NIOSH MINING PROGRAM REVIEW

Table of Contents

Panel Members/Affiliations

Cecile Rose, MD, MPH (Chair), Professor of Medicine, National Jewish Health and University of Colorado School of Medicine, Denver, CO

David Beerbower, MBA, Principal Consultant, Beerbower Safety Associates, LLC and former Vice President for Safety, Peabody Energy, Chesterfield, MO

Marifran Mattson, PhD, Professor and Head, Brian Lamb School of Communication, Purdue University College of Liberal Arts, West Lafayette, IN

Michael McCawley, PhD, West Virginia University School of Public Health, Morgantown, WV

David Newman, PhD, PE, President, Appalachian Mining & Engineering, Inc., Lexington, KY

Michael J. Wright, M.S. (Industrial Hygiene), Director of Health, Safety and Environment, United Steel, Paper and Forestry, Rubber, Manufacturing, Energy, Allied Industrial and Service Workers International Union (USW), Pittsburgh, PA

Executive Summary

The mission of the NIOSH Mining Program is to eliminate mining fatalities, injuries, and illnesses through relevant research and impactful solutions. The NIOSH research portfolio spans a broad range of focus areas with the goals of reducing occupational illness and disease; reducing injuries and fatalities; and disaster prevention and response.

The Panel found that the Mining Program Evidence Package provided substantial documentation and information on the health and safety burden for miners in the three areas reviewed: Disaster Prevention and Response, Ground Control, and Respirable Hazards. The Evidence Package contained numerous outcomes and interventions that addressed relevant mining health and safety priorities, with practical solutions that have been integrated into mines and Mine Safety and Health Administration (MSHA) inspection processes, resulting in positive impacts on miner safety and health.

The Panel noted numerous examples in which NIOSH Mining Program research has made substantial, unique, and vital contributions to the field. The majority of Intermediate Outcomes were rated at the highest levels for Impact and Relevance, and NIOSH is commended by the Panel for its sustained and effective research-to-practice efforts. Panel members noted that NIOSH research provides the foundation needed for the mining industry's evidence-based selection of efficacious equipment and programs and for research applications in industry and regulatory settings. The Panel found that NIOSH handled the determination of research priorities based on discussions with stakeholders and the identification of research gaps, both of which are challenging, extremely well.

For Disaster Prevention and Response, one particularly noteworthy contribution during the Program review period was NIOSH's work on rock dust to prevent propagation of explosions in underground mines. NIOSH findings dispelled decades of mistaken beliefs on best practices for applying and maintaining rock dust. Other notable NIOSH contributions include the explosibility meter to determine rock dust content in real-time; effects of treated rock dust; and seal design for abandoned underground mines. The Lake Lynn experimental mine was a valuable asset for many of these efforts. Additional relevant and impactful examples include NIOSH's work on efficacy of mine communication and tracking systems; mine conveyor belt flammability testing that led to new, evidence-based MSHA standards; and the work on portable refuge shelter use during mine disasters.

For Ground Control, similar important contributions from NIOSH efforts were evident. For example, NIOSH developed the industry standards for ground control software, and MSHA now relies on NIOSH pillar design and roof support programs for regulatory approval. NIOSH work on shotcrete and its S-Pillar software have become industry standards.

In the area of Respirable Hazards, NIOSH played a pivotal role in developing the wearable, real-time continuous personal dust monitor (CPDM). This technology was a quantum leap that enabled the industry to monitor mine dust levels and, along with miners themselves, make immediate changes to reduce miner exposures to respirable coal mine dust (RCMD). The recent surge in cases of rapidly progressive and severe pneumoconiosis among younger Appalachian miners has increased the relevance of NIOSH's efforts to develop a portable, real-time respirable crystalline silica (RCS) monitor. Future work should focus on particle type, size and number in addition to mass concentration as metrics for understanding RCMD, RCS and diesel particulate exposure-related health effects. Other examples of NIOSH research with significant impacts on dust control that have become industry standards include

roof bolter dust bags, air curtains, and extended cut ventilation. The HelmetCAM program is an excellent example of effective multi-disciplinary, multi-method research that encompasses how humans respond to new safety technologies.

Background for the Review Process

The National Institute for Occupational Health and Safety (NIOSH) is a public health agency within the federal government responsible for conducting research to reduce worker illness and injury and advance worker wellbeing; to promote safe and healthy workplaces through interventions, recommendations, and capacity building; and to enhance international worker safety and health through global collaborations. NIOSH is part of the Centers for Disease Control and Prevention (CDC), and serves as the lead for occupational safety and health.

This is the second formal external review of the NIOSH Mining Program, and is focused on three major areas: Disaster Prevention and Response, Ground Control, and Respirable Hazards. An external Review Panel was convened to review the relevance and impact of NIOSH's Mining Program from fiscal years 2008-2018. The Panel Chair was charged, in November 2018, with recruiting Panel members, conducting a Review Process, and producing a Report based on the scoring methodology provided by NIOSH. Selected to represent a balance of individuals from academia, labor, industry, and government, the Panel composition included a translation science expert, four subject matter experts, and an evaluation expert, each with experience in one or more of the mining areas covered in this Review; all Panel members reported no conflict of interest.

Scoring Model and Process

For this review, NIOSH adopted a slightly modified version of a program evaluation approach known as contribution analysis.[1] This approach seeks to identify a reasonable association between Program activities and outputs and observed Intermediate Outcomes to establish a theory that explains the contribution of the Program to a given outcome. All Panel members received an orientation and overview of contribution analysis and logic models prior to conducting the evaluation. In April 2019, Panel members participated in a webinar to receive an overview of the Review, evaluation model, and project timeline. The Panel then received a comprehensive, 250-page Mining Program Evidence Package (Evidence Package) for 2008–2018, prepared by the NIOSH Mining Program, providing detailed information about Program work and results.

Next, Panel members participated in a day-long, in-person meeting with Mining Program and other NIOSH staff in Atlanta, Georgia; two NIOSH staff members with expertise in diesel particulate matter participated remotely on the second morning of the meeting as well. The Panel members were presented with summary overviews of the work and results from Mining Program activities, with the opportunity to ask questions and engage in discussions following the presentations.

The following day, Panel member discussions included preliminary observations based on the materials provided, the presentations and discussions from the previous day, and their own personal experiences and expertise. Panel members then independently appraised all materials and provided, to the Panel chair, individual scores for relevance and impact, including supportive rationale for their scores. This Report is a synthesis of the Panel members' written reviews and discussion of the Evidence Package and the Mining Program presentation and discussions. All Panel members have reviewed and edited the Report, and each has provided individual Program scores for relevance and impact.

The Panel members' scores were averaged to issue a single Relevance score and a single Impact score (means), as well as a total Program score, the average (mean) of the sum of the scores for both Relevance and Impact.

The mean Relevance score was 5 on a 5-point scale, with "1" indicating the rationale for the activities completed by the Program were not justified and "5" indicating the rationale for the activities completed by the Program were highly justified.

The mean Impact score was 4.5 on a 5-point scale, with "1" indicating research activities and outputs do not result in, or are not likely to have, any application and "5" indicating the Research Program has made major contribution(s) to worker health and safety based on End Outcomes or well-accepted Intermediate Outcomes. All scores were rounded to the nearest 0.5 increment.

The overall Program score was 9.5.

Acknowledgements

The Panel members were honored to serve on the NIOSH Mining Program Review. The Panel was deeply impressed by NIOSH Mining Program leadership and staff expertise, professionalism, and commitment to doing the foundational research and dissemination needed to protect the health and safety of miners. Thanks to the presenters at the evaluation meeting who briefed the Panel on their research efforts and answered the Panel's numerous questions. The Panel would like to thank Amia Downes and Emily Novicki for their guidance on the evaluation process. The Panel also appreciated the logistical support from David Frye and Mary Dawson from AECOM and Jan Lane from Professional Staffing Partners, as well as editing support from Leslie Hamlin.

Panel Findings

The Review Panel gave the combined NIOSH Mining Program a unanimous score of 5 for Relevance and an overall score of 4.5 for Impact. For Relevance, this means that the rationale for the priorities set and activities completed by the Program is highly justified based on burden and need. For Impact, this means that the Research Program has made major contributions to worker health and safety on the basis of well-accepted Intermediate Outcomes. Panel conclusions and comments regarding Impact and Relevance of the Intermediate Outcomes for each of the three topic areas -- Disaster Prevention and Response, Ground Control, and Respirable Hazards -- along with general observations and recommendations from the Panel are detailed below.

Disaster Prevention and Response

Overview and Findings:

Throughout the history of mining, major disasters have been a blight that defined the industry and negatively affected public opinion about the overall safety culture in underground mines. Although these disasters are becoming less frequent, each time one of these low-probability/high-impact events has occurred, public outcry has led to politically motivated action that transformed the industry and increased regulatory oversight.

NIOSH has played a vital role in researching the causes of these disasters and mobilizing the weight of informed science to provide practical solutions for disaster prevention. In fact, NIOSH partnerships with industry officials, union leaders, federal regulators, and university experts are emblematic of the collaborations needed to eliminate disasters. Because the probability of mining events is considered low, it can be difficult to attach a causal nexus to each solution. But the fact that these disasters were much more common just a few decades ago leads us to assume that these combined efforts and partnerships have contributed to safer underground mine conditions.

Within the timeframe of this Panel Review, there are several notable examples. NIOSH's extensive research into the characteristics and effectiveness of common rock dust was groundbreaking, dispelling decades of mistaken beliefs regarding best practices for applying and maintaining rock dust. This resulted in new Mine Safety and Health Administration (MSHA) regulations for the percentage of incombustible materials allowed within intake airways. NIOSH also spearheaded research into treating rock dust to help these particles remain dry in damp mine environments, enabling them to become airborne in a propagating coal dust explosion, thereby minimizing the propagation of flame and intensity of the concussive wave forces.

To provide operators and MSHA inspectors a practical, real-time way to determine the rock dust content of mine samples, NIOSH developed a coal dust explosibility meter, which provided a means to instantaneously determine areas deficient in incombustible content and reduced the gap in time between noncompliance and re-dusting of the deficient area.

One of the major sources of underground mine fires is conveyor belts, used to remove raw product to the surface for processing. The heat resulting from friction on conveyor belts can start a fire that will consume the belt material. Belt entries can be remotely located, so a small fire can become a major

problem before it's even detected. NIOSH research into the flammability of mine conveyor belts led to small-scale field testing, which compared well to previous larger-scale tests. As a result, new regulatory standards were approved by MSHA to reduce flame propagation of mine conveyor belts. NIOSH also developed improved methods for the design and installation of fire suppression systems in underground belt entries, where air is used to ventilate active mine faces.

Traditionally, mined out, abandoned, and seldom used areas of underground mines have been sealed. The long-term stability and airtightness of the concrete block walls used to seal these mines have been a constant problem, requiring extra resources to keep the seals in proper order. In 2006, the Sago explosion in West Virginia and the Darby explosion in Kentucky, which resulted in the deaths of several miners, were attributed to leaky seals that allowed explosive mixtures of gas to accumulate behind the seal line. Based on subsequent NIOSH research, the methods for sealing underground areas have improved exponentially. New designs that increased the thickness of the seals dictated that they be made of poured cement materials. The experimental mine at Lake Lynn was a valuable asset during this time. Seals were installed and tested there to assure that they could withstand the impact of an explosion without failing structurally. Today, these seals are required by law and are standard industry practice.

The Mine Improvement and New Emergency Response (MINER) Act, signed into law in 2006, also requires the industry to purchase and install enhanced communication and tracking systems. Since there were no existing products available to meet these regulations, the MINER Act forced the development and use of technology. NIOSH took the lead in evaluating the efficacy of newly developed communication and tracking systems by hiring experts in the field to determine the best fit for the industry's specific needs. This assistance proved invaluable, as it gave companies a degree of confidence before making multi-million-dollar investments in these systems. NIOSH also provided seminars to educate managers and miners on the capabilities of each system.

MINER Act regulations required operators to purchase portable refuge shelters. This concept of refuge shelters was foreign to the industry, as miners had always been trained to attempt to escape from a mine in the face of a disaster; barricading themselves in place was considered a last-chance option to be used only when escape was not possible. NIOSH investigated the physical and psychological impacts on miners who entered portable refuge shelters during such disasters. As a result of this work, many new facts came to light that resulted in design changes to the refuge shelters. Through a NIOSH-funded report,[2] the National Academy of Sciences made recommendations that NIOSH increase their emphasis on human factors as they apply to a miner's ability to self-escape during a mine disaster; this work is ongoing and shows great promise. In the event of a disaster, NIOSH also developed a virtual reality lab for miners, in which they can experience and respond to life-like conditions they might encounter.

As demonstrated by these examples, the impact of NIOSH research on disaster prevention during the period of 2008–2018 cannot be overstated. Their willingness to listen to various stakeholders and to broker partnerships has opened doors that were not possible in the recent past. Their stature as the honest broker has led to scientific solutions to difficult, sometimes politically sensitive, issues.

Further human factors research is needed to assist mine rescue teams in the management of a disaster. The tension surrounding one of these events requires a unified approach as to how teams are managed and deployed. As of now, MSHA has the authority over any recovery action, but clear lines of command with an understanding of the responsibilities for all elements of the operation are imperative. Properly

handling these complex interactions can mean the difference between success and failure in disaster response.

Panel responses to questions from NIOSH:

Automation of mining operations is changing the nature of the mine work environment, and consequently, mine worker health and safety risks. While NIOSH has begun planning for research in this area, does the Panel have any recommendations regarding how we might adapt our research to address these issues?

The Panel discussed the question of how to adapt NIOSH research to understand the implications of increasing automation in the mining industry. How will this trend affect the work environment, as well as mining health and safety (H&S) risks? More information is needed on the extent of, and emerging trends in, automation in the industry. It will be important to understand not only equipment changes inherent to increasing automation, but also impacts on maintenance requirements and work processes and systems that affect miners' job duties and their health and safety training needs.

The Panel does not recommend that NIOSH research focus on developing new automation methods, but instead track trends in the industry and assess the H&S effects of these changes. For example, it is now possible to buy large, driverless haul trucks with no option for operator control in case of an emergency. What are the safety issues that are likely to occur with this approach? What if the driverless haul truck responds to the wrong signal?

There is also a need to examine and better understand work organization factors that may occur with increased automation. For example, a recent strike at Lucky Friday Mine was triggered, in part, by the question of who would control the automated equipment that is transported underground: the underground miners or the surface miners? NIOSH could have an important role in examining the effects of automated systems on work organization and miner health (e.g., stress levels, autonomy).

Moving equipment accounts for a substantial number of the accidents and fatalities that occur in coal and metal/non-metal mines. Proximity detection systems, to help protect miners from contact with moving machinery, are currently required on Continuous Mining Machines used in the face areas of underground coal mines. More research is needed to refine these proximity detection systems and to explore expanding these protective devices to all mobile face equipment.

Does the Panel have any recommendations regarding additional efforts NIOSH might undertake to facilitate self-escape research?

The Panel suggests ongoing research focused on the human factors aspect of self-escape. When under stress, how do people react when mobilizing for and facilitating escape? The Panel feels that NIOSH may need to focus more on social science/behavioral research, while acknowledging the difficulty in determining how to prioritize research for low-probability events. The Panel suggests that it might be helpful to first summarize relevant self-escape research from firefighters and the military to inform priorities and next steps for NIOSH research in this area.

Ground Control

Overview and Findings:

The NIOSH ground control research efforts provide wide and varied coverage of pillar, roof, rib, and floor stability in coal, limestone, and hard rock mining. NIOSH has done an excellent job of providing relevant research that is distilled into technical papers, reports, and software programs that are readily available to operators, mining engineers, and front-line supervisors. Practicing engineers and the academic community receive relevant information primarily through professional conference papers, research reports, and the NIOSH website. Importantly, those individuals (mine and quarry operators, front line supervisors, and miners) who will use the information on a daily basis are invited to attend NIOSH-sponsored conferences at minimal or no cost. In general, NIOSH does an excellent job of disseminating their research to the mining industry.

The Analysis of Coal Pillar Stability (ACPS), Analysis of Longwall Pillar Stability (ALPS), Analysis of Retreat Mining Pillar Stability (ARMPS), Analysis of Roof Bolt Systems (ARBS), Analysis of Horizontal Stress Effects in Mining (AHSM), Analysis of Multiple Seam Stability (AMSS), Coal Mine Roof Rating (CMRR), and S-Pillar suite of geotechnical software has become the standard for design of underground room and pillar and longwall mine stability, and is now required by MSHA for ground control plans. This mining software is readily available online, and for most conditions, provides reliable and essential information. The ARMPS and ALPS pillar design guidelines were revised to accommodate deeper overburden, as previous case histories were limited to shallow cover. Updated case histories have a wide user base with good industry penetration. The newest of the software suites, ACPS, integrates the algorithms of ARMPS, AMSS, and ALPS into one software package to avoid conflict and overlap.

One Panel member commented that the older program (MULSIM/BM) was brought back and analyzed as an alternative to the well-accepted and widely used LaModel program for numerical modeling of underground mines. The software still has a poor user interface, resulting in minimal industry penetration.

NIOSH rib support research provided the evidence base for MSHA regulatory and accepted practice changes. Injuries and fatalities caused by rib rolls and rib collapses have become more prevalent as coal seams with multiple coal splits and rock partings are being mined. The Panel noted that it would be helpful to the industry to have a field tool to help predict conditions where rib supports need to be installed, as well as information on the types of support (rib bolts, "pizza pans," welded wire mesh, metal straps, and fiber and plastic mesh) needed to address specific ground conditions. Panel subject matter experts also recommend that NIOSH perform research on rib support needs when the longwall shearer comes to the end of the panel and cuts into the open entry of the recovery room to better understand the supplemental supports needed in recovery rooms.

Mine Roof Simulator (MRS) testing is foundational for ground control plan development. Full-scale testing of cribs and standing support is critical to determine capacity and proper application. This line of research has made impressive and unique contributions to the field. NIOSH research equipment is able to induce horizontal pressures, and may be the only research equipment that can load standing support vertically and horizontally. Notably, the equipment is able to test a variety of standing support systems.

NIOSH is doing critical work to determine the interactive effects of longwall coal mining adjacent to frack gas wells, assessing the effect of subsidence-induced deformation on well casings. This research will provide MSHA the data it needs to determine the dimensions of the barrier pillar to leave around pads with multiple frack wells. Further research is recommended, as within the next five years, longwall mining and underground coal reserves will be affected by thousands of frack wells drilled in the Northern Appalachian coalfield.

Coal and metal mine seismicity monitoring requires a great deal of specialized expertise unique to NIOSH. The primary application of this research is in characterizing coal bump and rock burst potential in metal/non-metal mines. Additional research is recommended for the application of seismic networks in coal and deep metal mines.

New metal and stone mine blast software is promising in terms of limiting blast damage to the rock and reducing the amount of post-blast scaling. The DRIFT blast design software package will enable all mines to examine their blasting practices and provides an alternative to the proprietary software of powder companies. This marks some of the first blasting research since the U.S. Bureau of Mines' efforts to correlate blast parameters with structural damage in the Illinois Basin. Some of the work presented is preliminary, and it may be too early to assess impact on blasting practices.

NIOSH has done important research on cemented backfill, and should continue these efforts, especially in western underground mines. There is little sharing of in-house research done by mining companies on backfill mix design and the behavior of backfilled stopes, as effective backfill is directly related to the economics of underground metal mining. NIOSH research provides a means for summarizing the benefits of existing backfill practices and standardizing backfill mix design. This research is applicable in other mining efforts where support of a mined-out area is required.

Similar to backfill design, shotcrete mix design and application is critical to supporting poor ground in underground metal mines, tunnels, and other excavations in rock. NIOSH research on the development of a standard method of onsite testing of shotcrete panel strength, along with examination of bond strength, load capacity, and toughness, are all valuable and relevant. NIOSH's standardized approach to testing and practical applicability are excellent, thorough, and diligent. The impact on industry is high, the research is well-accepted, and the full-scale High-Energy, High-Displacement {HEHD} test machine was helpful to the evaluation of shotcrete. Testing commercial mesh and fibers using field size samples, with good documentation of how each behaved as they went through failure, enabled quantification of mix designs. NIOSH research has established standardized techniques for the application of shotcrete to rock, the evaluation of shotcrete mixes and provided standardized methods for evaluating results of shotcrete application. The shotcrete research program is an excellent example of research that is directly applicable to mining and tunneling industries, with appropriate involvement of stakeholders. The Panel feels that this area of research is approaching an End Outcome. Although NIOSH needs to maintain testing, it may not need to expand research in this area.

S-Pillar software created a standardized approach based on case histories, and the industry uniformly relies on it. Prior to the development of S-Pillar software, the design of underground stone pillars was not standardized. The dissemination of S-Pillar software was a multi-pronged, successful effort. The Panel recommends that NIOSH continue to add case histories to improve pillar design under dipping limestone beds, in multi-level mines, and with deeper overburden.

The AMSS software program is usable, but may over-simplify a complex ground control problem. Underground conditions should not be reduced to either a "gob-solid interface" or a "remnant pillar." The Panel was not sure whether assisting one mine, Darby Fork, as described in this Intermediate Outcome, adequately reflects the more general contributions from NIOSH technical support.

Research on bleeder entries is highly relevant, as entries on longwall and room-and-pillar mines are subject to overburden stress and side abutment stress as the longwall panels are mined or as the room-and-pillar panel is retreated. The Panel reiterated the suggestion that NIOSH expand research to examine support strategies for the longwall recovery entries and chutes.

Panel responses to questions from NIOSH:

Our current ground control research focus is primarily on underground mining. Does the Panel have any recommendations regarding other issues NIOSH might prioritize in ground control?

The Panel noted that there was no discussion of surface mine or quarry highwall stability in the Evidence Package, and suggested that these would be important areas for future research in ground control.

Does the Panel have any recommendations as to what additional efforts NIOSH might undertake in the area of seismic monitoring to address ground control issues?

NIOSH should consider the S-Pillar program research applicability for other commodities (e.g., salt, trona), multi-level quarries, and deeper mines that have had catastrophic failures. Similarly, for deep metal mines, seismic monitoring research on ground control issues may be relevant to address specific bounce/burst/collapse problems. NIOSH could consider lessons learned from the Brazilian dam collapse, as this event involved issues related to soil/mine waste liquefaction, seismicity, and ground control. The Panel noted that NIOSH work on the Buffalo Creek disaster influenced dam/coal refuse impoundment design. Given a recent review of coal mine impoundment stability, the major issue with dams may be less on research and more on implementation/enforcement.

Respirable Hazards

Overview and Findings:

NIOSH's goal of preventing respiratory diseases due to hazardous mining exposures is longstanding. During the review period, NIOSH focused its efforts on three major respirable hazards: respirable coal mine dust (RCMD), respirable crystalline silica (RCS), and diesel particulate matter (DPM). NIOSH researchers made substantial contributions to understanding the adverse respiratory health outcomes in miners from these exposures, including the pneumoconioses (coal worker's pneumoconiosis [CWP] and silicosis) and lung cancer. Other important exposure-related health outcomes for ongoing research include cardiovascular diseases and obstructive lung diseases, as well as research on elongate mineral particles.

The Intermediate Outcomes contained in the Evidence Package demonstrated substantial research productivity during the review period, including developing field-ready instruments to measure airborne contaminants, developing control technologies for high-risk jobs, reducing RCMD and RCS exposures, and characterizing and reducing diesel emissions. Multi-stakeholder partnerships have been, and

remain, vital for coordinated and meaningful research outputs. Information-sharing by NIOSH with the international mining community – on dust control, state-of the-art medical surveillance, and the clothes cleaning technology – has had important impacts, most notably in Australia.

The continuous personal dust monitor (CPDM), along with the 2014 changes in MSHA dust regulations, are among the most important NIOSH achievements during the years 2008–2018. NIOSH provided the research evidence base and platform for two iterations of the personal dust monitor (PDM) that were certified by MSHA. These efforts helped assure that the PDM was miniaturized and not machine-mounted, removing the light battery and cord from the system to improve cumbersomeness and decrease weight. NIOSH efforts on the CPDM drove rapid changes in the industry to diminish exposures. In addition to examples in the Evidence Package, the Panel noted other examples of how the CPDM has led to changes in behaviors and work practices to diminish dust exposures (e.g., adjusting water sprays, miners moving away from high dust areas). The Panel expresses gratitude and kudos to NIOSH for persevering through a long and arduous research process with an important outcome.

The recent surge in Central Appalachian cases of rapidly progressive CWP among younger miners, along with the most severe form of CWP, progressive massive fibrosis, has been and will remain a NIOSH focus. Efforts to develop an RCS monitor are highly relevant because of the emerging importance of measuring RCS (not simply total mass concentration of coal mine dust) in understanding risk for severe, progressive CWP. Improved RCS monitoring will also enhance understanding of RCS exposure risks in other mined commodities. NIOSH recognizes the need to continue its efforts on miniaturizing RCS monitoring technology and developing a real-time monitoring device. The Panel questioned whether there may be different, more optimal dust suppression methods that should be explored now that the evidence points to RCS as a major relevant exposure in underground coal mines. The Panel also suggested that NIOSH explore interactions between RCS and diesel particulates.

Decades of research by NIOSH were foundational for enactment of the new MSHA coal mine dust standard during the review period. One Panel member expressed concern that incomplete information led to creation of a standard that was not adequately targeted to RCS. Some Panel members were not reassured that the change in the RCMD permissible exposure limit (PEL) from 2 mg/m^3 to 1.5 mg/m^3 would be adequate to prevent future coal mine dust-related diseases. All Panel members agreed that inclusion of the CPDM in the new standard was a major step forward, as it provides real-time data that can affect behavior in real time. Several Panel members feel that current use of the CPDM does not enable optimal sampling and monitoring to enhance dust control programs, in part due to regulatory constraints. Panel members also expressed concerns about whether compliance sampling of designated occupations is representative of non-sampled miner exposures. NIOSH could play an important role as the honest broker in identifying ways to optimize the use of the CPDM as part of a holistic approach to reducing mining exposures.

A number of Intermediate Outcomes have had substantial impact on reducing exposure to DPM. Examples include the development and commercialization of a wearable, real-time DPM monitor; direct tailpipe measurement of DPM; the handheld electrostatic precipitator particle sampler; and the correction method and conversion factors for DPM that informed MSHA sampling methods.

The Panel requested, and NIOSH arranged, additional discussion of NIOSH's research efforts on diesel particulate matter (DPM). Further exploration of the effects of diesel particle size and number in addition to measurements based on mass concentration will enhance the applicability of NIOSH DPM

research. Ongoing research on the development of science-based technology, and its dissemination, is vital to protect miners from the effects of diesel particulate exposures, including partnerships with toxicologists and enhanced cross-sector collaborations.

Research on the canopy air curtain made an important impact on lowering dust exposures for all commodity miners. This area of research is approaching an End Outcome, and full dissemination is vital. Similarly, collaborative research conducted by Sy-Klone and NIOSH changed the ways companies buy mobile equipment, this area of research may be approaching status as an End Outcome if it becomes standard on all equipment.

The Helmet-CAM research program is a well-documented and well-received example of effective multi-disciplinary, multi-method research that takes into account how humans respond to safety technologies. The Panel emphasized that this type of interdisciplinary research needs to continue, with necessary and timely support in place from institutional review boards (IRBs) and the Office of Management and Budget (OMB).

Panel responses to questions from NIOSH:

Historically, NIOSH has focused on engineering controls for reducing miners' exposure to respiratory hazards. Does the Panel have any recommendations as to whether consideration for understanding fundamental characteristics (i.e., mine dust particle size particle shape, composition, etc.) of the exposure hazards and the associated health risks should also be prioritized?

The Panel believes that understanding these fundamental characteristics of mine dust particles is vital to controlling exposure hazards and associated health risks, and should be prioritized in future NIOSH research (as recommended in the 2018 National Academies of Sciences, Engineering, and Medicine's publication on Control of Respirable Coal Mine Dust Exposure in Underground Mines).[3]

One Panel member pointed to the increasing focus in toxicology on "ultrafine" aerosols, of which diesel particulate matter is an important example. Ultrafine aerosols cause inflammation, and may contribute to risk for cardiovascular, autoimmune, respiratory, neurological, and carcinogenic adverse health outcomes. A focus on ultrafine aerosols and associated disease risks may require a change in the way exposure monitoring is carried out, requiring more sophisticated, expensive instruments for future research. The mechanism for ultrafine particle sample collection will need to be adjusted from current sizing, which is based on the sedimentation rate of particles, to sizing based on a particle's diffusion rate. With current NIOSH projects for monitoring and control of diesel exhaust underway, consideration of the ultrafine fraction of the exhaust is important to keep those projects relevant. NIOSH appears to have sufficient and highly skilled expertise to address this area of research.

Does the Panel have any recommendations as to whether we should consider placing more of an emphasis on research toward respiratory and other exposure hazards in mineral processing facilities such as mills and coal preparation plants?

The Panel found this question important, but needed more information in order to provide guidance on how to prioritize this area of future research.

Mills and preparation facilities are known to use a range of chemicals. One relevant example is the chemical 4-methylcyclohexanemethanol (MCHM), a flocculant used in coal preparation facilities.

Approximately 5 years ago, an estimated 300,000 people were exposed to MCHM via an environmental spill into the Kanawha River. Knowledge of the health effects of MCHM were found to be insufficient during the course of the spill investigation. Many such chemicals are now making their way into the mining workplace and the general environment without the knowledge required to judge their toxicity. The workplace has always been assumed to be the environment where the highest and best-documented exposures occur, and offers an opportunity to learn about associated risks that could inform environmental exposures. Such efforts should be a primary interest for the Centers for Disease Control and Prevention (CDC) in protecting the general public. NIOSH is well-positioned, as part of CDC, to strengthen its communication and collaboration with its parent agency on topics that cross the boundary between workplace/occupational health and environmental/public health exposures. There seems no reason not to formalize efforts on data gap identification and data collection, and the Panel recommends that NIOSH consider how best to do so, going forward. Further, since NIOSH brings expertise and insight on how to integrate research on worker health with public health and the environment, NIOSH should consider how to work more closely with sister agencies (e.g., the Environmental Protection Agency) to assure that foundational principles (e.g., the hierarchy of controls for primary prevention) inform policy decision-making.

One Panel member suggested that there is a need for research on the ability to use less water for dust suppression in mill environments. This suggestion arose because of efforts to control exposure to silica dust around big crushers in iron mines, where wet methods are used extensively; consequently, miners in metal/non-metal industries in colder weather either work in misery (wet, cold) or cut back on water spray methods.

Additional Panel Findings and Recommendations

The Panel considered that some research efforts may not lead to frequent publication of findings with immediate applicability in the field, but instead may require more sustained support and effort to lead to foundational scientific observations. This may be particularly true for research on respiratory hazards in mining environments, which require data on particle size, shape, and composition, integrated with longitudinal data on miners' respiratory health outcomes.

For a number of Intermediate Outcomes, the Panel queried how NIOSH is getting the word out to mine operators and miners, how the information is being disseminated, and how reliable feedback and evaluation data are being obtained. The Panel understands the challenges of getting OMB approval for obtaining information from larger numbers of stakeholders, but expressed concern that some Intermediate Outcomes provided in the Evidence Package do not reflect the depth of NIOSH's research Impact and Relevance. For example, providing data on 92 downloads for Methane Control and Prevention software (with no contextual information to understand how many downloads would be expected) seems more of a process for tracking metrics than an Intermediate Outcome. Similarly, while the research on mine fire simulation and testing has been very effective, the metric provided of 200 downloads since 2015 is difficult to evaluate, as it is unclear what number of downloads would be expected or whether downloads reflect use of these training materials in the majority of underground coal mines. For this Intermediate Outcome, the information provided to the Panel seemed to be tracking data that lacked a clear context. Another example is the Intermediate Outcomes provided for

emergency response training and technologies. Although measurable, the metrics of downloads and YouTube hits are difficult to assess, so Intermediate Outcomes are difficult to rate for Relevance and Impact.

The Panel discussed several areas of NIOSH research that seem to be approaching End Outcomes. For example, NIOSH research on treated rock dust led to reductions in hazardous conditions and injury incidence, which may have surpassed the Intermediate Outcome metric since it resulted in fewer injury incidents. The Panel clarified that NIOSH defines an End Outcome as a measurable reduction in an adverse health or safety outcome (for example, reduced lung disease or accident rates) and an Intermediate Outcome as the adoption of a NIOSH output by an external stakeholder. Thus, a number of important and mature NIOSH projects such as their research on canopy curtains and on Sy-Klone kits for mining equipment are and will remain Intermediate Outcomes.

The Helmet-CAM research completed during the 10-year review period is emblematic of newer approaches for linking research on engineering technologies with human factors/social science, and points toward innovative cross-disciplinary research collaborations that will help ensure that future NIOSH efforts are highly impactful and relevant. The Panel appreciated the supplementary information provided during the presentations, and noted that, “Negative results are still results, and showing that something does not work is important (e.g., Through-the-Earth Communication Systems).”

APPENDIX 1 -- ABBREVIATIONS

ACPS – Analysis of Coal Pillar Stability

AHSM – Analysis of Horizontal Stress Effects with Mining

ALPS – Analysis of Longwall Pillar Stability

AMSS – Analysis of Multiple Seam Stability

ARBS – Analysis of Roof Bolt Systems

ARMPS – Analysis of Retreat Mining Pillar Stability

CDC – Centers for Disease Control and Prevention

CMRR – coal mine roof rating

CPDM – continuous personal dust monitor

CWP – coal worker's pneumoconiosis

DPM – diesel particulate matter

H&S – health and safety

HEHD – high energy, high-displacement

MCHM – 4-methylcyclohexanemethanol

MSHA – Mine Safety and Health Administration

NIOSH – National Institute for Occupational Health and Safety

OMB – Office of Management and Budget

PDM – personal dust monitor

PEL – permissible exposure limit

RCMD – respirable coal mine dust

RCS – respirable crystalline silica

APPENDIX 2 – SUMMARY PANEL SCORESHEET

NIOSH Mining Program Review Panel Scoresheet

Relevance Score

5 = Average Panel Relevance Score

Relevance Scoring Rubric

5 = The rationale for the activities completed by the program are highly justified.

4 = The rationale for the activities completed by the program are justified.

3 = The rationale for the activities completed by the program are moderately justified.

2 = The rationale for the activities completed by the program are minimally justified.

1 = The rationale for the activities completed by the program are not justified.

Impact Score

4.5 = Average Panel Impact Score

Impact Scoring Rubric

5 = Research program has made major contribution(s) to worker health and safety on the basis of end outcomes or well-accepted intermediate outcomes.

4 = Research program has made some contributions and/or demonstrates great potential to contribute to end outcomes or well-accepted intermediate outcomes.

3 = Research program activities are ongoing and outputs are produced that are likely to result in improvements in worker safety and health. Well-accepted outcomes have not been recorded, but potential for well-accepted outcomes has been demonstrated.

2 = Research program activities are ongoing and outputs are produced that may result in new knowledge or technology, but only limited application is expected. Well-accepted outcomes have not been recorded and the potential for well-accepted outcomes is limited.

1 = Research activities and outputs do not result in or are not likely to have any application.

Total Score

5.0 (Average Panel Relevance Score) + 4.5 (Average Panel Impact Score) = 9.5 Total NIOSH Mining Program Score

APPENDIX 3 -- REFERENCES

1. Mayne, J. (2011). Contribution Analysis: Addressing cause and effect. In K. Forss, M. Marra, & R. Schwartz (Eds.), Evaluating the complex: Attribution, contribution, and beyond (Vol. 18, pp. 53-96). New Brunswick, NJ: Transaction Publishers.
2. National Research Council. 2013. Improving Self-Escape from Underground Coal Mines. Washington, DC: The National Academies Press. https://doi.org/10.17226/18300.
3. National Academies of Sciences, Engineering, and Medicine. 2018. Monitoring and Sampling Approaches to Assess Underground Coal Mine Dust Exposures. Washington, DC: The National Academies Press. https://doi.org/10.17226/25111.