SME Annual Meeting
Feb. 25 - 28, 2018, Minneapolis, MN

Preprint 18-105

NIOSH EXTRAMURAL RESEARCH FUNDING: FULFILLING THE MANDATE OF THE MINER ACT

J. F. Burr, NIOSH, Pittsburgh, PA
D. P. Snyder, NIOSH, Pittsburgh, PA
G. W. Luxbacher, NIOSH, Pittsburgh, PA

ABSTRACT

The Mine Improvement and New Emergency Response Act (MINER Act) of 2006 established the Office of Mine Safety and Health (OMSH) within NIOSH and provided authority for awarding contracts related to the development and implementation of new mine technology and equipment. Subsequently, Congress provided additional funding to NIOSH to initiate and continue the program. OMSHR has fulfilled this Congressional mandate through annual Broad Agency Announcement (BAA) solicitations, directed Requests for Proposals (RFP) and Inter-Agency Agreements (IAA), and has further expanded the program through capacity building BAA contracts with U.S. university mining departments in the areas of mine ventilation and ground control. This paper describes the extramural funding program and broadly examines the results of the 150+ contracts issued to date, grouped into key focus areas.

INTRODUCTION

The Mine Improvement and New Emergency Response Act (MINER Act) of 2006[1] established the Office of Mine Safety and Health Research (functioning as the Office of Mine Safety and Health Research or OMSHR) within the National Institute for Occupational Safety and Health (NIOSH), and provided authority for awarding contracts related to the development and implementation of new mine technology and equipment. The OMSHR external contracts program was formed in accordance with the MINER Act and has since issued over 150 contracts focused on worker health and safety. Initial funding for this program was provided by Congress through two Emergency Supplemental Appropriations (ESA) and was focused on emergency oxygen supply, communications and tracking, and refuge chambers (also referred to as refuge alternatives). Since the MINER Act, Congress has continued to fund the program through the annual NIOSH mining appropriation. The program was supplemented starting in 2009 with an academic capacity building program directed toward developing university tenure-track faculty and facilities and supporting graduate students in the area of mine ventilation; ground control was added as an additional focus area in 2011. A short synopsis of each contract is published on the NIOSH Mining website[2] and final reports are available in digital form on request. A summary of the progress OMSHR has made over the 10-year period since the Act was published previously.[3]

External contracts are broadly classified by the following areas:

- Communications and Tracking
- Emergency Response
  - Self-escape and Breathing Air Supply
  - Refuge Alternatives
  - Escape and Rescue
- Equipment Safety
- Fires and Explosions
- Ground Control
- Mine Environmental Systems (Mine Ventilation and Atmospheric Monitoring)
- Worker/Workplace Health and Safety

Contracts are issued under a Request for Proposal (RFP), through a Broad Agency Announcement (BAA) or under an Interagency Agreement (IAA). An RFP solicitation includes a specific problem description and a well-defined scope of work to guide the offeror in preparing a bid to conduct the research; under the BAA several problem areas are described and the offeror develops the scope of work and deliverables for the proposed research. An IAA is very similar to an RFP except it is a contract between two federal government agencies.

An Interagency Working Group (IAWG) was established in 2007 to identify those areas where synergies existed and resulted in the execution of a number of IAAs; since then IAAs have been executed based on specific focus areas and more directed contacts between agencies. All three contracting mechanisms have been used to fulfill the OMSHR program intent and to supplement or extend the intramural research program within the NIOSH Pittsburgh and Spokane Mining Research Divisions (PMRD and SMRD).

Within the broad classifications outlines above, this paper highlights some of the extramural contracts awarded, with reference made to the contractor and to the outcome of the research, including prototype development and commercialization where relevant. The intent is to summarize successful collaborations with mining industry partners in developing technologies for use in mines, and to encourage ongoing and future participation by potential partners as new BAAs, RFPs, and IAAs are offered by OMSHR. For more detail on each contract summarized here, visit the NIOSH Mining website at www.cdc.gov/niosh/mining/.

COMMUNICATIONS AND TRACKING

Underground coal mine communications research was first initiated by the U.S. Bureau of Mines in 1922. At the time of the passage of the MINER Act in 2006 there were very few, if any, technologies commercially available to meet the requirements of the Act. OMSHR contract funding was critical in the research and development of systems that could meet these requirements; companies that were not funded still drew on the OMSHR work on radio signal propagation, network modeling and design parameters in the development of their own commercial systems, as did mining companies for installation guidance. Initial results of this work were presented at workshops (i.e. Mine Communications and Tracking Workshop, May 13-14, 2009, Lakewood, CO and May 19-20, 2009, Charleston, WV) and through distribution of a NIOSH Tutorial on Communications and Tracking.[4]

Mining operators have installed primary communications systems in all of the coal mines in the United States in accordance with the Act, with 56 percent being node-based and 44 percent being leaky feeder.[5] This widespread adoption of primary systems was greatly aided by the general recognition that these systems are usable for day-to-day operations and would contribute to productivity gains as well as improved safety.

Medium-frequency and through-the-earth (TTE) secondary systems, which do not have sufficient system bandwidth to support day to day operations and did not become available until after the mandated implementation dates in the Act, have not found acceptance within the mining industry. Since MSHA has accepted duplicate leaky feeder systems and node systems deployed in parallel entries as being sufficiently redundant, it is unlikely that mine operators will purchase TTE or MF systems. Even so, TTE communications offers the highest

potential for surviving a mine disaster, and OMSHR interest continues in this area.

Recently, the Defense Advanced Research Projects Agency (DARPA) has taken on an initiative to address the principal challenge for this type of communications—the development of a small, low-power, TTE transmitter and antenna.[6] OMSHR staff participated in the DARPA BAA process for the contract awards in this area and are continuing to track those efforts as they develop. OMSHR has also funded the collection of noise data in the TTE frequency band, at 35 site locations, so that if the demand drivers ever do develop for TTE, there will be representative noise data for manufacturers to use for development of their receivers.

Communications and Tracking contracts included:

- Mesh-based primary communications system (currently marketed through IWT).
- Enhanced leaky feeder system for post-accident communications (currently marketed by Becker Varis).
- Node-based tracking system integrated with the communications system (currently marketed by IWT).
- Medium-frequency communications system easily adaptable for post-disaster communications (derived from a system developed for the U.S. Army and developed and marketed for mining by Kutta Technologies; this system is also used by first responders in tunnel rescues).
- Standalone through-the-earth communications systems, using a magnetic field produced by a large loop antenna and another system using an electric field produced by direct current injection into the earth (commercial systems developed and marketed by Lockheed Martin, Vital Alert, E-Spectrum).
- Design considerations for system reliability and environmental survivability (Foster-Miller, Inc.).
- System design standards (National Institute of Standards and Technology, Defense Information Systems Agency Joint Spectrum Center).
- Alternate systems such as extreme power line communications methods (Northern Microdesign).
- Development of a uniform methodology for evaluating coal mine communications and tracking systems performance (Virginia Tech, hardware and software developed and available for use as needed).
- Demonstration and subsequent commercialization of a method for determining an intrinsically safe battery's remaining capacity (IWT, MSHA approval pending).

EMERGENCY RESPONSE: SELF-ESCAPE – BREATHING AIR SUPPLY

Before 1981, filter self-rescuers (FSR) were used to provide protection against toxic carbon monoxide; the first generation of self-contained self-rescuers (SCSRs) were introduced in 1981. They provided an escaping miner with oxygen but were too big and heavy to be worn and therefore had to be stored.

In response to a 1984 joint government task force effort, the second generation of SCSRs were introduced in 1989 (CSE and the USBM jointly shared a R&D 100 award in 1991 for the development of the CSE SR-100 SCSR). The second generation units allowed a miner to wear the SCSR.

While all stakeholders recognized the ongoing issues associated with SCSR deployment and use, technology development had stagnated through 2006, when OMSHR accelerated efforts to develop improved breathing air technology. The competing requirements of increased effective capacity and functionality versus the need for a small wearable device posed challenges that required ongoing development. In recent years, research and development efforts involving the U.S. Navy Experimental Diving Unit and the Naval Surface Warfare Center, NASA Kennedy Space Center have begun to show results consistent with stakeholder requirements.

Recently, breathing air supply research work has been transferred from OMSHR to the NIOSH National Personal Protection Technology Laboratory (NPPTL). A Breathing Air and Refuge Alternatives Partnership Meeting was held in Pittsburgh on June 7, 2017, to review results from recent research and solicit further stakeholder engagement.

Self-escape and Breathing Air Supply contracts included:

- Development of an SCSR equipped with a docking valve to allow change-out, a filter self-rescuer (FSR) with an improved life that can also be docked to the SCSR, and a breathing air monitor to indicate CO and O_2 levels to indicate when an SCSR or FSR is necessary (prototype developed by Technical Products, Inc.).
- Development of a "smart escape" self-contained breathing apparatus (SCBA)/combined FSR and SCSR with an oxygen dosing system dependent on the oxygen content of the mine atmosphere, with potential applicability primarily in metal/nonmetal mines (prototype developed by Avon Protection Systems).
- Development of designs for docking/switch-over valves (DSOV) and a hood/mask with a passive communications element (HMC) for integration into the next generation SCSR (prototypes developed by Avon, Carleton, Essex).
- Methods to improve SCSR efficiency, such as improvements to scrubber performance to remove CO from closed-circuit systems (Navy Experimental Diving Unit, Naval Surface Warfare Center).
- Use of very high-pressure (VHP) cylinders (5,000 to 10,000 psi vs. 3,000 psi used in current units) to reduce SCSR size (Luxfer, Carleton).
- Development of improved open-circuit self-contained breathing apparatus refill systems using human factors engineering (Eagle Compressors—available as an improved commercial product).
- Research and development into the use of cryogenics (NASA Kennedy Space Center) for:
  - Reduced size SCSRs
  - Improved mine rescue open circuit systems
  - Improved mine escape open circuit systems
  - Breathing air supply and cooling for underground refuge chambers

EMERGENCY RESPONSE: REFUGE ALTERNATIVES

Refuge alternatives (RAs) were mandated initially by West Virginia (Emergency Shelter/Chambers) and then nationwide under the MINER Act of 2006. The MINER Act required NIOSH to conduct research on the utility, practicality, survivability, and cost of various refuge alternatives in an underground coal mine environment, including commercially available portable RAs. The Act further required that NIOSH deliver a report to Congress not later than 18 months after the enactment of the Act on the results of this research; the supporting research is available under NIOSH Docket 125.[7]

NIOSH research has shown that heat and moisture dissipation requirements can significantly limit the capacity of RAs in warm ambient environments, and methods to reduce these stressors and to estimate effective RA capacity continue to be a significant R&D area. Therefore, the OMSHR extramural contracts program has continued to support further research into RA evaluation, design, implementation and utilization.

Refuge Alternatives contracts included:

- In support of Docket 125: Evaluation of refuge chamber design considerations and use. (Foster-Miller, Inc. Bluhm Burton Engineering, Rowan & Associates PTY LTD, Wheeling Jesuit University).
- Alternate construction techniques (Battelle).
- Systems analysis of refuge alternatives including evaluation of heat dissipation and other atmospheric considerations

(NASA Ames Research Center, Raytheon, University of Nevada Reno).
- Development of heat mitigation and breathable air generation systems (CRYO Life Support Systems LLC, expanding work done under the Breathing Air Supply cryogenic work under subcontract to NASA).
- Development of heat mitigation/air conditioning systems (DRS Environmental Systems, Inc.).
- Development of refuge chamber deployment alarm systems (Kutta Technologies, medium-frequency communications; Lockheed Martin, TTE communications).

EMERGENCY RESPONSE: ESCAPE AND RESCUE

Mine emergencies are unplanned events that require miners attempt to self-escape either as an individual or in a group. Mines are required to identify procedures and equipment that assist miners in self-escape and shelter miners that are unable to self-escape in an Emergency Response Plan (ERP). In 2013 the National Academies issued a report, funded by NIOSH, entitled "Improving Self Escape from Underground Coal Mines," which identified several areas for improvement that bear on the ability of the miner to be rescued as well as self-escape.[8]

Some emergencies may result in miners being injured or otherwise unable to self-escape. These miners will then seek refuge in a refuge alternative as described above. Specially trained rescue teams composed of miners (mine rescue teams) and MSHA Mine Emergency Operations personnel (MEO) are used to rescue sheltered miners. Attempts to rescue miners can be extremely dangerous and lead to additional fatalities, so every effort needs to be made to rescue miners quickly and safely.

The mine rescue teams and MEO are in need of technologically advanced equipment in order to more quickly and safely rescue any sheltered miners. To that end, NIOSH has funded contracts to develop rescue technologies as well as several contracts to improve the likelihood of the miners self-escaping.

Escape and Rescue contracts included:

- Review of best practices for escape and rescue in other countries and industries. (Galvin and Associates Pty Ltd, BBE Consulting (Sandton, South Africa), C. P. Lazzara, J. W. Pavlovich, George Washington University, Tetra Tech NUS Inc.).
- Modeling of explosions (U.S. Naval Research Laboratory).
- Structural analysis of seals and seal design (US Army R&D Center).
- Review of decision making and psychological issues associated with mine escape and rescue (John Hopkins, Carnegie Mellon University, The Group for Organizational Effectiveness, Inc.).
- Development of the NIOSH mine escape and rescue laboratory including virtual reality and training improvements (Orion International Technologies, Inc., LightsOn Safety Solutions, marketing gas simulator for mine rescue team training, Commercial Training Solutions, LLC).
- Development of the snake robot to be lowered through a borehole for post-disaster exploration of otherwise inaccessible areas (product development by Sarcos, LLC).
- Scout robot for mine exploration ahead of rescue teams as assistance during the rescue process (product development by Sandia National Laboratories).
- Development of a robotic support vehicle for mine rescue efforts (Rohmac, vehicle planned for MSHA A&CC testing, Rohmac anticipates marketing the vehicle commercially to mine rescue teams).
- Mantrip outfitted as a mine escape vehicle capable of being operated in zero visibility post-disaster (prototype developed by Raytheon UTD, Inc. and tested extensively in active underground mines).
- Design and fabrication of key time-critical drilling components, based on a comprehensive review of large-diameter drill technology for mine rescue used at Que Creek and in Chile (developed by Center Rock, Inc. and now transferred to and permanently housed and maintained by MSHA MEO for rapid deployment).

EQUIPMENT SAFETY

In response to MINER Act requirements for the use of new technologies, NIOSH has directed several efforts to establishing safe practices and evaluation of the safety of new equipment. A principal area of concern was the potential safety issues associated with the increase in the number of batteries required in the mine for emergency operations of communications and tracking systems.

As part of NIOSH's communications and tracking workshops and meetings to specifically discuss the battery issues, OMSHR presented its concerns about lithium-ion (Li-ion) batteries becoming potential ignition sources, which caused at least one manufacturer to change to alkaline batteries for its node-based system. More recently, lithium-ion battery fires in consumer electronics products have validated the NIOSH concerns. NIOSH-sponsored research has identified safer lithium battery chemistries, and some manufacturers are now implementing those in mining products and products in other industries.

Equipment Safety contracts included:

- Development of guideline documents for assessing risk and safely managing stored energy systems underground (Foster-Miller, Inc.).
- Evaluation of the inherent safety of Li-ion batteries in portable electronics used in underground mine environments (University of Kentucky).
- Development of internal short circuit detection methods and methods to de-energize batteries for improved safety of Li-ion batteries for mining applications (TIAX LLC).
- Assessment of the use of advanced large-format energy storage technology in underground mines (GE Global Research).
- Evaluation and determination of the equivalent safety of international intrinsic safety (IS) standards for acceptance of IS equipment used in other countries and industries (URS).

FIRES AND EXPLOSIONS

The tragedies at Sago and Darby mines in early 2006 which led to the MINER Act brought new attention to the potential explosion risks associated with sealed areas of the mine and the adequacy of the mine seals. At the request of MSHA and Congress, OMSHR and the NIOSH Mining Program sponsored testing and evaluation that ultimately showed that the requirements established by the 1969 Act were not adequate in some cases for modern coal mines. Additional efforts developed techniques to reduce the risk associated with mine seals, including strengthening mine seals and improving inertization behind the seals.

Fires and Explosions contracts included:

- In-mine inertization system for producing nitrogen to inert the area behind mine seals. (commercial system available through On-site Gas Systems Inc., purchased by the mining company hosting the demonstration).
- Seal strengthening method using polyuria (PPG Industries).
- Assessment of potential non-destructive methods to test the in-situ integrity of mine seals (Cardno MM&A, University of Kentucky and Virginia Tech).
- Structural analysis and design of seals (U.S. Army Engineering and Research Center).
- Investigation of explosion hazards using scaled model longwall coal mine (Colorado School of Mines).

Similarly, tragedies at Alma and Upper Big Branch mines illustrated the need for better mechanisms to prevent and detect mine fires and eliminate the propagation of mine explosions due to coal dust.

To address this issue, Fires and Explosions contracts included:

- Development of an additive to produce anticaking rock dust for improved inertization of float coal dust and explosion prevention (commercial product available through IMERYS and others).
- Development of an on-demand trickle dust rock dust application based on float dust generation (ROHMAC).
- Application of a fire blocking gel for control of mine fires and refuge alternatives (commercial product available through Northwest Barricade, LLC).
- Exploration of improved methods to determine coal dust concentrations (Electricore Inc., Akita Innovations and the University of California).
- Evaluation and testing of active explosion barriers (University of Kentucky and Missouri S&T University).
- Development of a computational model of a gas explosion in an underground coal mine (Naval Research Laboratory).
- Development of a computational model of a dust explosion in an underground coal mine (University of Maryland).

GROUND CONTROL

In response to the 2007 Crandall Canyon Mine disaster related to coal outbursts, Congress appropriated funds for modeling and seismic analysis. Since then, the OMSHR extramural contracts program has supplemented intramural Ground Control research through a focused technology contracting effort and a capacity building program.

Ground Control contracts included:

- Coal outburst assessment
  - Numerical modelling (WVU).
  - Seismic assessment (University of Utah, assisted by Virginia Tech).
- Photogrammetry and LIDAR applications underground (RESPEC, University of Missouri).
- Seismic tomography (Virginia Tech).
- Monitoring systems using roof resistivity (C-2 Innovations) and fiber optics (Montana Tech).
- Roof bolt interaction with surrounding strata (SIU).
- The role of gas desorption in the energetic failure of coal (Penn State).

After the Crandall Canyon disaster, OMSHR determined that there was a need to develop further ongoing ground control expertise within the mining industry through a capacity building program, initiated in 2011 and modeled on the program started in mine ventilation in 2009. A second round of Ground Control capacity building contracts were awarded in 2016. This program has included participation by the University of Utah, University of Arizona, University of Nevada Reno, Virginia Tech, WVU, University of Kentucky, Colorado School of Mines, and Penn State with the following results:

- Support of 20 PhD and 25 MS ground control students, a number of which are currently employed by industry (2011 round of contracts).
- Ensurance of an adequate number of university ground control programs and university faculty focused on ground control.

Research areas studied under the Ground Control capacity building contracts have included:

- Advanced numerical modelling (WVU).
- Mine seismic analysis and geotechnical modeling (University of Utah).
- Roof drill monitoring systems (Penn State).
- Remote sensing through DinSAR (University of Utah).
- Rock mass strength related to stability (Arizona, Nevada Reno, WVU, Penn State).
- Hazard identification (University of Kentucky, Virginia Tech, CSM).
- Mine design (Virginia Tech).

MINE ENVIRONMENTAL SYSTEMS (MINE VENTILATION AND ATMOSPHERIC MONITORING)

Since 2006, OMSHR has supplemented intramural ventilation and atmospheric monitoring research through an external technology contracting effort and a capacity building program.

Mine Ventilation and Atmospheric Monitoring contracts included:

- Intrinsically safe mine atmospheric monitoring systems (AMS) and components for utilization in active mine sections, sealed areas, and for post-disaster evaluations. Research has been conducted on five different system technologies, as follows.
  - Copper conductor (Conspec)
  - Fiber optic (RSL Fiber)
  - Medium-frequency radio (Kutta)
  - Wireless (IWT)
  - Tube bundle (SIMTARS)
- Sensor design (Ion Optics).
- Environmental sensor and communication node design (GE, IWT and SenSevere).

After the Aracoma Alma No. 1 Mine accident, NIOSH determined that there was a need to develop further ongoing mine ventilation expertise within both the academic community and the mining industry, and a capacity building program was initiated in 2009. A second round of Ventilation capacity building contracts were awarded in 2014. This program has included participation by the University of Utah, University of Arizona, University of Nevada Reno, Virginia Tech, WVU, University of Kentucky, Colorado School of Mines, University of Alaska–Fairbanks, South Dakota School of Mines, Missouri University of Science and Technology, and Penn State with the following results:

- Development of 18 PhD and 32 MS mine ventilation students, a number of which are currently employed by industry (2009 round of contracts, partial results from 2014 round of contracts).
- Ensurance of an adequate number of university mining engineering programs with qualified faculty focused on mine ventilation.

Research areas studied under the Ventilation capacity building contracts included:

- Mine ventilation network characterization using tracer gases (Virginia Tech).
- Modeling, cooling, and heat management in deep underground workings (University of Nevada Reno and University of Arizona).
- Mine ventilation system modeling, simulation, and control, in five areas.
  - Enhanced modeling of longwall gobs. (Colorado School of Mines)
  - Potential utilization of booster fans in underground coal mines (University of Utah)
  - System optimization (Nevada Reno, University of Kentucky)
  - Open pit mines in arctic or subarctic regions (University of Alaska Fairbanks)
  - Block caving mines/systems (South Dakota)
- Diesel particulate matter control through ventilation and water sprays (Virginia Tech).
- Fire modeling (Missouri, Virginia Tech).

WORKER/WORKPLACE HEALTH AND SAFETY

Worker/workplace health and safety is a multidisciplinary effort seeking to ensure that miners can have a safe working life and a retirement free from long-term consequences of occupational disease and injury. The MINER Act of 2006 challenged NIOSH to develop new technologies to enhance mine safety and health.

Worker/Workplace Health and Safety contracts included:

- Improvements in the utilization of injury surveillance data to guide hazard identification (University of Arizona, Stanford and University of Utah).
- Wearable low-cost sensors for various key mine contaminants:
  - o NO_2 (Platypus)
  - o NO_2 and CO (GE, International Electronic Machines)
  - o Respirable and alveolar dust (University of Illinois Chicago)
- Enhanced dust control through novel scrubber and air curtain technologies (J.H. Fletcher, University of Kentucky and Marshall University).
- New techniques for reduction in noise (University of Utah and Avec).

GOING FORWARD

Technology Contracts

NIOSH intends to continue awarding contracts for research, development, and implementation of new mine technology and equipment to improve the health and safety of miners. A primary mechanism for future awards will continue to be the Broad Agency Announcement (BAA). The BAA is a solicitation for concept papers to conduct research, exploratory development, testing, or evaluations of new technologies to improve mine safety, or to adapt technologies from other industries for application in mining environments.

Each BAA describes several topics and identifies them as a current OMSHR priority; however, OMSHR also strongly encourages responders to propose solutions to health and safety issues that are outside of the priority areas. Typically, the funded contracts are both OMSHR priority topics and solutions outside of the priority areas. The BAA solicitation is usually posted on FedBizOPPS (www.fbo.gov/) and the NIOSH Mining website (www.cdc.gov/niosh/mining/) in late November and the concept papers are due in early January. The evaluation criteria for the concept papers is included in the BAA solicitation. Full proposals are solicited from concept papers that are of "particular value" in light of the evaluation criteria for that specific BAA. Finally, the solicitation includes an estimated value for the typical contract award. Historically that has been between $200,000 and $300,000, with a ceiling of $650,000.

The BAA program encourages submissions from mining companies, equipment manufacturers, private laboratories, government agencies, universities, and any other entity that can enhance the development of new technology and technological applications, or can expedite the commercial availability and implementation of such technology in mining environments. Especially valuable are those proposals that include collaboration with mining industry partners who understand the reality of the mining environment and can provide insight into mine design requirements and potential commercialization of the technology.

Capacity Build Contracts

In addition to the above new mine technology and equipment program, NIOSH intends to continue supporting the capacity building program and intends to use a BAA solicitation to announce future funding opportunities. As such, all basic or applied mining research topics that have an impact on safety or health will be considered. Topics can be applicable to all types of surface or underground mining or can be pertinent to only a specific mining method or mineral commodity. A parallel intent is to provide an adequate supply of qualified engineers and professors specializing in mine ventilation or ground stability to ensure the future health and safety of our nation's mine workers.

Since contract awardees are expected to produce graduates with doctoral and/or master's degrees in mining engineering or a related field in an engineering discipline with specialization in mine ventilation or ground control, there are several eligibility restrictions on any potential award. For example, the Principal Investigator (PI) must hold a full-time academic position at the rank of Assistant Professor or higher at an academic institution within the U.S. The PI must also be employed by an academic department that offers an ABET-accredited undergraduate degree in mining or minerals engineering. Funded graduate students must possess an undergraduate degree in mining engineering or a related engineering/sciences field. Typical awards provide for graduate student tuition and stipends, equipment necessary for the proposed research and domestic travel required for conducting research.

The BAA solicitation is usually posted on FedBizOPPS (www.fbo.gov/) and the NIOSH Mining website (www.cdc.gov/niosh/mining/). Solicitations request full proposals that are evaluated on the overall scientific merit of the proposed research, the qualifications of the PI, and the number of proposed graduate students. Historically, these awards have been for approximately $250,000 and are annually renewable for up to five years.

CONCLUSION

The MINER Act of 2006 challenged OMSHR to research and develop new technologies and equipment to enhance mine safety and health. Noteworthy new technologies and equipment have been introduced into the mining industry as a result of OMSHR's extramural contracts program. However, much more needs to be done and OMSHR cannot do it alone. In fact, the ongoing effort must include more than mining stakeholders—it must include non-mining researchers and equipment manufacturers. In particular, access to operating mines for testing is a critical step in producing new technologies that are practical and can be expected to improve the health and safety of miners.

As advanced technology and equipment becomes available to the mining industry, it highlights the need for advanced degree mining engineering graduates. The application of the advanced technologies and the interpretation of data provided by some technologies requires a high level of post-graduate education and practical experience. OMSHR's Ventilation and Ground Control capacity building contracts have not only produced a significant number of advanced degree mining engineering graduates but have also strengthened the university mining engineering programs so that they can continue to produce the future mining experts needed to maximize the benefits of the new technologies.

DISCLAIMER

The findings and conclusions in this paper are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health. Reference to specific brand names does not imply endorsement by the National Institute for Occupational Safety and Health.

REFERENCES

1. PL 109-236 (S 2803) June 15, 2006, Mine Improvement and New Emergency Response Act of 2006 (MINER Act)
2. NIOSH, Mining, Research Program, Contracts, accessible at https://www.cdc.gov/niosh/mining/researchprogram/contracts/index.html
3. Snyder, David P., Burr, John F., Moore, Susan M., and Fernando, Rohan (2016), MINER Act technology, Past, present and the future, Mining Engineering, December 2016, pp. 45-54.
4. NIOSH, Mining, accessible at https://www.cdc.gov/niosh/mining/content/emergencymanagementandresponse/commtracking/advcommtrackingtutorial1.html
5. Damiano, Nicholas, Homce, Gerald, and Jacksha, Ronald (2014), A Review of Underground Coal Mine Emergency Communications and Tracking System Installations, Coal Age, 11:48, November 2014, pp. 34-35.
6. Snow, Shawn, 2016, New DARPA radio transmitter could revolutionize battlefield communications, MilitaryTimes, December 29, 2016, https://www.militarytimes.com/news/your-military/2016/12/29/new-darpa-radio-transmitter-could-revolutionize-battlefield-communications/

7. NIOSH, NIOSH Publications & Products, Docket https://www.cdc.gov/niosh/docket/archive/docket125.html

8. National Research Council. 2013. *Improving Self-Escape from Underground Coal Mines*. Washington, DC: The National Academies Press. https://doi.org/10.17226/18300