencies have political realities, specifically a federal anti-coal perspective is also stifling new technology uptake.

There was a lengthy discussion of workforce issues, and the need for a skilled workforce. This appears to be a barrier in the fact that skilled people are needed to maintain automated equipment.

### **Focused discussion on capital budgeting toward innovation and new technologies (facilitated by Hugh Miller)**

Change is often made through a progression of rebuild – incremental change may be made to operating equipment (i.e., small retrofits). The industry does share ideas, as do vendors. “The coal industry is in a race to be 2<sup>nd</sup>” – let someone else prove it first.

Coal industry will always share safety ideas within the industry, including new technology – there are *no secrets in safety*. That is a source of pride in the industry.

## Appendix C

R&D departments are not as robust in the industry and individual companies as they once were, and many simply do not have R&D departments or budgets. This is an area other research entities must help fill.

OEMs are always assessing customer need and risk. Remote locations, deeper mines, and more difficult underground environments are driving new technologies. Partnerships with operators are key to success for OEMS, including applications and specific risk assessments. This dialogue is critical to the generation of new ideas. Solutions from other sectors of the mining industry and other industries have also been very successful.

An example was given of a mine producing high and low sulfur coal to the same main belt (1980s). Ultimately, they installed clean coal segregation via Gammametrics. Started with an operator need and a vendor who could develop the technology. From this mine the technology moved to many mines.

For the most part, there is consistency in new technology across a single company's mines. The workforce is now more mobile (between shifts and operations) → allows technological innovation and safety innovation to move more rapidly.

There was some discussion of public financing and proof of new technology. There was little concern over proving new technology for investors.

One attendee said that he finds (especially in automation) perfect is the enemy of the good.

There was a brief discussion of union influence. Most attendees said they did not see substantial opposition to automation because many workers are still needed. It was noted that the most highly automated coal mines do tend to be non-union.

There was discussion of the role of OEMs in data ownership. One attendee indicated that there is case law associated with raw data (the operator owns it). Processed data is typically contractual. Data security is also an issue, both due to cybersecurity and protected data (such as gas monitoring).

MSHA will use the tracking record to determine if the mine has been adequately firebossed or look at machine logs and gas detection data, but really only for investigation (e.g., injuries, fatalities, G investigation, etc.), not a typical compliance visit. There is a question, what right does MSHA have to high level analytics from a mine site? This is and will be a barrier to high level analytics in underground coal mines. Tracking data is a good example.

### **Breakout Groups**

The group discussed the decision-making process and THEN the percentage barrier. They took a bit of a different approach and first discussed how a board would work through a major capital project especially in comparison with equally impactful safety and efficiency projects. They determined that the conversation would only occur if the project were economically viable, then

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1. Regulation; 2. Technology Readiness; 3. Social; 4. Technology Readiness; 5. Corporate Willingness.

**Determination of Barriers by the full group:**

Regulation	33%
Economics	35%
Technology Readiness	17%
Corporate Willingness	10%
Social	5%

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## Workshop 7

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From an OEM perspective, everything sold on the business-to-business level is price/performance sensitive. If you get new tech that competitors would use to improve their tech, that will ultimately hurt you, but if you can add something that upscales the employee and also improves safety and efficiency, that would help, but when a new vendor discovers the market, the advantage could be lost unless you can get some IP protection around the improvement. Otherwise, there is “unintended tech transfer” via the OEM.

This might be a problem in the high-end industrial minerals sector. It might not be a problem at the commodity material level (i.e., construction aggregate). They might be an early adopter of new tech if they feel it would give them a competitive advantage even for some period. Example, what made them (an aggregates producer) comfortable buying a drone? They had been shown it, etc.

What are our four core KPI’s? How can we use technology to make our technology more efficient? The IP part centers on what materials they are finding and how they are using them. However, the aggregate producer found drones to be too inaccurate for stripping. There are simple tech fixes that can really help like inputting mine plans into excavation equipment, underwater sensors for dredges, level sensors, etc. It is a mix of leading and reacting. Are you concerned about the competitors finding out? Yes, it will all come out eventually, but you get an advantage from it at least for a period.

How do you identify these kinds of simple improvement opportunities? Some of it comes from employees and equipment operators. If it allows the operator to pay more attention to quality and takes away distractions, that would be significant.

Looking at automation that maximizes the expertise of the people you have and takes it so that you do not need the seasoned employee? Yes, that is a part of it. The OEMs are making interfaces or controls that are more user friendly. The same thing is being applied to plants... wash plant systems, etc. Heidelberg has an aggregates academy that was training folks in how the industry works but is now trying to break that up into bite size pieces.

Asking new hires to go and work at a basic level in a process before coming back to them to be hired at higher-level jobs. Most of their senior managers have gone through their academy.

The brownfield nature of the industry requires that new systems need to be seamlessly integrated with legacy equipment. Some plants that used to be controlled by PLC can now be run from a cell phone, but the problem is hardening the phone so that it cannot be hacked. One problem is mixed fleets. If all the equipment were robotic, they would all talk to each other. At a customer’s site, MSHA showed up, there was no one in the seat, and the inspector ignored it.

## Appendix C

The only thing that could be pointed to was when broadband backup alarms were introduced, they wanted to implement them because safer and less problematic for the neighbors MSHA was skeptical but eventually adopted it.

Look at it in a risk-based approach. What problem are we trying to solve and what is this going to do... What may be all the added risks and what is the net result? What is MSHA's reason for being? Are they here for safety or are they here for enforcement?

What is the payback framework in which you look at investment payment? Three-year payback is generally accepted. Of course, it depends on the life of the equipment. No requirement for payback if the change improves safety. But generally, 20% IRR. Using what you think the market acceptance of the product is going to be over the time. Some companies use market price at the time of the decision. Sometimes it is done just because it is the right thing to do. You know that eventually it is going to take over that area of operations. There are "intrinsic reasons" for this. Sometimes it is done to create employee comfort so that it ultimately lowers turnover.

"Total addressable market" ("TAM") is what is used to determine whether some sort of improvement would be made to a particular piece of equipment. Decarbonization of equipment is driving a lot of change and there is a fair amount of automation in that equipment. There is going to be a sea change from internal combustion to electric and there will be a number of solutions just like when automobiles came out.

Does the way you finance affect the way in which you make decisions regarding increased automation? In the past no, but now that we are publicly traded, maybe. It also depends on how the company has met its performance indicators.

Below is the consensus on barriers to automation:

Regulation	10
Economics	40
Technology Readiness	28
Corporate Willingness	16
Social License	6

Industrial minerals or sand/gravel operations employ many GED operators, relatively small operations, no investment hurdle rate but expected <3 yr payback. Use payback because it is easy to calculate.

More advanced industrial mineral operators require at least 20% IRR related to technology development projects.

Any automation project is not a replacement of person what can the person generate more value through automation.

## Appendix C

For mines, it is all about community engagement. A mine must consult with the community and manage stakeholders.

Concerns about digital network innovation and the resulting network security issues. Concerns about rogue state attacks.

Conflict between OEMs and operators on ownership of data and use of data to provide contract maintenance.

Data management systems are different between FIXED and MOBILE assets. Mobile data management was difficult 10-15 years ago. Getting easier with time. The more machines the more innovation due to market size

Cybersecurity is a huge thing.

R&D investment for specialty materials company is always about the money – payback, IRR, competitive advantage, value add or improve price-performance advantage. Internal innovation is cobbling commercial things together to make something special.

Return on investment ranges from 1 yr to 3 yr to 5 yr. Depends on workforce availability. In 5 years, there will not be enough workers. Senior people are leaving and making big voids. A large experience cliff coming.

Significant discussion on workforce development. Companies must get engaged. Career tech development in high school is not a college degree. Starting entry wages need to improve to compete with other opportunities. Need to convince people to stick around – mentor patience and provide a clear path for advancement.

One company invites school administrators to visit mines to see jobs. Use social media to highlight what workers do. Offers junior high tours. They believe these activities improve their ability to maintain a social license to operate. Technology emphasized during tours. Drones. Joystick operations.

For professional ranks, finding people with critical thinking and skills is difficult.

Those with former military experience are considered good employment targets.

It would be useful if NIOSH could have workshops on how technology can help operators make money or what technology can enable them to do.

People are long term “reserves” like “in ground” reserves. Technology helps leverage personnel abilities.

NSSGA has 150 producers as members. There are 10000 aggregate mining operations. Difficult to collaborate.

## Appendix C

For small operations, moving to advanced technologies is often difficult to quantify/predict value to drive economics.

Diesel generators removed (DPM decrease, safety improvement) for stationary power.

15–20-year approval time for quarry in Australia. For gravel, permitting is a barrier to entry and creates a competitive advantage.

Sand and gravel are not earlier adopters. They may adopt technology from other parts of the country or mining segment. Their IP is related to exploration activity, and we are “better” than competitors.

Drones were implemented quickly. Easy demonstration. Reduced time to collect data. Obvious improvement to operation.

Automation can help improve engineering management systems, generate data for KPIs, reduce energy, etc.

Innovation for sand and gravel needs to be simple tech, idiot proof, prevent accidents, automates physical labors – needs to be cheap and easily installed.

Ideas are generated by employees, operators, and management.

Expertise and technical experience built into control systems for wash plants and mobile equipment.

An “Aggregate Academy” which captures and transfers knowledge in bite size delivery modules would be useful.

It is easier to find an MBA than someone who will do hard labor and work their way up.

Bite size implementation of technology is preferred.

The barrier for technology is payback and economics. Selling automation to bring capacity back to design in some cases.

For smaller operations, no one wants to be first. Need scale not 1-3 haul trucks.

A desire for MSHA small mines program to offer “tech support” and partner with NSGGA.

Corporate safety team struggled with regulations are a barrier to technology implementation – Core system is in compliance with MSHA.

Example: broadband sound backup system was introduced – safety improvement and benefits to neighbors – informal “agreement” then followed by MSHA buy in

Another example: Start-up alarms and warnings on conveyors – 30 second delay before start-up (not sure of this point)

## Appendix C

Risk-based approaches to innovation should be implemented.

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### Experience with Automation

- The consensus was that investment in any given technology was a function of capital availability and need, where payback would need to be made within 3 years.
- Given that most aggregate operations have traditionally been family owned and operated and are locally significant in terms of employment and economic impact, social and community engagement are important considerations when making changes. Companies must demonstrate that automation must have a positive net impact on the mine as well as the employees/community. This translated to a different set of parameters associated with a cost: benefit analysis than other groups/mining sectors.
- Major driver for technology implementation at operations is often associated with regulations. Safety was not brought up by the group as a motivating factor at this juncture (later in the discussion).

### Data Ownership and Security

- Who owns the data derived from automation and how to assess whether it is secure? The group thought these represented significant issues not generally considered but that they had far reaching implications.
- The belief was summarized by “who owns the machine – should own the data.”
- In addition, it appears that if the data was derived from a fixed plant (e.g., a processing facility) that it should remain with the company and be confidential, whereas mobile equipment becomes more complicated because of leasing, the use of contractors, and OEM contracts regarding maintenance & performance.
- Data derived from small and auxiliary equipment is viewed differently than larger class production equipment.
- Many of the operators present at the workshop contract out services.
- When purchasing new capital equipment, the expectation is that the data would be belong to the company. Regarding the acquisition of used or leased equipment, it is something that should be negotiated.

### Availability of Skilled Labor

- With regards to automation, the scarcity of skilled labor needs to be considered.
- It is part of the narrative, just like other key drivers that encourage or discourage the implementation of technology.

## Appendix C

- Cannot estimate the influence of labor as a percentage of investment like other industries.

### Value Concepts

- For a valuable/successful technology which is considered to be fully mature (marginal risk), it should achieve a specific return between 35-45 percent.
- It is critical for an operation to achieve incremental improvements in productivity and cost efficiency on a regular basis, particularly on long-lived investments.
- Advancement in technology is usually a collaborative activity between hardware and software development. Example: without the computer systems built by Dell, the development of MS Windows would not have been possible.
- If not driven by safety or regulation, the motivation for innovation must reflect the value (economics) of doing something (doing more activities faster – combination of cost and productivity). The concept is different depending on unit operations (how it is measured and evaluated).
- Regardless of the reason, innovation and the integration of new technologies must be attractive to labor. Must have buy-in.
- Finding value in the aggregate industry for technology is different than other industry sectors. It is difficult to establish collaboration between companies (competitors) and with the OEMs.
- In addition, given the types of data normally collected, it is often difficult to ascertain or estimate economic benefits.
- Most technologies must have quick returns, where project life is relatively limited.
- Government approval for quarries is often 15-20 years, where permitting and social license are the biggest challenges to operations.
- The General Public are generally adversarial to aggregate operations (Not in my backyard)

### Workforce Considerations

- Most companies are resistant to technology investment due to labor considerations.
- The industry is price performance centric, comprised of raw material (place value) + value added component. If all operators are using the same technology and workforce, revenues are similar.
- Attrition is a major concern with so many other producers (employment opportunities)
- Labor requirements largely require a multifaceted skilled hourly work force. Not a great deal of specialization or professional labor is needed.

## Appendix C

- Competition in this industry sector necessitates concerns over labor costs, capital costs, and impact of labor productivity.
- Investing in technology also raises concerns about the transferability of Intellectual property. The unintentional transfer of IP/technology to competitors is perceived to be a concern. Companies know what others are doing, yet very limited collaboration.

### Barriers to Technology

- Technologies that help to create a competitive advantage are internally highly desirable. As are innovations that create value-added opportunities for products and technology that can be integrated by other operational units in the company.
- People must be focused, demonstrate safety advantages and the ability to prevent accidents. Unknown hazards must be quantified.
- Competitive advantages are usually short lived, where innovation must be a continuous process.
- Technology and innovations stem from numerous sources, including what competitors are doing and from employee ideas. Employee acceptance is extremely critical.
- A staged approach towards innovation generally works best to ensure employee acceptance and that the technology is properly implemented (successful).
- Technology interface with labor must be user friendly in order to be successful.
- Prior to implementation of technology, the company must determine the required skills and aptitude of the workforce to effectively operate the technology.
- Given that the aggregate market is dynamic, companies must do sufficient due-diligence and planning.
- Employees must undergo internal task training and education on these innovations, and it is worthwhile to have this training propagate throughout the workforce. Critical thinking is important, as is the transfer of knowledge from experienced workers to inexperienced workers.
- Australia and Canada have skill training and certification programs that might serve as models for the US.
- There was some discussion on whether skill loss within the labor force would occur with autonomous equipment operations. Consensus was that this would depend on whether this was incremental or whole-scale replacement of sectors of the workforce.
- A barrier and limiting factor to the implementation of technology was mine infrastructure.
- When mature operations consider upgrading technology, they must also consider lost production associated with the implementation period. Downtime is a killer.
- For both aggregate producers and equipment OEMs, nobody wants to be first in adopting technology. Too much risk.

## Appendix C

- Again, operations are very dynamic (markets and operating conditions) and must be able to be flexible when selecting and implementing technology.
- Above all else, the integration of technology must be done “right.” Minimize mistakes, oversights, and downtime.
- Additional Concerns:
  - Monitoring and assessing the technology.
  - MSHA oversight & Regulations
  - Difficult for small mines with limited financial capacity.
  - Risk based approach: what are the risks associated with investing in technology and what are the overall objectives? How do you determine if it has been successful?
- What are the metrics for technology investments? This will vary by company and operation, as well as the type of project.
  - Types of companies (public vs. private) and (domestic vs. international)
  - Smaller vs larger investments
  - Length of time
  - Perceived risk.
- For innovation investments associated with safety – no payback or return on investment is required.
- Specific to equipment autonomy, it will depend on the unique attributes of the site and project. The determination is largely gut feel – “Is it the right thing to do.”
- Discussions will often include employees and the impact on marketing to customers.
- Usually step increases are preferred and are dependent upon empirical evidence.
  
- In most cases, investment decisions land in the following buckets:
  - Considered as investments in Safety & Health
  - Considered a business decision (economic benefit)
  - To address employee comfort, aid in performance, or prevent loss.
- For most OEMs, the speculation is they innovate for safety, productivity, and to differentiate their products.
- The Concept of Value (Business Model): it is far better to be a fast follower of technology and innovation than the first company to implement it.

### Barriers to Technology Ranking

- |                          |     |     |
|--------------------------|-----|-----|
| • Regulations:           | 10% |     |
| • Economics:             |     | 40% |
| • Technology Readiness:  | 28% |     |
| • Corporate Willingness: | 16% |     |
| • Social License:        | 6%  |     |

## Appendix C

### Follow-up thoughts by the group:

- It would be helpful to benchmark aggregate companies in terms of innovation both for global markets and associated with like-minded companies (specific products sold and size)
- Include a summary and review of new innovations applicable to aggregates.
- Conduct a similar type of analysis (industry workshops) for the best environmental practices.

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This meeting was focused on the aggregates industry and was hosted just prior to the NSSGA annual conference. We were limited to 2 producers, a representative from Pronto.ai and the new SME president, an industrial minerals representative.

Discussions were wide-ranging and did stray from the topic of automation, but much of the deviation was focused on labor issues. Constructional materials and industrial minerals have similar or potentially more acute impacts from labor shortages. Strategies utilized by representative companies to improve labor access included: middle and high school outreach, social media, and technology demonstrations.

Construction materials mines tend to have smaller fleet sizes both in truck capacity and number. They view themselves as unlike the large mines that can implement widescale automation projects. Many sites only have 3-5 trucks with the larger sites using a dozen trucks.

Based on tighter margins, the required ROI for technology projects must exceed 20%. Although payback periods of two years are more likely to be funded. Projects with a higher safety return can deviate from this requirement.

Many of the large aggregates producers are evaluating complex automation projects such as AHS, but they are more likely to implement task automation to improve operations at a lower cost and lower risk of production interruptions. Some targeted tasks included conveyor train startups, safety signaling, and surveying.

Data security and ownership are important to companies. Friction between equipment OEMs and the miners occurs over data ownership. Discussion regarding cyber security attacks covered public events and other less public events. Cyber security threats to production occur and have impacted some construction material operations.

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## Workshop 8

8	Triadelphia, WV	March 2024	MSHA ACC	14
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Kray Luxbacher gave an overview of the project and preliminary findings.

Hugh Miller facilitated the first discussion, beginning with *where is automation going in mining?*

The automation of small repetitive tasks, often with innovation from the workforce, has resulted in incremental changes in automation.

As we look toward the future there was discussion offsite remote operation – would it eventually be completely offshored to other countries?

Skill sets are changing – the skill of the miner is still critical but so are other high-tech skills. What will cause people with these skills to choose the mining industry instead of a different industry? Another participant pointed out that this is a two-way street – now we have a larger high-tech workforce also available to us.

People in the room had experience with many different companies so it was difficult to coalesce around single questions and discussion was wide ranging.

In discussion of coal two barriers were identified (versus m/nm). First, the small market stifles innovation, and the dynamic nature of the coal mine face also makes automation more difficult (as compared to a block cave, for instance). One operator indicated the following automation priorities:

- Automation of longwall operation (they have not decided where to locate the operator yet, the headgate is loud)
- Improved communication
- iPad for multiple uses (maintenance, records, etc.)
- Google-like goggles so a maintenance coordinator can see what a mechanic/electrician sees.
- Autonomous shuttle car

There was some discussion of Part 46/48 training and how it can be limiting (somewhat old-fashioned, does not really acknowledge upskilling of labor).

There was discussion of automation within MSHA in multiple ways.

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First, the mine rescue technology that MSHA owns is highly specialized, difficult to maintain and may have some automated processes. The operator in the room admitted they do not maintain as much mine rescue technology as they used to. It is difficult to invest in this technology, but it must be maintained in a state of readiness. MSHA really needs designated funding for such technology and for emergency response. The static nature of the budget means that when there is a mine emergency, an unpredictable event, budget must come from other areas. Likewise, there has not been enough investment in certification laboratories which are critical to technology in mining. Further, MSHA experiences the same criticality around recruitment of workforce that industry does, and the workforce for technology is highly specialized.

There was discussion of technology ratcheting regulation (e.g., communication and tracking, proximity detection, potentially the new silica regulation) versus other regulations. There was a general sense that while it can be difficult to point to regulation as a barrier it has the capacity to “chill” innovation. There is a general sense that industry takes a risk when MSHA uses petition for modification to allow pathways to technology uptake, but conversely, an acknowledgement that the regulator is willing to work with industry.

There was some discussion of Part 18 rulemaking and the comment that rulemaking is a “slow lever” for implementing new technology.

There was extensive discussion of proximity detection in underground coal as an innovative technology, approved, that has had a very positive impact on safety. There are currently 4 approved systems, 3 on the market, with 2 unique approaches.

As we moved to discussion of barrier and percent barrier contributing to each it was difficult to reach consensus in this group – both labor and MSHA have had experience with many different companies. They pointed to companies where corporate willingness and safety drivers caused the company to make the decision to go well beyond compliance with proximity detection (e.g., shuttle car proximity detection) and others where a company was fighting compliance with continuous miner proximity detection every step of the way.

Their examples and broad knowledge of the industry made barrier percentage agreement hard, and the group ultimately agreed to assign 20% to each.

Regulation	20%
Economics	20%
Technology Readiness	20%
Corporate Willingness	20%
Social License	20%

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## Comments from the Group Regarding Automation and Perceived Barriers

### General Comments Regarding Innovation, Technology, and Automation

- A general comment was made that the impact and implication of insurance was an important factor influencing the implementation and advancement of technology at operations.
- Labor considerations are of paramount importance and must be thoroughly assessed.
- MSHA is experiencing similar difficulties in attracting professional talent as industry, other government agencies (NIOSH Mining & BLM), and academia. Given MSHA's mission, they need to recruit professionals that are tech savvy and highly specialized.
- Organized Labor
  - The primary focus is on the safety and wellbeing of the workforce.
  - Represents a major factor that can both encourage or impair technology depending on the specific circumstances (perceived impacts). Labor is not necessarily adversely against automation and the adoption of new technology in many applications (example cited – Goat foot Excavator)
  - It is important to consider that end users and labor unions are not consultants and may not have extensive technical insights and experience in specific technologies. They need to be consulted and educated, where they are open to advocating for any innovation that improves worker safety and the work environment.
  - It is needed to discuss and consult with mine employees about technology before implementation and get buy-in. Miners/mine workers are usually extremely knowledgeable about responsibilities associated with their workplace and can be an excellent resource when considering new technology and automation. That said, it needs to be done in the correct manner (collaboratively).
  - In the event a technology would result in a reduction of workforce, this is something that could be negotiated. That said, most technology, including autonomous trucks, would result in changing labor roles (different skill sets and responsibilities) rather than worker displacement.
  - With regards to integrating technology from other mining sectors, it would be a bargaining process to fully vet and understand how the technology would impact a given commodity or location.
- Employee buy-in is critical and was reiterated several times. If employees are not supportive, the technology will not be accepted and will likely fail. A process needs to be designed to introduce the employees, organized labor, and regulators on the technology, why it is being implemented, and its benefits. Similar to the arguments that must be made to educating company officials, board members, and shareholders on the merits of new technology.
- The implementation of any automation or new technology will likely create some unforeseen hazards. This needs to be fully evaluated before its implemented.

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- As stated previously, before a company seeks to implement significant technologic advances, they should first approach the local labor union, and then the workforce. This becomes a matter of trust.
- Mine rescue and emergency response appear to be excellent areas that are well suited for robotics, new technologies/processes, and remotely operated vehicles. It would present an opportunity to develop support vehicles capable of working in and around existing hazards and assisting in mine rescue activities (NIOSH's current efforts in these areas were discussed). That said, additional sources of funding would be required.
- MSHA is targeting technology to address specific challenges. Regulations that encourage tech ratcheting technology was discussed (e.g., dpm and diesel power plants). The "Buy America Act" has some applicability (need to investigate this).
- Examples of successful technical advancements that have undergone compliance testing and approvals include proximity detection, communications/tracking, dust sampling, and dpm.
- When developing technology and automation, OEM expectations are often different than operators. The perception of what is important is rarely the same.
- Often new technologies and innovations do not consider regulatory issues until well into development. If permissibility approvals are required, this can be disastrous.

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## Workshop 9

9	Elko, NV	March 2024	Elko Mining Expo	10
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Drones have taken over surveying. Dozers, trucks, and drills have all been automated. Excavation is last on the list, but this speaker does not think the actual excavators will look anything like what we are using today. FAA has recently changed rules to allow some innovation and FMS systems are running better under wireless. Everything is constrained by obsolete communications technology. FCC put in interoperability requirements, and it changed the phone industry. But that has not shifted to equipment, so it is a “tower of babble” between machines. Industry has not gotten really into current automation capability because it does not really directly relate to moving rock. Major issues over the years that had moved closer and closer to autonomy were not necessarily related to extraction because improvements in fragmentation really reduced maintenance and smoothed out the production cycle.

There was a multi company group working on coming up with common language, but it really hasn't come to anything. The only things that are common language are DSS(?) DXS(?) DXX(?) and one other. There is a whole GIS standard that is common. GIS systems will not talk with each other across a common buss. You cannot have automated equipment without accurate GIS data. Three maps were created using different systems for one of the mines, the maps are all different and there is no good way to figure which, if any, is accurate. Company IT rules are not as restrictive as you might think. You can work around them if you have a good argument for what you want. Another company requires that everything goes through IT, and it takes longer and costs more, but it generally works ok. There is careerist resistance to change. FCC has made some changes to interconnection rules that have really helped. Especially by allowing private use of previously public areas.

Some of these systems impinge on personal safety because people depend on the systems and if they do not work, they endanger people, but MSHA insists that if it has been put in place you must continue to work with it (speaker is referring to the defects affecting safety rule 56/57.14100).

Speaker spent 2 years to put in an automated pump system because vendors who said they could do all of it actually could only do different parts of it. Companies adopt goals but have very little tolerance for failure. They want results in the next quarter and make it work rather than in a few years. There is very little tolerance for failure from which you could learn an important thing and then go forward.

Is cybersecurity a concern that impedes change? You can change steering on a truck without any verification. It is a huge concern, but the systems generally do not have much control. A 400-ton truck that is self-aware and free roaming should have no interface with anything other than what

## Appendix C

is needed to stop it if there is a problem. There are different levels of autonomy, ranging from fully autonomous to remote control to supervised remote control (using a screen that operates the joystick). At this speaker's mine, all the autonomous equipment went into a DMZ, and it was extremely difficult to get into. Ad hoc like collision avoidance through vehicle to vehicle (v to v) now communicates in a way that allows for avoidance at 140 mile closing speed. V to v and v to x will be needed to get to autonomy. The shovel will be the hub for that. This speaker's new mine is not really looking into automation at the planning stage because it is second operating mine in the company and there is no tolerance for unproven technology. They will look at automation in processing, pumps, surveying, etc. but not mobile equipment. At the NEPA stage, you would have to go back and reassess impacts. The feasibility study did not include mobile equipment automation so there is no desire to change what has already been scoped out. BLM is, however, hesitant to approve automated monitoring which reacts to data, like closing gates, or counting critters. It should be able to be species specific. But BLM is not likely to accept it as a solution. For instance, it could set off a bird canon when it senses a bird.

A speaker recounted a recent conversation with an OEM re: bringing autonomous equipment. The OEM brought up that a consideration of the implementation was a labor saving, but it turned out that no labor had actually been saved in the three years it had been there. There may not be a reduction in head count, but there is significant maintenance saving overtime. The manpower shed really did not happen.

On the safety side, collision avoidance is where it has mostly been installed but it could take responsibility away from the individuals. Collision avoidance that is zero based will only get you to level 7 automation. One contractor expressed that, in their circumstances, there is no point in using automation unless it can be picked up and moved to the next location. Current collision avoidance systems are not accurate enough to really prevent the problem and the equipment operators tend to ignore the warning system. The speaker had seen numerous pictures of autonomous haul trucks wrecked and drills trampling into each other, etc.

Savings will not be from personnel reduction but will be from smoothing the production cycle and reducing maintenance. The OEMs know so little about how their autonomous systems work that they call everything a "coms problem" even if you can prove that it is not.

Ken Pavloski volunteered to send information about FCC regulations.

[kpavloski@nevadagoldmines.com](mailto:kpavloski@nevadagoldmines.com)

Caroline Macmillan volunteered to send information about BLM reticence to accept remote monitoring [caroline.macmillan@nov.com](mailto:caroline.macmillan@nov.com)

Within the next ten years, 4,000 miners will be approaching retirement age in the Elko area and there are not enough folks around to replace them. There will be no experienced miners to train the new entrants. Losing the labor base will incentivize the companies to automate. Great Basin College has already started a program to train equipment operators, mechanics, etc. and there

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will need to be a course in electronics as well. Having the staff to support autonomous smart equipment is a whole different challenge.

Final importance rankings:

	GroupsA	B	Consensus
Regulations	25	5	13
Economics	20	20	20
Technology Readiness	20	15	17
Corporate Willingness	30	30	30
Social License	5	30	20

### Final Comments

There is a legitimate question as to whether the regulations are a barrier to automation, or whether the regulatory agency is the barrier.

The workshop was a good way to see what is going on. It is good to see that NIOSH is doing this.

It just seems that the mines are unwilling to stick their necks out. There ought to be a way to encourage innovation.

Regarding incentives, the question was posed as to whether an operator might be more likely to put in automation at a new mine if the permitting process were streamlined. The answer was yes if the permitting process were streamlined significantly, and litigation were eliminated. Similarly, were the technology to be de-risked, would you consider using it? The general answer was yes, but there would have to be support for the equipment. An example was brought up about the use of ETF trucks at a Vale mine in Brazil.

The regulation that should come would be to regulate automation only zones (“AOZ”). That would generally entail producing common communication protocols.

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**Comments from the Group Regarding Automation and Perceived Barriers**

Relevant Mining Applications for Innovative Technology and Automation

- While autonomous truck haulage is extremely topical and on the leading edge of innovation, particularly in surface gold, there are numerous other technologies that are critical for making sustained advancements. These include:
  - Real-time Surveying (automated – without human operators) and expanded technologies associated with drones (e.g., communications, rock characterization & movement, dispatch, etc.).
  - Automation associated with blasthole drilling, hole placement and down hole surveying & explosive loading.
  - An extremely overlooked piece in surface mining is the automation of the rock loading. That implies significant changes in the way shovels and wheel loaders operate, potentially autonomous, but need to be significantly more efficient and reduce reliance on the skill and talent of human operators.
  - Improved communications and the transmission of data. Significant expansion of bandwidth & frequencies. Departing on reliance on radio communications. This is a critical and imperative step towards more sophisticated, mine-wide automation. There are significant challenges with FCC regulations and approvals, including LTE approvals and MF data speeds. US standards need to change. For further information on this issue: Jordan Oxborrow is an excellent contact.
  - Sensor technology has undergone radical changes in the last two years by several companies due to limitations and lack of robustness. This trend must continue for significant improvements in technology to occur.
  - Automated systems for keeping birds out of ponds.
  - Autonomous road graders
- Interestingly, several of the Workshop participants indicated that the motivation for pursuing technology and innovation was not about operating cost or production capacity but improving the mechanical availability of the equipment while reducing downtime associated with maintenance and unscheduled breakdowns. Labor availability is a major concern and challenge for the operators, but it was not necessarily a driver to automate.
- An interesting discussion occurred regarding the merits and risks between equipment autonomy versus remote controlled/guided automation. Very different opinions on the opportunity of each and future of each technology where labor was not a constraint.

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- Another recent innovation has been the development of ad hoc technologies by many small, specialized companies that provide “add-ons” onto equipment manufactured by big name OEMs.

### Experience & General Discussions Regarding Automation

- When adopting or developing any technology, it is important that the company consider downstream implications. Needs to be compatible with other systems and equipment at the mine, including those from different OEMs and fixed infrastructure (in some instances, this may also include mineral processing and loadouts). This sounds easy but is extremely difficult.
- Need to have control over final products (e.g., characteristics and grade). This presumably includes ores going to leach pads or concentrators, as well as mineral products being sold (cons & metal).
- Open standards concerning software are critical. There is currently an absence of commonalities (?). They must be able to share common source codes, positioning data and communications. RTK is important. Geopositioning and GPS incapacibilities are major challenges. Need to be able to match systems with known accuracies.
- OT acceptance by the industry is a driver for automation.
- Individuals advocating for adopting technology should not be focused on being “blamed” if it is not successful. The focus should be on overcoming the identified challenges. The level of risk is different for every company.
- Unfortunately, some systems and technologies that are considered reliable in a controlled environment or at a mine with a given set of operating characteristics, may not be reliable at another mine with different parameters. This represents one of the hazards of not doing proper due diligence and needs to be considered.
- When operators become dependent upon systems/technology, workers may become complacent and take things for granted. This also represents a hazardous situation.
- For many technologies, there are not a lot of experts that understand the big picture. How the proposed technology works and fits into the entire mine environment. There may be people who understand the technology but are not experts (proficient in the overall system). People marketing technology are generally specialized, and do not fully understand everything in the mining process and how everything interrelates. Most operators just want to “get er done,” without sufficient due-diligence and review. They must know the individual parts of the system and the implications of using aftermarket parts or products from different suppliers. Often reliant on case histories associated with the technology (very hard to be the first to implement).

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- The consensus was that a given technology needed a short time horizon for payback to be acceptable to Company Boards and leadership, where a clear economic argument was necessary.
- There is low tolerance for failure.
- Cybersecurity was considered a major issue by all participants in the Workshop.

### Business Case for Technology

- Labor shortages are a major issue for most Nevada operations and are likely to get worse as the skill level increases.
- The issue is NOT to facilitate a reduction in the total labor force through the use of technology, but rather to upscale the job opportunities (different roles and skill sets).
- Is there a correlation between automation and improved maintenance, resulting in better efficiencies, availability, and operating costs? Most thought this was the case – no empiric evidence. This is an interesting hypothesis, where OP and CAP costs may be secondary drivers.

### **1) General Comments**

- Discussions associated with factors, such as Collision Avoidance system built into autonomous equipment, resulted in several interesting statements. Several thought that operators are increasingly relying on automation and technology to overcome safety hazards, where operators were becoming so heavily reliant on it that it represented a hazard in itself. They thought that it was better to continue having human-centric safety training for operators in hazard identification, even if the hazards are minimized by technology. Discussion turned to Hierarchy of Controls.
- Autonomous equipment must be able to adapt from one location of the mine to another. The same goes for different operating environments. The operation of the equipment must be consistent with minimal adjustments that rely on judgement.
- Service and maintenance issues and liability associated with new equipment and systems must be resolved. The ability to secure insurance is a must and becoming increasingly difficult.
- Risk tolerance of the operator must increase with greater reliance on automation/autonomy.
- Systems must be properly designed for the specific mine environment. OEMs are not always competent or interested in the specific factors influencing a particular operation (usually small economic investment at initial stages and lack of knowledge by the OEM/supplier).

## Appendix C

- Optional safety devices that often create problems with system reliability can sometimes be removed under specific situations. This is a bad process or philosophy and may be against regulations.
- One operator indicated that they normally buy haul trucks and loaders stripped down (baseline models) and then add the accessories and automation that they want. They try to keep the units as simply as possible and uniform with other equipment on site.
- When assessing technology, the related cost implications of decisions are key. For example, cameras purchased from military contractors are better built, having better quality than those from a cheap industrial vendor. The selected camera will depend on the application, the needed requirements, and the required length of life. No sense in purchasing better quality equipment if it is not needed. Viewed as disposable.
- The availability of skilled labor is important and needs to be considered. Labor cost savings should not be part of the assessment, but availability is huge, particularly in some remote areas. Many companies are near-sighted with respect to labor costs, and do not understand the importance of upgrading labor skill sets with automation despite the increase in costs. It can be disastrous for an operation.
- Labor attrition and competition are major concerns with so many producers looking for talent (numerous employment opportunities – if you can pass a drug test)
- Labor requirements largely require a multifaceted skilled hourly work force. Depending on the technologies being utilized, specialized professional labor will likely be required.
- There needs to be some MSHA guidance in adopting new technology regarding regulatory compliance. For new regulations, MSHA needs to provide options for achieving the new regulations. Local MSHA Inspectors need to understand the technology and be competent in the guidance provided by tech support.
- Corporate philosophies regarding technology and innovation change with new company management (Barrack & Newmont as compared to Nevada Gold)
- In assessing new technologies, it is important to find ways to empirically test them. This can be extremely difficult for large systems, where major capital investment is required to test the technology. They need to build it in order to test it.
- Mines (competitors) will often band together regarding a technology to diminish risk or to address regulatory issues (the use of autonomous haul trucks and DPM).
- Key concept: “Serviceable Automation” – are companies available with the expertise to fix a problem in a new system so they are not reliant on a single OEM or supplier.
- Smaller companies generally cannot have significant failures associated with technological development. As such, they limit the technology integration to relatively small step improvements. Not wholesale equipment replacements.

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- Even for the majors, companies must implement a good PR program for shareholders, regulators, and employees when adopting new technologies. The company must have employee buy-in.
- Nobody wants to utilize technology they do not fully understand and cannot explain to corporate managers and the Board.

<u>Barriers to Technology Ranking</u>	Initial Vote	Final Vote
• Regulations:	5%	25%
• Economics:	20%	20%
• Technology Readiness:	15%	20%
• Corporate Willingness:	30%	30%
• Social License:	30%	5%

The rankings varied over the course of the discussion.

### Follow-up thoughts by the group:

- Not a lot of companies can tolerate failure.
- Regulations are generally considered low in the ranking, but in the event of an accident, the regulations might then become the highest motivating factor.
- Industry will advance technology faster than government can approve it and is driven by need. Government approvals will always lag.
- Without common regulations and industry standards, it would be the wild west.
- The group liked the collaboration between NIOSH Mining and SME and thought it might be beneficial for other critical safety and technology issues.

## **10. Appendix D**

### **Workshop Materials**

Included here are the following items:

1. Meeting Agendas with the Contractors for early planning
2. Copy of the Invitation Letter to Identified Stakeholders
3. Copy of the Thank You Letter to Participants
4. Agenda for all of the Workshops
5. A copy of the first presentation
6. A summary of all the presentations

Appendix D

1. Meeting Agendas with the Contractors for early planning

# Agenda

Meeting for SME/CDC Contract 75D30122C14149-  
Eliminating Barriers for the Implementation of Automation in the Mining Industry

November 4, 2022  
1:00 PM- 2:00 PM MT  
MS Teams Meeting

[Click here to join the meeting](#)

***Expected Attendance:***

Dave Kanagy  
Mike Moats  
Mark Savit  
Hugh Miller  
Ben Lewicki  
Kray Luxbacher  
Marc Le Vier  
Ron Parratt

***Regrets:***

Mark Savit

1. Welcome/Safety Share/Let's get going!
2. Summary of Proposal
3. Workshop Planning
  - a. AZ Conference – December 4, 2022
  - b. SME Annual Meeting – February 25, 2023
  - c. SME MN Conference – April 10, 2023
    - i. Who to Invite
    - ii. Agenda
    - iii. Facilitator
4. Review of Regulations
5. Sample Report from Rand
6. Other issues

# Agenda

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**SME/CDC Contract 75D30122C14149- Eliminating Barriers for the Implementation  
of Automation in the Mining Industry Contractors Meeting  
Tuesday, February 27, 2024  
Phoenix, Arizona  
Sheraton Hotel, South Mountain Room**

**Expected Attendance:**

Kray Luxbacher  
Hugh Miller  
Mike Moats  
Mark Savit  
Ben Miller

Marc Le Vier  
Ron Parratt  
Marc Herpfer  
Genny Homyack  
David Kanagy

**Topics**

1. Finalize Plans for March 22, 2024 Workshop – Nashville, TN
  - a. Focus on Aggregates Industry –
  - b. Who's Attending
  - c. Modifications to Workshop Agenda
  
2. Finalize Plans for April 18, 2024 Workshop – Triadelphia, WV
  - a. Focus on Mine Safety and Health Research Advisory Committee (MSHRAC)
  - b. They will have 6 union representatives in attendance (expecting 20 people right now)
  - c. Modifications to Workshop Agenda
  
3. Plans for the remainder of 2024
  - a. Define other workshops and groups of people needed
  - b. Timing and locations
  - c. Examine automation barriers for smaller operations
  - d. Potential Impact of cybersecurity on automation
  
4. Develop plans for the Final Report
  - a. Due on December 31, 2024, preliminary report due September 30, 2024
  - b. Outline our report by July 31, 2024
  - c. Assign segments
  - d. Other updates to Regulatory Summary Report
  - e. Other items we need to examine

***Attachments:***

Contract with supplement contract  
Summary of Year One slides  
Homework summaries

# Agenda

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**SME/CDC Contract 75D30122C14149- Eliminating Barriers for the Implementation  
of Automation in the Mining Industry Contractors Meeting  
June 20, 2024**

**Expected Attendance:**

Kray Luxbacher  
Hugh Miller  
Mark Savit

Ben Miller  
Genny Homyack  
David Kanagy

**Topics**

1. Finalize Plans any remaining Focus Groups
  - a. Identify Smaller Groups
    - i. Examine automation barriers for smaller operations
    - ii. Potential Impact of cybersecurity on automation
    - iii. Other
  - b. Who's Attending
  - c. Set Dates
  - d. Modifications to Workshop Agenda for Virtual Meetings
  
2. Finalize 3<sup>rd</sup> Quarter Report and Workshop Report
  - a. Send any notes to Genny by July 3
  - b. Review drafts
  - c. Genny to send by July 29
  
3. Develop plans for the Final Report
  - a. Preliminary report due October 31, 2024 (assuming we get approval)
  - b. 508 Compliant due on December 31, 2024
  - c. Outline our report by \_\_\_\_\_
  - d. Assign segments
  - e. Other updates to Regulatory Summary Report

Appendix D

## 2. Copy of the Invitation Letter to Identified Stakeholders

November 7, 2022

**Re:** Invitation: Eliminating Barriers for the Implementation of Automation in the Mining Industry

Dear SME Member and Industry Experts,

We are excited to announce that SME has been awarded a grant from the CDC/NIOSH to conduct a series of workshops to help eliminate barriers for the implementation of automation in the mining industry. We are seeking feedback from those active in the industry who have different types of roles and responsibilities for production, processing, equipment, and equipment design in the advancement of automation in our industry.

You are invited to join our inaugural research session on Sunday, December 4, 2022 in Tucson, Arizona. This interactive working session will be held prior to the SME Annual Arizona Conference at the JW Marriott Starr Pass Resort & Spa. SME has engaged top collaborators for this project including Kray Luxbacher, Ph.D., P.E., Hugh Miller, Ph.D., QP, Michael Moats, Ph.D., Ben Miller, Ph.D., Mark Savit, J.D., Ronald Parratt, P.G., and Marc Le Vier.

In our industry, mining companies are incentivized to automate processes and operating systems in hopes of increasing productivity, reducing costs, improving safety and achieving quality gains. These incentives however are often eroded by regulatory barriers that impair the implementation of these technologies. Everyone in the industry has a responsibility to operate in the safest manner possible and the integration of new technology in U.S. mining operations is imperative as we continue to achieve efficient and cost effective mines at high levels of production. We welcome your thoughts and expertise, and hope that you can join us for this engaging discussion.

The workshop schedule is as follows for Sunday, December 4, 2022:

- 10:00 AM – 10:30 AM – Background/Goals of Study
- 10:30 AM – 12:00 PM – Explore automation experiences and barriers
- 12:00 PM – 1:00 PM – Lunch
- 1:00 PM – 2:30 PM - Interactive Discussion: Regulation– how it helps or hinders production improvements. What are the regulations addressing?
- 2:30 PM – 3:00 PM – Break
- 3:00 PM – 4:30 PM – Break-Out Groups: Absence of Regulations – what happens in the industry specific to productivity, safety, and other concerns. What do you want to see?

We hope you will join us and share your knowledge and experience. For this initial workshop, we are seeking to have a group of 15 key supporters. Please respond with your acceptance of this invitation to Genny Homyack ([homyack@smenet.org](mailto:homyack@smenet.org)) by Monday, November 14, 2022. If you are unable to attend, please consider sharing this invitation with someone else at your company who might also be a good match. We will also be offering several more opportunities over the next two years to participate in this project. We welcome your thoughts and hope to see you there!

Sincerely,



David L. Kanagy  
Executive Director and CEO

Appendix D

### 3. Copy of the Thank You Letter to Participants

Dear Mark:

Thank you for your participation in the Eliminating Barriers for the Implementation of Automation in the Mining Industry Workshop One held in Tucson, Arizona on December 4, 2022. This first workshop out of six planned workshops was to support SME's work with NIOSH to determine what, if any, barriers exist for the implementation of automation in the mining industry

The expertise you provided will be of enormous help to SME in developing and finalizing a comprehensive final report by September 2024. We will be pleased to provide you with a copy of this report upon its completion. Your feedback to improve the remaining workshops is also appreciated; we will be implementing these ideas to enhance the remaining workshops.

As required by our contract, SME will inform NIOSH of all the individuals who participated in the workshops, however, your name is not available for public disclosure in the report or on any NIOSH website or other public forum. In addition, we will not attribute comments to any individual or company in the report.

If you have any questions or thoughts regarding this project, please do not hesitate to contact us. In the meantime, thank you again for your participation and help. We wish you a wonderful 2023!

Sincerely,

David Kanagy, SME Executive Director and CEO  
Kray Luxbacher, Ph.D., P.E., University of Arizona  
Hugh Miller, Ph.D., QP, Colorado School of Mines  
Michael Moats, Ph. D, Missouri S&T  
Ben Miller, Ph.D., Autonomous Correct, LLC  
Mark Savit, J.D., Predictive Compliance, LLC  
Ronald L. Parratt, SME 2022 President  
K. Marc Le Vier, SME 2023 President



Appendix D

## 4. Agenda for all of the Workshops

**Eliminating Barriers for the Implementation of Automation in the Mining Industry**  
**Workshop One**  
December 4, 2022  
Tucson, Arizona  
CDC/NIOSH Contract 75D30122C14149

## Agenda

***SME Team:***

Dave Kanagy  
Mike Moats  
Mark Savit  
Hugh Miller  
Ben Miller  
Kray Luxbacher  
Marc Le Vier  
Ron Parratt  
Genny Homyack

- |  |                     |
|--|---------------------|
| 1. Background/Goals of Study   | 10:00 AM – 10:30 AM |
| 2. Explore automation experiences and barriers   | 10:30 AM – 12:00 PM |
| Lunch  | 12:00 PM – 1:00 PM  |
| 3. Interactive Discussion:<br>Regulation– how it helps or hinders production improvements. What are the regulations addressing?                              | 1:00 PM – 2:30 PM   |
| Break  | 2:30 PM – 2:45 PM   |
| 4. Break-Out Groups:<br>Absence of Regulations – what happens in the industry specific to productivity, safety, and other concerns. What do you want to see? | 2:45 PM – 4:15 PM   |
| 5. Re-cap and Steps Forward  | 4:15 – 4:30 PM      |

# Questions:

1. Is applied research and technical innovations an important component in your company's operating strategy?
2. How does your company prioritize which technologies to pursue and invest in? What is your capital budgeting process? Do regulatory constraints influence these decisions?
3. In terms of timeframes, what is an acceptable pay back for project investment in new technologies?
4. Do provisions of conventional debt financing by commercial banks deter implementation of new technologies?

*Thank you for attending!*

## Eliminating Barriers for the Implementation of Automation in the Mining Industry

### Workshop Two

February 28, 2023

Denver, Colorado

Capitol 1-3

7:30 AM to Noon

CDC/NIOSH Contract 75D30122C14149

# Agenda

### **SME Team:**

Genny Homyack

Dave Kanagy

Kray Luxbacher

Marc Le Vier

Mike Moats

Hugh Miller

Ben Miller

Ron Parratt

Mark Savit

- |  |                     |
|--|---------------------|
| 1. Breakfast/Introductions   | 7:30 AM – 8:00 AM   |
| 2. Background/Goals of Study   | 8:00 AM – 8:20 AM   |
| 3. Explore automation experiences and barriers   | 8:20 AM – 9:10 AM   |
| 4. Interactive Discussion:<br>Regulation– how it helps or hinders production improvements. What are the regulations addressing?                              | 9:10 AM – 10:00 AM  |
| Break  | 10:00 AM – 10:15 AM |
| 5. Break-Out Groups:<br>Absence of Regulations – what happens in the industry specific to productivity, safety, and other concerns? What do you want to see? | 10:15 AM – 11:15AM  |
| 6. Re-cap and Steps Forward  | 11:15– Noon         |

# Questions:

1. Are applied research and technical innovations an important component in your company's operating strategy?
2. How does your company prioritize which technologies to pursue and invest in? What is your capital budgeting process? Do regulatory constraints influence these decisions?
3. In terms of timeframes, what is an acceptable pay back for project investment in new technologies?
4. Do provisions of conventional debt financing by commercial banks deter implementation of new technologies?

*Thank you for attending!*

**Eliminating Barriers for the Implementation of Automation in the Mining Industry**  
**Workshop Three**  
Monday, April 17  
Virginia, Minnesota  
10:00 AM to 4:30 PM  
CDC/NIOSH Contract 75D30122C14149

## Agenda

### ***SME Team***

Dave Kanagy  
Hugh Miller  
Ben Miller  
Kray Luxbacher  
Marc Le Vier  
Genny Homyack

- |  |                     |
|--|---------------------|
| 1. Coffee/Introductions  | 10:00 AM – 10:10 AM |
| 2. Background/Goals of Study   | 10:10 AM – 10:30 AM |
| 3. Explore automation experiences and barriers   | 10:30 AM – 12:00 PM |
| Lunch Break  | 12:00 PM – 1:00 PM  |
| 4. Interactive Discussion:<br>Regulation– how it helps or hinders production improvements. What are the regulations addressing?                              | 1:00 PM – 2:30 PM   |
| Afternoon Break  | 2:30 PM – 2:45 PM   |
| 5. Break-Out Groups:<br>Absence of Regulations – what happens in the industry specific to productivity, safety, and other concerns. What do you want to see? | 2:45 PM – 4:15 PM   |
| 6. Re-cap and Steps Forward  | 4:15 – 4:30 PM      |

# Questions:

1. Are applied research and technical innovations an important component in your company's operating strategy?
2. How does your company prioritize which technologies to pursue and invest in? What is your capital budgeting process? Do regulatory constraints influence these decisions?
3. In terms of timeframes, what is an acceptable pay back for project investment in new technologies?
4. Do provisions of conventional debt financing by commercial banks deter implementation of new technologies?

*Thank you for attending!*

## Eliminating Barriers for the Implementation of Automation

### Workshop Four

Sunday, June 11, 2023

Boston, MA

11:00 AM to 4:30 PM

CDC/NIOSH Contract 75D30122C14149

# Agenda

### **SME Team:**

Dave Kanagy

Mark Savit

Hugh Miller

Marc Le Vier

Ronald Parratt

Genny Homyack

- |  |                     |
|--|---------------------|
| 1. Introductions   | 11:00 AM – 11:10 AM |
| 2. Background/Goals of Study   | 11:10 AM – 11:30 AM |
| 3. Explore automation experiences and barriers   | 11:30 AM – 12:15 PM |
| Lunch Break  | 12:15 PM – 1:00 PM  |
| 4. Interactive Discussion:<br>Explore Root-Causes – what encourages or hinders the implementation of new technologies?   | 1:00 PM – 2:30 PM   |
| Afternoon Break  | 2:30 PM – 2:45 PM   |
| 5. Break-Out Groups:<br>What are the trends in the industry specific to productivity, safety, and regulations? What are your concerns? What would you like to see? | 2:45 PM – 4:15 PM   |
| 6. Re-cap and Steps Forward  | 4:15 – 4:30 PM      |

# Questions:

1. What percentage of your work is in mining vs. heavy civil construction?
2. Are applied research and technical innovations an important component in your company's operating strategy?
3. How does your company prioritize which technologies to pursue and invest in? What is your capital budgeting process? What constraints influence these decisions?
4. In terms of timeframes, what is an acceptable pay back for an investment in a new technology?
5. Do provisions in project financing, bonding, or contracts deter the implementation of new technologies?

*Thank you for attending!*

**Eliminating Barriers for the Implementation of Automation in the Mining Industry**  
**Workshop Five**  
Sunday, August 27  
Phoenix, Arizona  
10:00 AM to 4:30 PM  
CDC/NIOSH Contract 75D30122C14149

## Agenda

***Expected Attendance:***

Dave Kanagy  
Hugh Miller  
Kray Luxbacher  
Mark Savit  
Mike Moats  
Marc Le Vier  
Ronald Parratt  
Genny Homyack

- |  |                     |
|--|---------------------|
| 1. Coffee/Introductions  | 10:00 AM – 10:10 AM |
| 2. Background/Goals of Study   | 10:10 AM – 10:30 AM |
| 3. Explore automation experiences and barriers   | 10:30 AM – 12:00 PM |
| Lunch Break  | 12:00 PM – 1:00 PM  |
| 4. Interactive Discussion:<br>Regulation– how it helps or hinders production improvements. What are the regulations addressing?                              | 1:00 PM – 2:30 PM   |
| Afternoon Break  | 2:30 PM – 2:45 PM   |
| 5. Break-Out Groups:<br>Absence of Regulations – what happens in the industry specific to productivity, safety, and other concerns. What do you want to see? | 2:45 PM – 4:15 PM   |
| 6. Re-cap and Steps Forward  | 4:15 – 4:30 PM      |

# Questions:

1. Are applied research and technical innovations an important component in your company's operating strategy?
2. How does your company prioritize which technologies to pursue and invest in? What is your capital budgeting process? Do regulatory constraints influence these decisions?
3. In terms of timeframes, what is an acceptable pay back for project investment in new technologies?
4. Do provisions of conventional debt financing by commercial banks deter implementation of new technologies?

*Thank you for attending!*

**Eliminating Barriers for the Implementation of Automation in the Mining Industry  
Workshop Six**

Wednesday, October 25, 2023  
Canonsburg, PA  
Hilton Garden Inn  
Parlor B  
10:00 AM to 4:30 PM  
CDC/NIOSH Contract 75D30122C14149

## Agenda

***Expected Attendance:***

Dave Kanagy  
Hugh Miller  
Kray Luxbacher  
Mark Savit  
Mike Moats  
Marc Le Vier  
Ronald Parratt  
Genny Homyack

- |  |                     |
|--|---------------------|
| 1. Coffee/Introductions  | 10:00 AM – 10:10 AM |
| 2. Background/Goals of Study   | 10:10 AM – 10:30 AM |
| 3. Explore automation experiences and barriers   | 10:30 AM – 12:00 PM |
| Lunch Break  | 12:00 PM – 1:00 PM  |
| 4. Interactive Discussion:<br>Regulation– how it helps or hinders production improvements. What are the regulations addressing?                              | 1:00 PM – 2:30 PM   |
| Afternoon Break  | 2:30 PM – 2:45 PM   |
| 5. Break-Out Groups:<br>Absence of Regulations – what happens in the industry specific to productivity, safety, and other concerns. What do you want to see? | 2:45 PM – 4:15 PM   |

## Questions:

1. Are applied research and technical innovations an important component in your company's operating strategy?
2. How does your company prioritize which technologies to pursue and invest in? What is your capital budgeting process? Do regulatory constraints influence these decisions?
3. In terms of timeframes, what is an acceptable pay back for project investment in new technologies?
4. Do provisions of conventional debt financing by commercial banks deter implementation of new technologies?

## **Eliminating Barriers for the Implementation of Automation in the Mining Industry Workshop 7**

Friday, March 22, 2024  
Omni Nashville Hotel  
Mockingbird 3 Room  
10:00 AM to 4:30 PM  
CDC/NIOSH Contract 75D30122C14149

# Agenda

### ***Expected Attendance:***

Dave Kanagy  
Michael Moats  
Ben Miller  
Hugh Miller  
Ronald Parratt  
Mark Savit  
Genny Homyack

- |  |                     |
|--|---------------------|
| 1. Coffee/Introductions  | 10:00 AM – 10:10 AM |
| 2. Background/Goals of Study   | 10:10 AM – 10:30 AM |
| 3. Explore automation experiences and barriers   | 10:30 AM – 12:00 PM |
| Lunch Break  | 12:00 PM – 1:00 PM  |
| 4. Interactive Discussion:<br>Regulation– how it helps or hinders production improvements. What are the regulations addressing?                              | 1:00 PM – 2:30 PM   |
| Afternoon Break  | 2:30 PM – 2:45 PM   |
| 5. Break-Out Groups:<br>Absence of Regulations – what happens in the industry specific to productivity, safety, and other concerns. What do you want to see? | 2:45 PM – 4:15 PM   |
| 6. Re-cap and Steps Forward  | 4:15 – 4:30 PM      |

# Questions:

1. Are applied research and technical innovations an important component in your company's operating strategy?
2. How does your company prioritize which technologies to pursue and invest in? What is your capital budgeting process? Do regulatory constraints influence these decisions?
3. In terms of timeframes, what is an acceptable pay back for project investment in new technologies?
4. Do provisions of conventional debt financing by commercial banks deter implementation of new technologies?

*Thank you for attending!*

**Eliminating Barriers for the Implementation of Automation in the Mining Industry  
Workshop 8**

Thursday, April 18  
10:00 AM to 3:00 PM

MINE SAFETY AND HEALTH ADMINISTRATION  
Approval & Certification Center  
765 Technology Drive  
Triadelphia, WV 26059  
Building 2

CDC/NIOSH Contract 75D30122C14149

## Agenda

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**SME**

Genny Homyack  
Kray Luxbacher  
Ben Miller  
Hugh Miller  
Mark Savit

- |  |                     |
|--|---------------------|
| 1. Introductions                         | 10:00 AM – 10:15 AM |
| 2. Background/Goals of Study             | 10:15 AM – 11:00 AM |
| 3. Discussion: Automation/Barriers I     | 11:00 AM – 12:00 PM |
| Lunch                                    | 12:00 PM – 12:30 PM |
| 4. Discussion: Automation/Barriers II    | 12:30 PM – 1:30 PM  |
| 5. Interactive discussion                | 1:30 PM – 2:30 PM   |
| 6. Re-Cap, Steps Forward and Conclusions | 2:30 PM- 3:00 PM    |

## Eliminating Barriers for the Implementation of Automation in the Mining Industry Workshop 9

Wednesday, June 5, 2024  
10:00 AM to 4:00 PM

Luna Event Venue  
2715 Argent Avenue, Suite 9  
Elko, Nevada 89801

CDC/NIOSH Contract 75D30122C14149

# Agenda

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### SME Attendees

Genny Homyack  
Hugh Miller  
Michael Moats  
Ron Parratt  
Mark Savit

- |   |                     |
|---|---------------------|
| 1. Coffee/Introductions   | 10:00 AM – 10:10 AM |
| 2. Background/Goals of Study  | 10:10 AM – 10:30 AM |
| 3. Explore automation experiences and barriers  | 10:30 AM – 12:00 PM |
| <i>Lunch Break</i>  | 12:00 PM – 12:30 PM |
| 4. Interactive Discussion:<br>Regulation– how it helps or hinders<br>production improvements. What are the<br>regulations addressing?                                       | 12:30 PM – 2:00 PM  |
| <i>Afternoon Break</i>  | 2:00 PM – 2:15 PM   |
| 5. Interactive Discussion:<br>Absence of Regulations – what happens<br>in the industry specific to productivity,<br>safety, and other concerns? What do<br>you want to see? | 2:15 PM – 3:45 PM   |
| 6. Re-cap and Steps Forward   | 3:45 – 4:00 PM      |

Appendix D

5. A copy of the first presentation

# Eliminating Barriers for the Implementation of Automation in the Mining Industry



Workshop One  
December 4, 2022  
Tucson, Arizona

CDC/NIOSH Contract 75D30122C14149

# Collaborators and Contacts



Hugh Miller  
hbmiller@mines.edu



Kray Luxbacher  
kraylux@arizona.edu



Mark Savit  
msavit@predictivecompliance.com

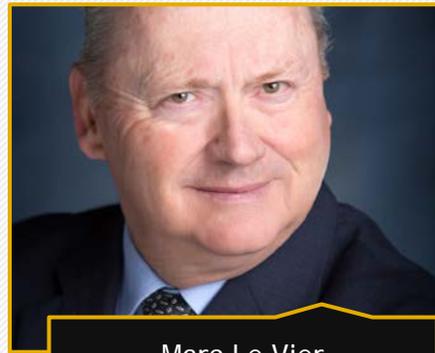


Michael Moats  
moatsm@mst.edu

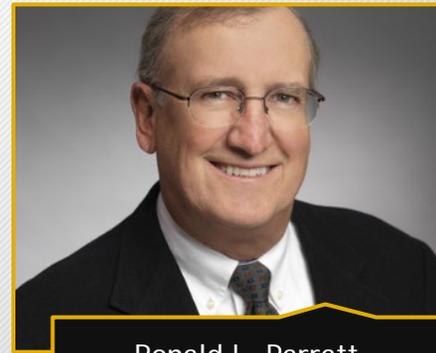
Pictures of  
collaborators and  
Contacts.



Ben Miller  
ben@lewicki.biz



Marc Le Vier  
Marc.levier@comcast.net



Ronald L. Parratt  
RONPARRATT@AOL.COM



David L. Kanagy  
kanagy@SMEnet.org

# Focus Area: Regulatory Review for Automation

- Companies are incentivized to adopt new technologies and automate processes
  - Increase Productivity
  - Reduce Costs
  - Improve Safety & Occupational Health
  - Achieve Quality Gains
  - Shareholder Expectations
  - ESG Goals



Picture of a compass pointing to the word Incentive.

# Regulatory Review for Automation

- Incentives are eroded by regulatory barriers
- Disincentives that impair the implementation of automation and new technologies
- Regulations are mandated to ensure the highest level of compliance
- Regulations could not have foreseen the rapid development of technical advances

# Regulatory Review for Automation

- Prescriptive regulatory system under which US mines operate provide little motivation and create barriers to implement new technologies and highly automated systems



Picture of a green highway sign with the word Motivation across the top, the word Intrinsic on the bottom left with a down arrow and word Extrinsic on the bottom right with an angled up arrow.

# SME's Focus

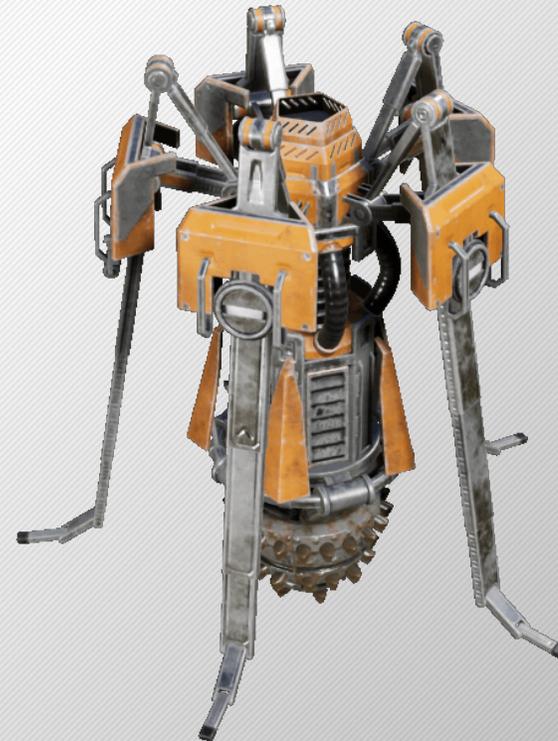
- Mining
- Mineral Processing
- Exploration



Picture of a sign on an arrow pointing left that says Focus.

# SME's Focus

- Automation provides opportunities to isolate workers from potential hazards, adverse health exposure, and risk



Picture of an automated mining drill.

# Objectives

## Objective One

- Identify and evaluate current US federal regulations that serve as barriers to implementation of automation and new technologies.

## Objective Two

- Identify regulatory strategies successfully adapted in other industry jurisdictions and countries.

## Objective Three

- Describe potential avenues for the successful implementation of automation in the US- demonstrate that an equal or higher standard of safety can be achieved.

# Objectives

- All objectives must be achieved with a complete commitment to worker safety.



Picture of a yellow construction hat on a table next to a rolled up paper, laptop and person outside.

# Scope of Work

- Review Current State of Technology
  - Automation
  - **Equipment Autonomy**
  - Sensors
  - Artificial Intelligence
  - Communication/Data Transmission Systems
  - Drones



Picture of drones over a mining site.

# Phases of Work

Task One: Review of regulation, and changes in regulations that have encouraged mine automation in other countries

Task Two: Identification of stakeholders and organization of workshops

- Stakeholders advancing and using automation
- Technical groups who understand barriers

Task Three: Workshops and Data Collection

- Include Stakeholders who have expertise and knowledge
- Six Workshops in various parts of the US
- Small focus groups convened as necessary

# Thank you for attending!



Picture of a sign with an arrow pointing right and the word Begin.

Appendix D

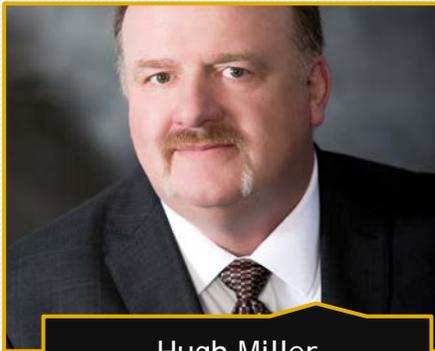
6. A summary of all the presentations

# Eliminating Barriers for the Implementation of Automation in the Mining Industry



NIOSH Automation Partnership  
CDC/NIOSH Contract 75D30122C14149

# Collaborators and Contacts



Hugh Miller  
hbmiller@mines.edu



Kray Luxbacher  
kraylux@arizona.edu



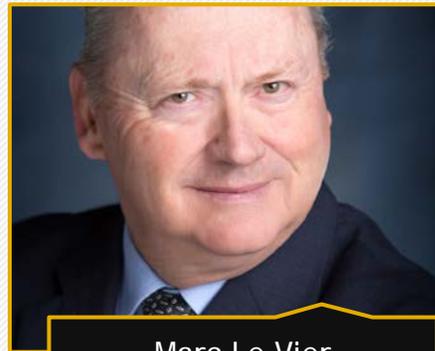
Michael Moats  
moatsm@mst.edu



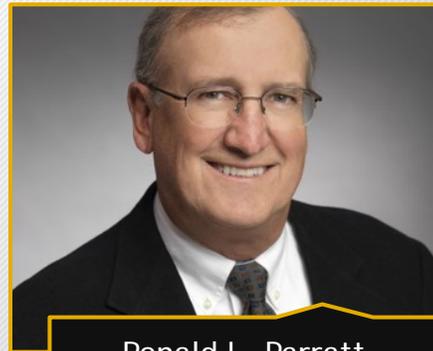
Mark Savit  
msavit@predictivecompliance.com



Ben Miller  
ben@Lewicki.biz



Marc Le Vier  
Marc.levier@comcast.net



Ronald L. Parratt  
RONPARRATT@AOL.COM



David L. Kanagy  
kanagy@SMEnet.org

Pictures of the  
Collaborators and  
Contacts.

# Focus Area: Regulatory Review for Automation

- Motivations
  - Improve Safety & Occupational Health
  - Achieve Quality Gains & Risk Mitigation
  - Increase Productivity & Reduction in Costs
  - Compliance with Current & Future Regulations
  - Technology Ratcheting Standards
  - Shareholder Expectations
  - Skilled Labor Shortages
  - ESG Goals



Picture of a compass pointing to the word Incentive.

# Regulatory Review for Automation

- Perception - Incentives are eroded by regulatory barriers
- Regulations could not have foreseen the rapid development of technical advances
- Disincentives that impair the implementation of automation and new technologies
- Regulations are mandated to ensure the highest level of health and safety

# SME's Focus

- Mining
- Mineral Processing
- Exploration
- Expanded Work to Include:
  - Health & Safety
  - Technical Challenges
  - Environmental Issues



Picture of an arrow sign pointing left with the word Focus.

# Objectives

## Objective One

- Identify and evaluate current U.S. federal regulations that may serve as a barrier to implementation of mine automation with potential to improve mine safety and health, as well as identify other technical areas preventing or slowing the progress of automation.

## Objective Two

- Identify regulatory strategies that have been successfully adapted in other industry jurisdictions and countries that encourage implementation of mine automation and other new technologies to improve mine safety and health including the economics, permitting and other technical matters.

## Objective Three

- Describe potential avenues for the successful implementation of mine automation in the U.S., including research required to demonstrate that an equal or higher standard of mine safety and health may be met.

# Phases of Work

**Task One: Review of regulation, and changes in regulations that have encouraged mine automation in other countries**

**Task Two: Identification of stakeholders and organization of workshops**

- Stakeholders advancing and using automation
- Technical groups who understand barriers

**Task Three: Workshops and Data Collection**

- Include Stakeholders who have expertise and knowledge
- 7-8 Workshops in various parts of the US
- Small focus groups convened as necessary

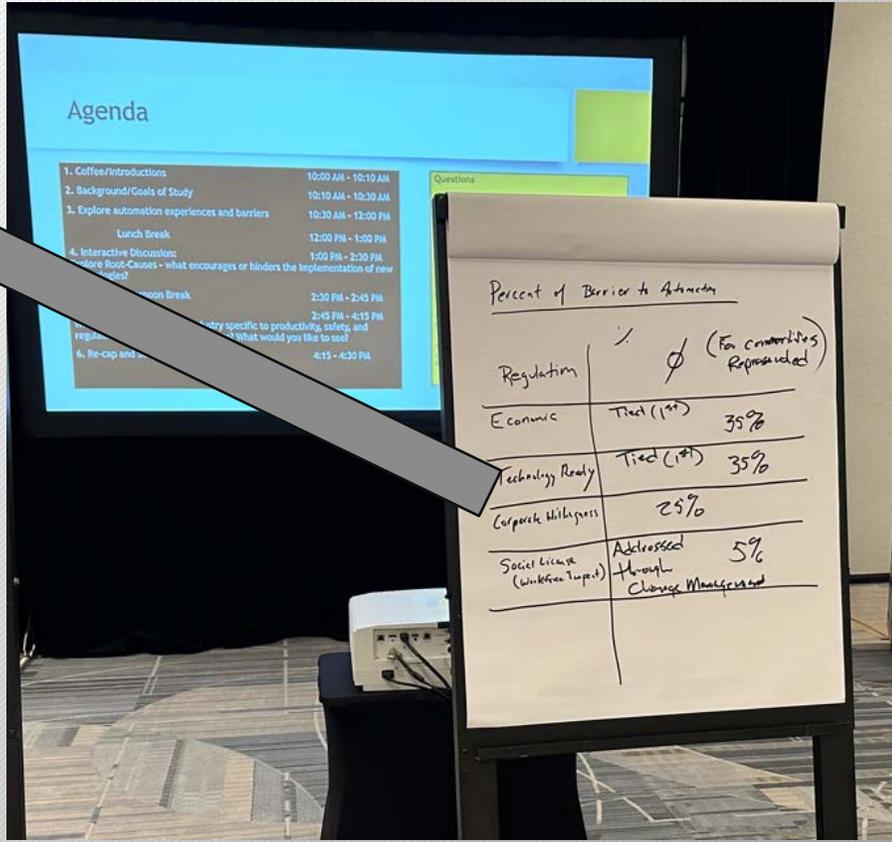
**Task Four: Development of Deliverables**

- A final report will be completed by December 31, 2024

# General Workshop Organization

- Themed expertise
- 10-20 participants
- Introductions
- Broad discussion
- Focused discussion → area of expertise
- Breakout groups with set questions
  - Motivation for automation
  - Company practice in research and capital projects
  - Barriers/Drivers

Regulations  
Economics  
Technology Readiness  
Corporate Willingness  
Social License



Picture of the live presentation screen, a flip-chart with notes and an arrow pointing to a box on the left.

*Please Note: Every group has included relevant OEM and consultants*

# Workshops

**SME Annual Meeting**  
Denver, Colorado  
February 2023  
*Diverse Group*

**Elko Mine Expo**  
Elko, Nevada  
June 2024  
*Industry*

**Hydrometallurgy**  
Phoenix, Arizona  
August 2023  
*Processing & Plant Automation*

**SME AZ**  
Tucson, Arizona  
December 2022  
*Major Copper Operators*

**SME MN**  
Virginia, Minnesota  
April 2023  
*Iron Range Operators*

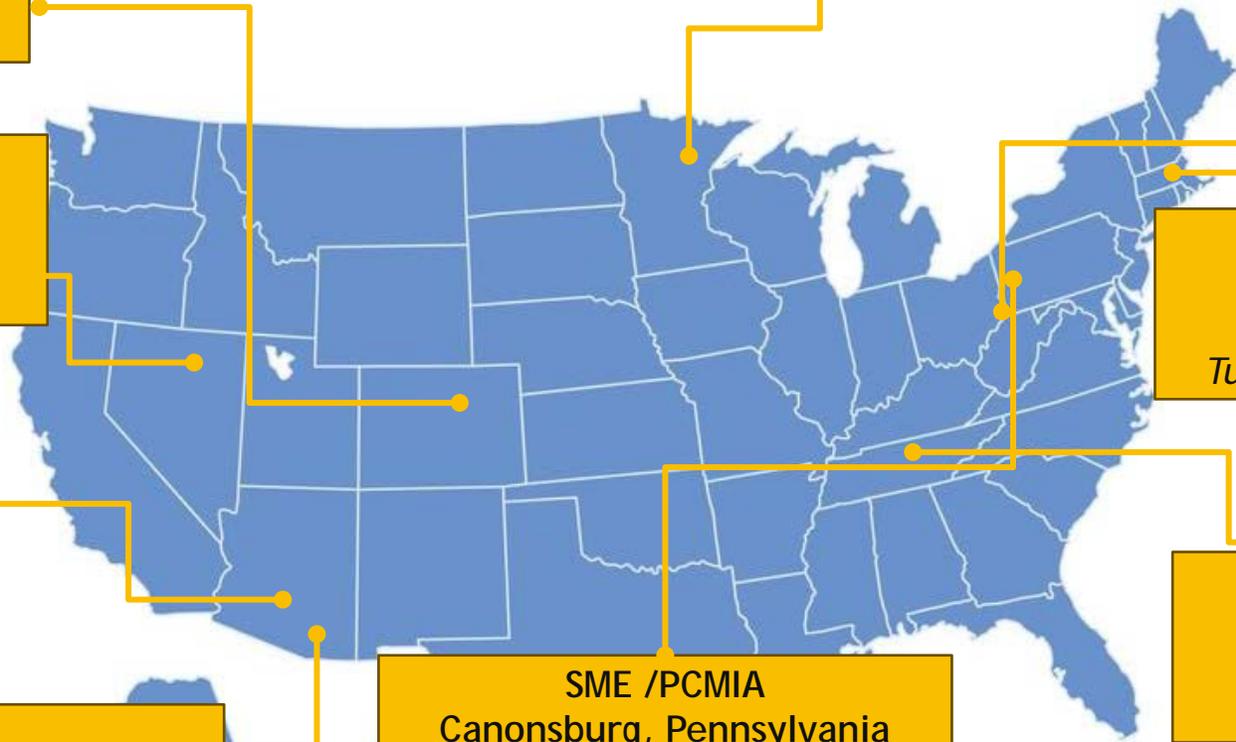
**Mine Safety and Health Administration**  
Triadelphia, WV  
April 2024  
*MSHA Professionals*

**Rapid Excavation and Tunnelling**  
Boston, Massachusetts  
June 2023  
*Tunnelling Construction Professionals*

**NSSGA Annual Meeting**  
Nashville, TN  
*Aggregate Operators*

**SME /PCMIA**  
Canonsburg, Pennsylvania  
October 2023  
*Coal Operators*

Picture of the map of the United States.



# Workshop #1 – Tucson, AZ

## Major Copper Operators and OEMs

- *Need for a collaborative relationship between industry and regulators*
- *Something like the EMSR (Earth Moving Safety Roundtable in AUS)*
- *Small operators need the most assistance from NIOSH and MSHA*
- *The brownfield nature of a majority of U.S. operations has made implementation more difficult.*
- *Significant drivers of technology in the U.S. currently include the lack of workforce and low carbon tech.*

Barrier	%
Regulation	5
Economics	55
Social License	10
Corporate Willingness	15
Technology Readiness	15

Successful Tech
Fatigue Monitoring
Fleet Management
Drons
INSAR
RADAR/LIDAR
Dynamic ERP (Enterprise Resource Planning)
Electronic blasting delay
Automated guarding (belts)

# Workshop #2 - Denver, CO

## Diverse group, UG, Surface, OEM

***“The problem is not a specific regulation but the specificity of regulation”***

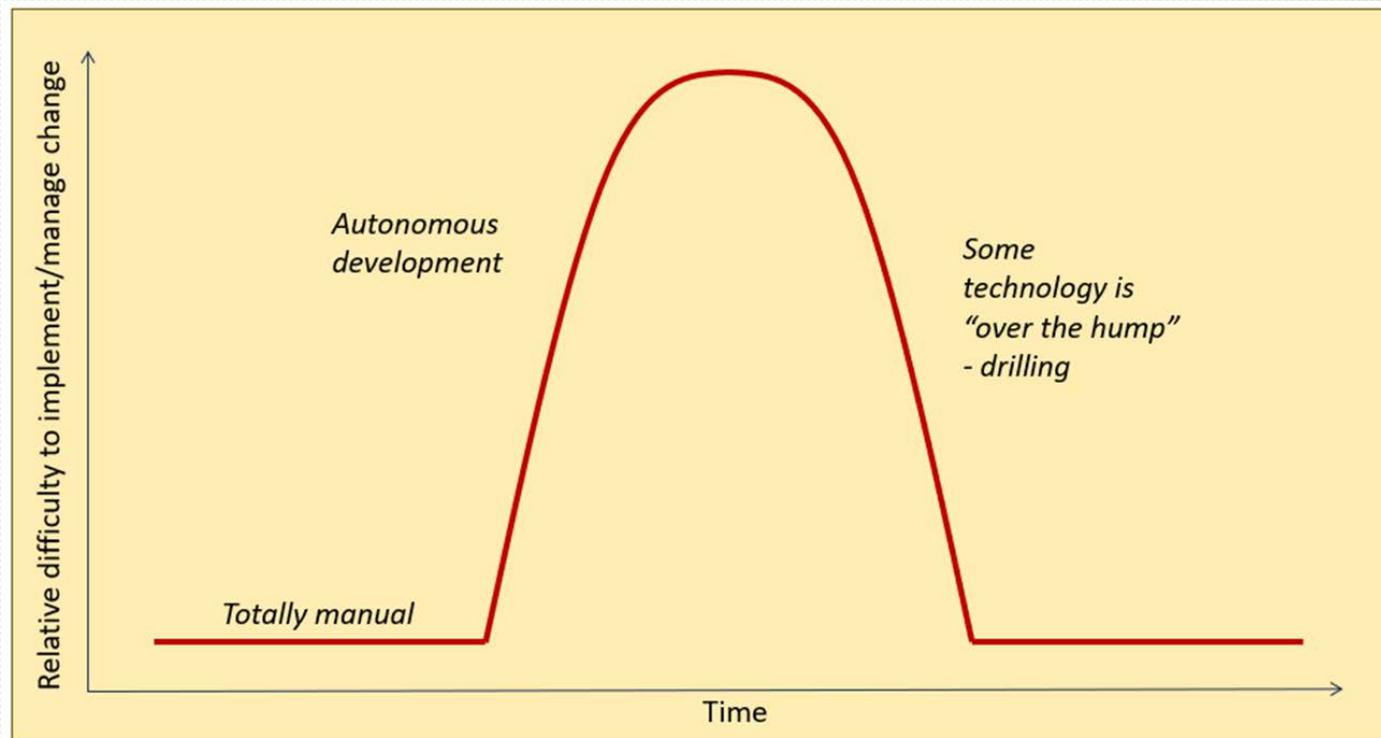
*-Workshop attendee*

- Exposure based regulation is driving autonomy in some cases.
- Discussion of workforce - automation will *change* the workforce but not reduce it in the short term
- Level 7 automation is currently attainable (system runs in an automated mode with monitoring and opportunity for operator intervention, but Levels 7-9 (fully autonomous) is difficult legally and operationally

Barrier	Percentage
Regulation	25%
Economics	40%
Social License	5%
Corporate Willingness	5%
Technology Readiness	25%

# Workshop #2 - Denver, CO

## Diverse group, UG, Surface, OEM



Picture of a hump shaped chart comparing "Relative difficulty to implement change" going up on the left side with "Time" going across on the bottom. The chart shows the words "Totally manual" on the bottom left, "Autonomous development" on the left higher part of the hump and the words "Some technology is 'over the hump'- drilling" on the right side of the hump.

# Workshop #3 - Virginia, MN Iron Range Operators

- The workshop was an outlier in terms of workforce. Strong unions in the region and a mature workforce. Operators were not as concerned about lack of skilled labor in this workshop, but they are concerned about alienating the community with automation.
- Capital budgets are fairly small for mine automation at this time, where the focus is downstream in processing and steelmaking.
- Phased process is key → collision avoidance is high priority
- There was some discussion regarding automation and the control an OEM has over the business.

Barrier	Percentage
Regulation	25%
Economics	50%
Social License	5%
Corporate Willingness	10%
Technology Readiness	10%

# Workshop #4 - Boston, MA

## Construction/Tunnelling Contractors

- Labor shortage is a driver (COVID changed perspective)
- Dust and environmental exposure
- Iterative barriers exist
- Gaps between US uptake and others:
  - Liability
  - Zero Harm Mentality (as opposed to acceptable risk)
  - Compliance vs. Risk regulatory perspective

Barrier	Percentage
Regulation	15%
Economics	35%
Social License	5%
Corporate Willingness	20%
Technology Readiness	25%

# Workshop #5 - Phoenix, AZ

## Mineral Preparation and Processing, OEM

- Fixed plant nature has allowed for early and long time adoption of automation.
- There is a need to replicate the highly experienced and skilled metallurgist with sensing and data science.
- Maintenance is also a difficult area to automate.
- Many OEMs working in one plant - connectivity and data access are issues. One operator just had a major IT security breach so this is becoming a significant technical concern. Standardization would be helpful.

Barrier	Percentage
Regulation	3%
Economics	35%
Social License	15%
Corporate Willingness	15%
Technology Readiness	32%

# Workshop #6 - Canonsburg, PA

## Coal Mining Companies and their Suppliers

- Within the region, the greatest need for automation in underground coal applications stem from mining in low coal environments.
- Operators have expectations that the OEMs should be intimately involved in terms of equipment and system innovation and automation.
- In these operating environments there are not a lot of alternatives for driving technology other than the OEMs. Operators don't have much capacity to facilitate automation on their own.
- While significant hazards exist in these mining environments, the economic incentives for OEMs to engage in R&D are fairly limited since there are very few customers to warrant the amount of time and investment required.

Barrier	Percentage
Regulation	33%
Economics	35%
Social License	17%
Corporate Willingness	10%
Technology Readiness	5%

# Workshop #7 - Nashville, TN

## Aggregates and Industrial Minerals

- Significant discussion was devoted to workforce development. Senior people are leaving and creating significant void. While automation may be able to positively offset some of the impact of these shortages, it does not replace people. People are critical to these operations and are analogous to “ore reserves” in terms of importance.
- Automation and technology are selling points to attract workers.
- Concern about network security and cybersecurity is very important as automation increases.
- In sand and gravel/aggregates, automation is occurring to build back capacity lost by lack of people, “bite size” projects, mobile equipment unlikely for small operations.
- MSHA small mines program is needed for tech support in these industry sectors (many small operators).

Barrier	Percentage
Regulation	10%
Economics	40%
Social License	28%
Corporate Willingness	16%
Technology Readiness	6%

# Workshop #8 - Triadelphia, WV

## MSHRAC Committee & MSHA ACC

- The mine rescue technology that MSHA regulates is highly specialized and difficult to maintain, where there may be some opportunities for automated processes and improvements. MSHA really needs designated funding for new technology and for emergency response.
- MSHA experiences the same criticality around talent recruitment of workforce that industry does, and the workforce for technology is highly specialized.
- There was discussion of technology ratcheting regulation (e.g., communication and tracking, proximity detection, potentially the new silica regulation) versus other regulations. There was a general sense that while it can be difficult to point to technology and its implementation as a barrier, it has the capacity to “chill” innovation.
- There was extensive discussion of proximity detection in underground coal as an innovative technology, approved, that has had a very positive impact on safety. There are currently 4 approved systems, 3 on the market, with 2 unique approaches.

Barrier	Percentage
Regulation	20%
Economics	20%
Social License	20%
Corporate Willingness	20%
Technology Readiness	20%

# Workshop #9 - Elko, Nevada

## Gold Operators, Contractors & Suppliers

- There is a legitimate question as to whether the regulations are a barrier to automation or the regulatory agency is the barrier. The regulations of concern extend beyond MSHA, and include the FCC.
- It seems that companies are unwilling to take a risk with new technology. There ought to be a way to incentivize innovation.
- If the permitting process were streamlined significantly and the potential for litigation reduced, an operator might be more likely to implement automation at a new mine.
- Similarly, if new technology risks were eliminated, companies would be more willing to engage, but there would have to be support for the equipment.
- The regulation that should come would be to regulate automation only zones ("AOZ"). That would generally entail coming up with common communication protocols.

Barrier	Percentage
Regulation	13%
Economics	20%
Social License	17%
Corporate Willingness	30%
Technology Readiness	20%

# SME Contacts and Acknowledgement

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SME thanks NIOSH for their support of this project.