Grant AFC215-1
Title: Development of Guidance for the Selection and Use of Atmospheric Monitoring Systems to Improve Decision-Making During Routine and Post-Accident Operations

Organization: Penn State University

Principal Investigator(s): Jeffery L. Kohler

Partnerships: Alpha Natural Resources

Focus Area: Health and Safety Interventions
Topical Area: Monitoring Systems and Integrated Control Technologies

Problem Statement and Justification: The potential of mine wide monitoring systems to improve mine safety and health has been recognized for decades, and yet the deployment of these systems for such purposes has been extremely limited in the U.S. and globally. Although not perfect, the technologies to enable mine-wide atmospheric monitoring systems (AMS) have been commercially available, and to a great extent, technology itself has not been the barrier to widespread adoption of these systems. Rather, it has been a lack of knowledge on where the sensors will be placed and how the resulting information will be used to achieve specific safety or health outcomes. The on-going challenges and costs associated with acquiring AMS information are appreciable, and this underscores the need for a purposeful strategy for every installed sensor. The difficulty in actually using the large quantities of data to improve decision-making at the mine is a persistent problem. The question of “what to do with the volumes of data generated by these systems” is as difficult to answer today as it was thirty years ago. While large graphical displays of sensor values superimposed on maps and diagrams appear impressive, the practical use of this information to improve safety and health outcomes is another matter. The current state-of-technology makes it easier to incorporate a greater numbers of sensors, which will likely produce even larger quantities of data, with an even greater risk that meaningful information will be obscured. Furthermore, the interest in employing backup systems, such as tube bundle systems, to improve post-accident functionality increases the complexity of the problem faced by the mine operator. Mine operators need practical guidance on the selection and location of sensors to achieve defined safety goals, as well as guidance on the alignment of the performance characteristics of the monitoring system with these safety goals.

Impact of the Research: The selection and configuration of the atmospheric monitoring system(s) for routine and post-accident functionality at a mine must be based on a logical construct of exactly how the information will be used to improve safety. Definitive guidance to align sensor selection and location with decision-making requirements will be developed for both routine and post-accident application. Information requirements to support decision making inside the mine, for example to aid self-escape, as well as outside the mine, will be incorporated into the guidance. The purposeful use of atmospheric monitoring can result in the detection of hazardous conditions as they begin to develop, and could serve the needs of escaping miners for information on atmospheric conditions in the mine.

Objectives and Research Approach: Event scenarios for routine and post-accident decision making will be defined, and the sensory information needed to support those decisions will be identified, as will "sentinel" sensors that would serve as early warning of incipient hazards. These decision processes will be analyzed to identify the smallest set of sensors to support those processes, given practical constraints. Computer simulations will be used to study the event scenarios and the corresponding affects on sensors, and the results of these will help to establish practical guidance on the location for specific sensors and their output changes that are significant. Data collected from an in-mine AMS, augmented with information in the literature, will be used to help formulate, evaluate, and validate a practical guidance document for mine operators.

Grant AFC215-13
Title: Enhanced Ground Control Assessment for Improving Safety in Mine Design

Organization: University of Kentucky

Principal Investigator(s): Zacharias Agioutantis

Partnerships: Appalachian Mining and Engineering Inc
Cardno Inc

Focus Area: Health and Safety Interventions
Topical Area: Ground Control

Problem Statement and Justification: Over the last 20 years, NIOSH has developed and validated a number of free software tools addressing safe coal mine design with respect to ground control. These tools have been designed as stand-alone PC based software packages. As cloud computing gains momentum, many engineering applications have been converted to work through a distributed or cloud environment. Clearly there is a need to move forward with mine design computer tools and update their utility and application by placing them in a distributed environment. The vision behind this proposal is to fulfill this need and create a software platform which can ultimately embrace several tools used by mining professionals under a common roof. Such information will then be available anywhere and at anytime through the power of distributed or cloud computing, even while underground. Data will be safely stored and preserved in database servers at operations headquarters, applications will not need to be updated on PC-based computers and users will not have to deal with compatibility issues. Web applications will be available to multiple platforms through the respective web browsers.

Impact of the Research: This new web-based product (webGroundControl) will allow for faster and easier access to existing ground control designs, on-the-fly calculations in the field if needed, and instant online collaboration between planning personnel and operations engineers. This shared working platform will ensure more transparent calculations in cases of variable conditions as well as the instant recognition of problematic areas under a specific design. It is expected that the industry will rapidly embrace this product and, as it is common with all new innovative technologies, it will be a new paradigm for mining engineering computer applications. Furthermore it is expected that upon the completion of this project, the need will emerge to populate this platform with additional tools and packages.

Objectives and Research Approach: A new software product (webGroundControl) will be developed by fulfilling the following objectives: (a) to develop a server-side module for the new web-based software product; (b) to develop a web browser module; (c) to generate web-based help files for the above products; (d) to develop an installer and a quick reference guide that will include step-by-step instructions on how to install and/or uninstall the product; and (e) to disseminate and publish the results in a number of US based conferences. The outcomes or deliverables include: (a) server and browser-side modules for the new web-based software product; (b) a web version of ALPS; (c) a web version of ARMPS; (d) a web version of ARBS; e) web-based help files for the above products; (f) an installer package that will seamlessly install the software; (g) Quick reference guides for the above products that will include step by step instructions; and (h) at least three peer-reviewed publications.

Grant AFC215-15
Title: Improved Face Ventilation for Extended-Cut Continuous Mining using a Wing Regulator and Scrubber Control System

Organization: University of Kentucky

Principal Investigator(s): William Chad Wedding, Thomas Novak

Focus Area: Health and Safety Interventions
Topical Area: Dust Control

Problem Statement and Justification: During deep cut mining of coal with a continuous miner, the ventilation system has difficulty delivering fresh air to the region immediately out by the face when using curtains. Whether a blowing or exhausting curtain is used, the fresh air in the intake does not reach the face but rather takes the path of lesser resistance. For blowing systems, this phenomenon can be described as early airflow separation from the rib. This leaves a region close to the face with elevated concentrations of methane and dust. This dusty air presents a health hazard for miners operating the continuous miner and shuttle car operators as it rolls back over them, in the form of elevated risk of coal worker's pneumoconiosis. Elevated methane concentrations increase the potential for ignition, due to the action of the continuous miner's bits at the face. Various controls have been used to address this problem, including a machine mounted scrubber and sprays, but fail to address the root of the problem. Additional fresh air needs to be brought closer to the face to dilute the dust and methane generated by activity of the continuous miner.

Impact of the Research: The impact of the research will have three major influences in the mining community. The immediate impact is the knowledge gained through the research effort which should lead to an improved understanding of how to manage the health and safety hazards of dust and methane at the face, using the best combination of technology available. It will further provide a near term impact to the health and safety of the mine workers provided the wing regulator technology is advanced to a design that MSHA approves and miners will adopt. The third major lasting impact is the availability of a dust gallery for future studies which will assist the industry in meeting the new dust standards.

Objectives and Research Approach: The primary objective is to determine how best to ventilate a coal mine face, using the best available technology which includes the wing regulator. The research approach is a layered sequence of experimentation and CFD modeling that builds towards real world testing. Reduced scale physical modeling and CFD modeling add insight to the problem of air reaching the face. This in turn helps develop the next step in modeling which is full scale modeling at a dust gallery to be constructed in an underground limestone mine. This model, with the full array of ventilation controls used to ventilate the face of a room and pillar coal mine, will allow the team to determine the impact of each of these controls on dilution efficiency. This will be further served by CFD modeling. Once the response of the ventilation system is understood, a set of best practices for using the wing regulator will be developed and validated with testing at three or more mine sites. The major outputs include the refinement of a compelling piece of technology which has the potential to solve the problem of dilution of dust and methane at the immediate face, and a set of guidelines for how best apply the device in the mine, in conjunction with the scrubber and sprays systems.

Grant AFC215-20
Title: Numerical Tools for Mitigation of Methane Explosions in Coal Mines

Organization: University of Maryland

Principal Investigator(s): Elaine Oran, Ryan Houim

Partnerships: Naval Research Laboratory

Focus Area: Health and Safety Interventions
Topical Area: Fire and Explosion Prevention

Problem Statement and Justification: Accidental gas explosions in coal mines are low-probability, high-impact events that cause devastating losses of both human life and property, in addition to having a strong impact on the mining industry. These explosions are usually caused by methane that naturally accumulates in mines to the point where it creates explosive mixtures with air. These mixtures are most likely to form in abandoned, unventilated areas that can be several kilometers long. Once formed, the mixtures may be accidentally ignited and burn quickly, thus releasing large amounts of energy and generating high pressures. To protect workers from possible methane explosions, abandoned areas are separated from active areas by concrete walls, or seals, meant to withstand the high pressures generated by explosions and prevent propagation of shock waves and flames into working areas. To ensure that seals are strong enough, they must be designed to withstand the maximum pressures that can be generated by explosions that could occur in coal mines. In the absence of large-scale test facilities where pressures could be measured, computational models capable of predicting details of gas explosions are the only option for determining explosion pressures. Our research team, consisting of scientist and engineers from the University of Maryland (UMD) and the Naval Research Laboratory (NRL), is one of the world's leading research groups in numerical simulation of combustion systems and ideally suited to developing and testing the computational models needed. The importance of such a predictive capability extends beyond protective seal design, and even beyond the coal-mine industry. The same computational technology can be instrumental in developing new devices that could prevent or mitigate explosion in the many industries where there is a risk of gas explosions.

Impact of the Research: We propose to develop the numerical technology needed to predict the development of methane-air explosions in coal mine environments, and then use this technology to analyze protective-seal designs. For example, computed explosion pressures will be compared with current MSHA requirement for seal design. This technology can also be used in conjunction with experiments to develop other devices for explosion prevention and mitigation, thus making coal mining safer and reducing the number of disasters. This capability could benefit all industries where there is the risk of gas explosions.

Objectives and Research Approach: The objectives are to: (1) develop models that predict the properties of explosions for both uniform and non-uniform methane-air mixtures in appropriate large-scale geometries, and (2) use these models to analyze the efficiency of passive blast attenuators by computing the propagation of flames, shocks, and detonation through piles of rock placed at some distance from the protective seal. This project addresses a computational technology gap that exists in coal-mine research by developing and calibrating models that can accurately compute pressures at seals for different explosions scenarios. Computed pressures will be compared with current MSHA criteria for seal design.

Grant AFC215-21
Title: Low noise efficient rim driven auxiliary ventilation fans

Organization: Virginia Polytechnic and State University

Principal Investigator(s): Ricardo A. Burdisso, Pablo A. Tarazaga

Focus Area: Health and Safety Interventions
Topical Area: Machine Design and Ergonomics

Problem Statement and Justification: Physical hazardous agents that mine workers are exposed to on a daily basis include noise, vibration, temperature, dust, and so forth. Noise-induced hearing loss is a critical issue for a healthy mine workforce. There is still a need to reduce the exposure of miners to noise. If the Permissible Exposure Level (PEL) is exceeded, the mine operator is required to use all feasible engineering and/or administrative controls to reduce miner's exposure. There are many noise sources in a mine operation. Ventilation fans are one of the most dominant noise sources and thus a prime target for noise controls. In fact, ventilation fans are the second loudest noise source in coal mine operations (Cherniack et al., 2012). Ventilation systems must provide air to all places in an underground mine to maintain a safe level of oxygen, dilute and remove noxious gases, control airborne dust, control temperature and humidity in the working areas. The primary ventilation system for underground mines consists of a very large surface fan pumping air and distributing it through the mine. Temporarily mounted auxiliary ventilation fans are also used to supplement the air to specific working areas. These fans are much smaller that the primary one. However, these auxiliary fans are in close proximity to the miners and thus they have a more detrimental impact on the workers. This ventilation fan noise problem is not unique to the mine operations but is very common through many other industries.

Impact of the Research: This effort will significantly contribute to the improvement of the health of mine workers by reducing their exposure to high noise levels, i.e. preventing hearing loss. This is the primary goal of this project. A reduction of 15-20 dB relative to the current fan system used in the mines would imply that the fan will become one of the quietest sound sources in a mine operation.

Objectives and Research Approach: The main aim of this project is to experimentally demonstrate a new quiet portable ventilation fan that will improve the mine environment by preventing noise-induced hearing loss of the workers. The new quiet fan make used of technologies developed for other applications, primarily in the defense and aeronautic fields. The target is that this new advanced quiet fan will be 15 to 20 dB quieter than current commercially used fans while maintaining or improving aerodynamic performance. Given the current trend for rise in energy costs, it will also be shown that the energy consumption will be reduced using modern high efficiency brushless motors in the new quiet fan design. This is important since ventilation systems account for a significant proportion of the energy consumed in mines. The research approach is to design and built two prototype ventilation fan systems to demonstrate with actual hardware and measured data the technologies proposed here.

Grant AFC215-25
Title: Effective MERD Training - Design, Implementation, Retention and Evaluation

Organization: UMWA Career Centers, Inc.

Principal Investigator(s): Marlon Whoolery, Douglas J. Myers

Partnerships: West Virginia University

Focus Area: Mine Escape, Rescue, and Training
Topical Area: Training and Decision Making

Problem Statement and Justification: The matter of effective response in the immediate aftermath of a mine disaster remains a very serious concern. In this study, we will assess the effectiveness of the currently mandated training required of Responsible Persons employed in mines in Pennsylvania, Ohio and West Virginia with regard to their ability to coordinate and implement their mine's Emergency Response Plan in a disastrous event. We will also explore whether Mine Emergency Response Development exercises conducted by the UMWA Career Centers, Inc.'s Mining Technology and Training Center are a more effective form of Responsible Person training than is currently required by the Mine Safety and Health Administration. This proposal is saturated with historical data emphasizing the need for more comprehensive, specialized training for the Responsible Persons within a Command Center. The decisions made by the Responsible Persons in the first hours after a mine disaster ultimately determine the number of lives saved or lost. Our research focuses on the coal mining industry, particularly mine escape, rescue and training. It is our hope that the results obtained from this study will be used at other training facilities and become the norm, therefore improving the safety of miners throughout the industry.

Impact of the Research: Our specific aims focus on Mine Escape, Rescue and Training as identified in the solicitation and are designed to determine if the current training gives the Responsible Persons and Mine Rescue Team members the necessary skills to lead to proper and successful decision making during a mine emergency. We believe that this evaluation research will demonstrate the value of training that goes beyond what is currently legally required.

Objectives and Research Approach: The study will use quantitative and qualitative methods to: 1) assess the effectiveness of the currently mandated Responsible Persons training and 2) compare the performance of these individuals and teams with that of a second group of Responsible Persons who have gone through a training program developed by the United Mine Workers of America Career Centers, Inc. personnel at the Mining Technology and Training Center (MTTC). Responsible Persons will be evaluated as they direct Mine Rescue Teams during Mine Emergency Response Development exercises conducted at the MTTC. A quasi-experimental design will be used to evaluate the potential improvements in mine rescue performance of the Responsible Persons who were trained at the MTTC.

Grant AFC215-30
Title: Characterization and Effectiveness of Safety and Health Management Systems in the U.S. Mining Industry

Organization: University of Utah

Principal Investigator(s): Tom Hethmon, Mike Nelson

Partnerships: National Mining Association
Hecla Mining Company, Luminant Mining Inc., Alpha Natural Resources, Peabody Energy, Jim Walter Resources, Freeport-McMoRan, Arch Coal, Prairie State Energy Campus, Newmont Mining, and CONSOL Energy

Focus Area: Safety and Health Management and Training
Topical Area: Safety and Health Management

Problem Statement and Justification: U.S. mining companies are voluntarily adopting safety and health management systems (SHMS) to supplement regulatory compliance efforts. The impact of these risk-centered systems is promising. Unpublished data from the National Mining Association (NMA) suggests that between 2011 and 2014 only 25% of U.S. mining fatalities occurred in companies utilizing these tools, many of whom were early in their application. However, SHMSs can require significant resources and while their popularity grows, the benefits are primarily anecdotal and qualitative. As U.S. companies continue to adopt SHMSs, or if their use in part or whole is considered for future regulation, it is essential to understand how they work or don't work, and the most effective variables for their development and implementation. It is also important to assess the relative impact of MSHA regulations versus SHMSs on mine safety outcomes. This challenge (and opportunity) is not unique to any U.S. mining sector.

Impact of the Research: This research will establish the first comprehensive characterization of multiple independent variables affecting SHMS development, implementation and performance [define the intervention(s)]; track trailing and leading metrics associated with both SHMS and regulatory compliance performance [longitudinal surveillance]; and provide analysis regarding the empirical and statistical effectiveness relationship of both individual elements and as well as whole SHMS system [intervention effectiveness]. This information will significantly enhance the chronic research gap by simultaneously including multiple active mines across diverse mining commodities, with differing degrees of SHMS implementation, methods and resources. More importantly, these results should have immediate application to the U.S. mining industry, policy makers, and the international mining community.

Objectives and Research Approach: Phase one of the research will begin with a cross-sectional assessment of safety and health management philosophies, strategies, prerequisites, priorities and SHMS approaches, structures, resources and performance metrics at a minimum of 15 U.S. mines. Phase two will involve longitudinal surveillance of parameters identified in phase one and tracking SHMS and regulatory compliance performance metrics for two years to allow for an adequate intervention effect. Phase three is a detailed closing assessment repeating phase one to clearly define the organizational, regulatory, and safety performance impacts of the SHMS. To date, research in these domains has been limited to single interventions that were not specific to U.S. mining with no analysis of intervention effectiveness across multiple combinations of interventions as well as the whole SHMS. No related research has been conducted with adequate access to multiple mines that are simultaneously implementing similar SHMSs, i.e., CORESafety.

Grant AFC215-31
Title: Revisiting Lung Cancer Risk from Silica Exposure in Miners: Proposed Standards, Prevailing Biases and Modern Methodology

Organization: University of California, Berkeley

Principal Investigator(s): Sadie Costello

Partnerships: University of California, San Diego

Focus Area: Injury and Disease Exposure and Risk Factors
Topical Area: Respiratory Disease

Problem Statement and Justification: Silica is one of the most common occupational exposures worldwide and silicosis is the oldest known occupational disease. The Mine Safety and Health Administration (MSHA) plans to propose a more stringent silica standard has prompted industry to suggest that the current permissible exposure limit (PEL), twice the proposed level, is adequate to protect worker health. In addition to causing silicosis, silica has been classified as a human carcinogen by the International Agency for Research on Cancer (IARC), however the association between silica and lung cancer is still controversial. Much of the controversy stems from inconsistencies in results from occupational epidemiology studies. There are, however, several systematic biases that lead to the underestimation of effects from occupational studies and it is reasonable to expect that these biases are particularly strong in studies of silica and lung cancer. We propose to reanalyze Checkoway's cohort of diatomaceous earth miners, one of the studies that influenced the IARC classification, to address these biases and further illuminate the shape of the exposure-response curve at the levels of the existing and proposed PELs.

Impact of the Research: Evaluating the impact of silica exposure on the lung cancer risk of miners requires the application of modern statistical methods to address the prevailing biases in occupational epidemiology. Our objectives are to apply such methods to four areas of concern in the diatomaceous earth cohort: the entanglement of duration with exposure rate, competing risk by silicosis, the role of silicosis in the development of silica- related lung cancer, and the healthy worker survivor effect. A better understanding of the effect of silica on lung cancer will help inform standards and protect the health of miners and other workers exposed to silica.

Objectives and Research Approach: Although methods have been developed to address the prevailing biases in occupational epidemiology, they have not yet been applied to understand the health effects of silica in cohorts of miners. Our research group is well poised to apply these methods to Checkoway's cohort of silica-exposed miners and to interpret them to maximize the transportability into worker protection policy. We anticipate producing four original manuscripts for publication in peer-review journals; one paper for each objective. These papers will help further the field of occupational epidemiology to promote methods that will better illuminate the health risks of workers in general and of silica-exposed diatomaceous earth miners in particular.

Grant AFC215-41
Title: Management with Bag Barriers of Dust Explosion Risks in Underground Coal Mines

Organization: Missouri University of Science and Technology

Principal Investigator(s): Stewart Gillies

Partnerships: Arch Coal Inc
Skillpro

Focus Area: Health and Safety Interventions
Topical Area: Fire and Explosion Prevention

Problem Statement and Justification: The most significant and powerful hazard that exists in an underground coal mine is a coal dust explosion. Since 2001 disasters due to explosions in US underground coal mines have caused 59 deaths, including 29 deaths in a single mine explosion at the West Virginia Upper Big Branch (UBB) mine in 2010. Many controls have been developed and implemented in different countries to reduce the impact of coal dust explosions. One of the most significant controls internationally is the bag barrier explosion barrier. Explosion barriers have not been adopted in the U.S. because of the erroneous belief that preventative strategies (such as use of inerting limestone dust) will always be 100% effective. In risk management parlance these explosion barriers are a final contingency control for the rare occasion when one or more of the preventative controls fails. This proposed study will utilize the bag barrier explosion barrier and engage the U.S. industry in discussion and development of guidelines for their use in the United States. The use of explosion barriers has over 15 years become well established in coal mining countries outside the U.S.

Impact of the Research: Following the UBB disaster many people have realized that additional defenses are needed to prevent propagation of a methane explosion into a coal dust explosion. Research and revised guidelines specific to U.S. mines are needed to demonstrate the practical application of bag barriers as supplemental protection, with generalized rock dusting to prevent explosion propagations. If this effort succeeds, and the bag barrier system is adopted in the U.S., it will assist in reducing fatalities. Coal mine explosion barrier systems are in use across the developed world. There are clear benefits from saving lives with introduction of explosion barrier systems. The bag barrier explosion barrier system is well established and is a particular barrier which is widely in use in Australia, Britain, South Africa, Germany, Poland and other developed countries. Adoption and use of this system will benefit U.S. miners, mining companies, and society in general.

Objectives and Research Approach: Significant effort will be undertaken at mine sites in undertaking trial explosion barrier installations in U.S. mines and demonstrating the use of bagged barriers as part of a technology transfer effort. Guidelines for use in U.S. coal mines that have for instance, low seams, will be developed. A major part of the project will involve educating mine management and other industry authorities on the merits and advantages and the importance of introducing explosion barriers to the U.S. In parallel, the views of these mine leaders will be sought. National leadership groups drawn from mining corporate leaders, the National Mining Association, MSHA, the West Virginia Office of Mine Health, Safety and Technology, the United Mine Workers Association and NIOSH will be approached for comments at two stages of the project.

Grant AFC215-42
Title: Free and Open Source Professional Development for the Mine Ventilation Community: An Innovative Approach to Improving Competence

Organization: Virginia Polytechnic and State University

Principal Investigator(s): Kray Luxbacher, Steven Schafrik

Focus Area: Safety and Health Management and Training
Topical Area: Training

Problem Statement and Justification: Catastrophic failures of engineered ventilation controls, or a failure to understand the role of the mine environment on the ventilation system have resulted in multiple fatality incidents many times over the years; most recently, the Sago Mine and Upper Big Branch Mine Explosions highlight the need for improved education and professional development resources. The group of mining professionals with expert competence in ventilation is small and dwindling, despite the fact that most mine engineers will, at some point, be involved in ventilation engineering. For professionals who want to improve their competence there are relatively few opportunities for professional development and even fewer specialized consultants. This proposal aims to develop an innovative set of online tools for underground coal, metal, and non-metal ventilation engineering training with considerable impact on safety in underground mines. This work will involve investigating and collating best practice at state-of-the-art underground mines around the world, and distributing this knowledge via an innovative online course platform. Based on the premise that knowledge should be accessible, the course will be distributed via a free and open source platform. It will be piloted during the project, and a successful platform will be maintained with researchers and professionals adding material for community consumption.

Impact of the Research: The specific aim of this work is to develop a novel and universally accessible professional development platform to enhance safety in underground mines. This work will allow for the dissemination of knowledge, including theory, best practice, and practical application in mine ventilation engineering. Ultimately, the work is targeted toward practitioners with engineering backgrounds, but would also be appropriate for workers engaged in mine ventilation work without any such formal training (e.g., foremen and supervisors). By providing unlimited access to professional development for ventilation professionals catastrophic and routine failures of engineered ventilation systems can be avoided, with a considerable positive impact on underground safety.

Objectives and Research Approach: The primary objectives of this work are to: i) collect and distribute best practice and basic and advanced principles of mine ventilation engineering for the improved competency of the industry; ii) to demonstrate an innovative online platform for professional development in the mining industry; and iii) to enhance immediate mine safety while building a body of knowledge that will continuously enhance safety. The materials developed will be targeted toward the US industry. International case studies and perspectives will be utilized; they will be described in the context of US regulation. The project will identify and disseminate "beyond compliance" controls and best practices. This work is particularly novel because little free and open source materials are available to mining professionals, and none through a formal web- based learning platform. Additionally, the goal of these materials is to highlight theory and application of mine ventilation principles with state-of-the-art case studies to improve engagement and relevancy. The demonstrated successful development in this critical application will provide a guide to other key knowledge areas in mining including sustainability and environment, mineral processing, and rock mechanics and ground control.

Grant AFC215-54
Title: Full-Wave Electromagnetic Simulator for Statistical Characterization, Optimal Deployment, and On-the-Fly Reconfiguration of Wireless and Through-the-Earth Communication and Tracking Systems

Organization: University of Michigan

Principal Investigator(s): Eric Michielssen

Partnerships: Office of Mine Safety and Health Research (OMSHR), National Institute for Occupational Safety and Health (NIOSH)

Focus Area: Mine Escape, Rescue, and Training
Topical Area: Communications and Tracking

Problem Statement and Justification: Reliable wireless communication, sensing, and tracking systems for underground mine tunnels/galleries play a vital role in ensuring miners' safety and operational effectiveness during daily routine and catastrophic events. The 2006 MINER Act requires operators to implement wireless communication systems capable of surviving disasters and supporting two-way post-event communication and tracking functions. The design, deployment, and post-event reconfiguration of such systems would greatly benefit from electromagnetic (EM) simulators for characterizing wave propagation in mine tunnels and galleries occupied by miners and equipment and possibly obstructed by debris from a cave-in. Unfortunately, present EM simulation techniques are not up to this task as they fail to capture the complexity of wave propagation in such real-world mine environments. Moreover, they do not provide statistics/uncertainty quantification (UQ) of key observables (e.g., the probability density function (PDF) of received signals). Current simulators cannot produce site-specific quantitative data that aids in the design of these systems and/or their on-the-fly reconfiguration when disaster strikes, forcing system designers to rely on expensive experimental deployment procedures and to overdesign systems.

Impact of the Research: The objective of the proposed research is to develop a new computational framework that leverages a novel full wave EM simulator in concert with modern UQ techniques to produce qualitative insights and actionable quantitative data to aid in the design, deployment, and post-event reconfiguration of wireless and Through the Earth (TTE) communication and tracking systems customized to specific mine environments. The proposed framework will aid mine operators and designers of wireless and TTE communication and tracking systems to: (i) determine survivability thresholds and assessment metrics for communication and tracking systems; (ii) evaluate signal path transmission loss and noise interference in communication technologies, including through-the-earth communication devices; and (iii) assess the coverage capability, quality of service and accuracy of current communication and tracking technologies.

Objectives and Research Approach: The above stated objective will be attained via a four-pronged approach: (i) Development of a fast multipole method - fast Fourier transform based EM simulation + UQ framework that incorporates domain/Tucker decompositions, impedance and resistive boundary conditions and Karhunen-Loeve expansions to deal with the most general mine layouts and configurations; (ii) Extensive verification and validation of the framework by comparison with measurements obtained from our OMSHR partners and other entities, as well as published data; (iii) Application of the EM+UQ framework to statistically characterize numerous systems, ranging from leaky feeder networks (VHF - UHF) replete with amplifiers and repeaters, TTE systems composed of surface or buried loops (VLF), medium frequency (MF) radio systems, various wireless mesh network (WMN) systems utilizing IEEE 802.11b (2.4 GHz) and 802.15.4 (900 MHz) protocols, as well as ultra-wide band (UWB) radios (during normal mine operations as well as post-event); and (iv) Evaluation of the framework's promise in lowering the cost of deploying wireless systems and enhancing mine safety through optimal system design and reconfiguration.