NATIONAL OCCUPATIONAL RESEARCH AGENDA (NORA)

NATIONAL MINING AGENDA

FOR OCCUPATIONAL SAFETY AND HEALTH RESEARCH AND PRACTICE IN THE U.S. MINING SECTOR

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Developed by the NORA Mining Sector Council

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INTRODUCTION

What is the National Occupational Research Agenda?

The National Institute for Occupational Safety and Health, NIOSH, an agency of the Centers for Disease Control and Prevention, CDC, has established a program to stimulate research and technology transfer that is designed to reduce accidents and industrial disease in the workplace. This program is called the National Occupational Research Agenda, NORA. On their web site (NORA, 2013), they describe the agenda and its goals.

NORA is a partnership program to stimulate innovative research and improved workplace practices. Unveiled in 1996, NORA has become a research framework for NIOSH and the nation. Diverse parties collaborate to identify the most critical issues in workplace safety and health. Partners then work together to develop goals and objectives for addressing these needs. The following types of information help develop the program's priority-setting process:

- The numbers of workers at risk for a particular injury or illness
- The seriousness of the hazard or issue
- The probability that new information and approaches will have an impact

Participation in NORA is broad, including stakeholders from universities, large and small businesses, professional societies, government agencies, and worker organizations. Involvement ranges from providing input electronically to volunteering for a Sector Council.

The program entered its second decade with a new sector-based structure to better address research to practice in workplaces. The national agenda will be developed and implemented through the NORA Sector Councils.

What is the role of the NORA Sector Councils?

For manageability, NIOSH has aggregated industries into ten major sector groups (listed below) and with its partners, has formed ten corresponding NORA Sector Councils to develop and promote implementation of the National Occupational Research Agenda.

NORA Sector Group	NAICS Code
Agriculture, Forestry & Fishing	11
Construction	23
Healthcare & Social Assistance	62, 54194, 81291
Manufacturing	31-33
Mining (except Oil and Gas Extraction)	21
Oil and Gas Extraction	211, 213111 & 213112
Public Safety	93212, 92214, 92216 & 62191
Services (except Public Safety)	51-56, 61, 71-72, 81 & 92
Transportation, Warehousing & Utilities	48-49 & 22
Wholesale and Retail Trade	42 & 44-45

Sector definitions follow the North American Industry Classification System (NAICS, 2007).

Participation in the NORA sector councils is broad, and includes stakeholders from universities, large and small businesses, professional societies, government agencies, and worker organizations. The diversity of NORA Council members is one key to its success.

It should be noted that although Oil and Gas Extraction is included in the NAICS code for Mining, a separate NORA Sector Council was formed for the Oil and Gas Extraction industry sector.

Each Sector Council is tasked with identifying the most prominent safety and health needs of its sector and developing a strategic plan—the sector's contribution to the national Agenda—to address those needs. The strategic plans seek to highlight the most important research questions, recognize priority safety and health concerns, understand the most effective intervention strategies, and disseminate information on ways to implement those strategies to achieve sustained improvements in workplace safety and health practice. Implementation plans for the nation will then be developed based on the sector strategic plans.

What is role of the NORA Mining Sector Council?

NIOSH established a NORA Mining Sector Council in 2005 and then re-established it with new membership and a renewed charge in 2009. Membership is in two categories: member and corresponding member. A list of members follows and more information about them is included in Appendix A. Significantly, the Society for Mining, Metallurgy, and Exploration, SME, has identified two of the Council members as liaison to its Board of Directors, thus endorsing directly the activities of the Sector Council. A number of NIOSH scientists and engineers have participated as Corresponding Members and they will be identified with their respective Objective Subcommittees.

In creating the NORA Mining Sector Council, NIOSH considered the long and tragic history of fatal and disabling accidents in the mining sector. It also noted the nation's response to this record when it created, in 1910, the Bureau of Mines, and then, in 1995-1997, transferred the responsibility for research in mining safety and health to NIOSH. Additionally, the nation created and enforced rigorous safety and health codes for the mining industry, first through the Bureau of Mines and, since 1977, through the Mine Safety and Health Administration (MSHA) within the Department of Labor. Hence, unlike many decentralized industries in the United States, mining has had a research focus for over a century and a national enforcement focus for more than 50 years. It should be noted that the individual states had provided safety enforcement much earlier than national involvement and continue to fulfill that role vigorously to this day.

The greatest number of people working underground in U. S. mines was during World War I. The incidence of fatal accidents during that period is now seen as unconscionable. As noted, however, in an MSHA Fact Sheet (MSHA, 2011), the numbers of fatalities and injuries have been falling dramatically and almost monotonically since those days. A table illustrating some of the data is reproduced below.

Fatalities and Injuries for All Mining (Coal & Noncoal)		
Year	**Average Annual Deaths**	**Average Annual Injuries**
1936-1940	1,546	81,342
1941-1945	1,592	82,825
1946-1950	1,054	63,367
1951-1955	690	38,510
1956-1960	550	28,805
1961-1965	449	23,204
1966-1970	426	22,435
1971-1975	322	33,963
1976-1980	254	41,220
1981-1985	174	24,290
1986-1990	122	27,524
1991-1995	99	24,201
1996-2000	86	17,500
2001-2005	62	12,952
2006-2007	69	11,800

More recent information suggests that the trend will not decline to zero fatalities without further applied research and enforcement effort. In recent years we have seen coal-mine disasters of the sort that we thought were extinct. MSHA records the following fatality totals: 2006, 74; 2007, 67; 2008, 53; 2009, 34; and 2010, 71. In a year such as 2009, with 34 fatalities, there was no major disaster. In the other years, the upward perturbations can be linked directly to a major incident or disaster. Named for the mine in which they occurred, the tragedies at Sago (2006), Crandall Canyon (2007), and Upper Big Branch (2010), in particular, have led to swift legislative response.

Further stimuli to the work of the NORA Mining Sector Council are consideration of accident rates, both non-fatal with days lost and non-fatal with no-days lost, and the prevalence of occupational diseases. In the latter case, we have some knowledge of conditions such as noise-induced hearing loss and of dust-based diseases such as silicosis and coal-workers' pneumoconiosis, but uncertainties remain about their true extent. We know less about other occupational diseases such as contact dermatitis, stress-related cardio-vascular diseases, and the like. While data gathering on accidents leading to fatalities has become very reliable, reporting of other kinds of accidents and of the incidence of disease is less reliable.

If the nation is to continue its admirable trend in the reduction of the hazards of mining and the improvements in mine safety, it will need an organized and concerted research effort to do so. Increased enforcement of existing laws may partially achieve this result but we may also need different, more internally driven forms of enforcement. We may also need further technical advances in mining systems, accompanied by advances in safety management systems, that increase their inherent level of safety. The NORA Mining Sector Council has much defined for it to do.

What is the Vision and Mission of the Mining Sector Council?

After the Sector Council co-Chairs were able to obtain member agreement on initial statements of sector Vision and Mission, both statements were refined further in a teleconference with the co-chairs and selected members and corresponding members of the Council.

VISION

Mine safety and health research will provide a workplace where miners will have their quality of life unimpaired by accidents or disease. Benchmarks for this vision will be progressive and continuously improving, having miners' occupational safety and health statistics better than any previous year in mining, setting the best practice world-wide, and with individual mine units – large or small – supporting the Vision.

MISSION

The NORA Mining Sector Council will produce a current and renewable strategic plan for national research needs in mine safety and health. Guided by developing statistical analyses that are tempered by the expertise of Council members, the plan will identify those long-term research and development goals that most likely will achieve the Vision. As the plan matures, it will provide priority for these goals. The plan will examine existing NIOSH Office of Mine Safety and Health Research goals along with future goals that may be uncovered through the operation of the Sector Council. Suggestions for action that are nested under the individual goals will be the basis for mid- and short-range research that may be performed by academia, government, and industry.

Who is the target audience?

The National Mining Agenda provides guidance on prioritization of safety and health issues to industry, labor, federal, state, and local governments, as well as to experts in professional associations, academia, and public interest/advocacy groups. It can be used to improve health and safety of mine workers by providing areas of focus for partnering efforts. The Agenda will provide guidance to investigators concerning where information is lacking and what gaps need to be addressed in future research.

What process was used to develop the goals for the National Mining Agenda?

At its first meeting, the NORA Mining Sector Council considered the elements of strategic planning: guidance by statements of vision and mission; definition of long-term objectives; assignment of achievable sub-objectives to each major objective category; provision for adoption of sub-objectives by active research entities; creation of a system of monitoring of achievement of sub-objectives; and provision for renewal of the entire strategic plan. To help the Council achieve these elements within the confines of a one-day meeting, a schedule and agenda for the all-day meeting in Phoenix, AZ, was assembled by the co-chairs and distributed to the NORA Sector Council Members before the meeting.

Since the overarching goal for a NORA Sector Council is to provide a research agenda for the Nation, it is meant to be broader than any one agency or organization. Nonetheless, and unlike most other industrial sectors in the United States, NIOSH has an Office of Mine Safety and Health Research (OMSHR) that maintains research laboratories in Pittsburgh, PA, and Spokane, WA. The development of this NORA Mining Sector Research Agenda was done with an acute awareness of the goals and capabilities of the OMSHR and, thus, the goals of the Council's agenda are to be separate but linked.

Because the OMSHR has its own strategic plan and its own advisory committee, the Mine Safety and Health Research Advisory Committee, MSHRAC, an official federal advisory board, the Sector Council took a moment to review the distinctions between MSHRAC and NORA. (see Appendix B for details). Essentially, the Mining Council will write a strategic plan for the entire country and all of its research and development entities, whether government, higher education, or industry related, while MSHRAC will advise the OMSHR on its research program within the confines of its budget. The NORA Mining Sector Council received a lot of input from NIOSH personnel and is certainly aware that the NIOSH research program represents many topics that will bear fruit in the near future. Nonetheless, the Council strives to set objectives that are broader than those in the NIOSH strategic plan and also somewhat longer in term.

After the vision and mission statements were considered and approved by the Council Members, the next step, that of defining long-term goals, was undertaken by first developing a framework for Mine Safety and Health Research Objectives. To this end, the Council spent some time reviewing a logical framework for its objectives. In organizational terms, they looked at a taxonomy of objectives. As might be guessed from the complexity of the issue, the final list blends several of the different taxonomic cases.

Commodity: Enforcement of mine safety and health codes is done by commodity. MSHA is divided into coal and metal and non-metal. Within the latter grouping, metal mines and non-metal mines such as quarries for construction materials are treated differently. This commodity-based division is seen also in the labor movement where the United Mine Workers of America is dedicated to coal and several other unions divide up the metal and non-metal commodities. When some of the distinctions among the mining methods are considered, there is logic to this division. Fires and explosions, while not exclusive to coal, certainly characterize the bulk of the

coal-mine disasters. Ground control for bedded deposits such as coal has many practical differences from that used for deep metal mines. Ventilation techniques, again with many similarities in theory, have many differences in practice, particularly for deep metal mines.

Given the historical commodity enforcement basis, however, there may be many more similarities than differences: underlying scientific principles do not distinguish among commodities. The pernicious impact of excessive dust in the ventilating air can be found in all commodities. The application of technology across commodity boundaries has blurred the differences among them. Of all the examples that can be given of methods and technologies that cross commodity boundaries, perhaps the biggest is the application of digital techniques to monitoring and control of mining methods. Keeping in mind a commodity-based framework for certain research objectives such as fire and explosion, the Council decided to explore other ways of framing its objectives.

Human Impact: Accidents that cause injuries and conditions that lead to disease are the targets for research. If there were no humans in a mine, then there would be no incentive for research. Precisely, it is those technologies and conditions that impact human health that are the prime targets for research. An examination of current research programs from the NIOSH Mining Program web site (http://www.cdc.gov/niosh/mining/) shows that many of their programs are impact driven: disasters, dust-based diseases, noise-induced hearing loss, accidents, and fatalities. Yet, while the reduction of fatalities is a noble objective, it is not rapidly defined in terms of actions. To do that, we need to look at system failures and the sources of accidents.

Source of Impact, System Failures: A mine disaster, particularly one of fire and explosion, is a result of a failure of the ventilation system in combination with a failure of one or more technical systems and/or one or more failures of human behavior. The latter could include smoking, ignoring or avoiding fire alarms or warning signs, tolerance of unsafe conditions, or intentional disabling of safety equipment. To be fair to the bulk of the conscientious mine workers, disasters often also result from un-seen system failures such as short circuits, faulty equipment, unforeseen ground conditions, sudden changes in the weather, and the like. While not as deadly, many other kinds of accidents and system failures are the result of the same kind of combination of precipitating conditions.

Consequently, the Council considered whether or not a logical framework based on impact sources would be sufficient to define all objectives. The answer, as can be seen in the list of objectives, is no.

Combination Logical Framework: In the case of disasters and many deleterious impacts on human health, the Council created objectives that are impact based: disaster prevention, disaster response, and health. The remaining objectives are based on reducing or removing system failures: human behavior, mine design and management, ergonomics, and ventilation.

This combination categorization started with suggestions made by the co-chairs in the material sent in advance of the meeting. Although the suggestions were there in the beginning, the Council began its discussion with a clean slate. They started from the vantage point of mining conditions that most need to be addressed through research. As these research targets accumulated, they were sorted into objective categories that turned out to be not much different from that suggested by the chairs. As Council Members discussed potential research targets, they were sorted into like categories. When the meeting was nearly over, some trading of targets into other categories was done so as to improve the logic of placement. The categories became the research objectives, of which there were originally eight, and the targets became the sub-objectives. Subsequently the objectives were reorganized in order to streamline the Agenda and reduce redundancies. As a result, there are 7 major objectives for the National Mining Agenda.

How were the Objectives developed?

At the first meeting of the Sector Council, Members were asked to share their particular interest in mine safety and health. As the conversations on mining research developed, Members with particular interests helped to identify the health and safety research objectives that would meet the needs of the U.S. mining industry. Once the needs were written and sorted, Members were asked to serve on subcommittees that would eventually flesh out the strategic goals for each area along with a written narrative that could become the basis for a National Mining Agenda. The following eight areas were selected for emphasis:

1. Disaster Prevention
2. Disaster Response
3. Health
4. Atmospheric Control, Ventilation
5. Behavioral
6. Operations and Management
7. Mine Design and System Improvements for Normal Operations
8. Ergonomics also known as human factor engineering

Council members were then assigned to subcommittees established for each area and were asked to determine research objectives. The Sector Council members who were linked to each of these categories are identified in Appendix C. Notes taken during the teleconferences were transcribed by the co-chairs and circulated to the teleconference attendees for their review and approval.

In its second annual meeting, the Council was able to refine objectives and suggest points of duplication. Given the significance of many of the identified research issues, duplication was not surprising. As a result of that meeting, some of the sub-objectives in 4. Atmospheric Control, were moved to 3. Health, and Objective 6. Operations and Management, was redistributed in its entirety to other Objectives, namely to 1., 5., and 7. No research sub-objective was lost in this re-organization. The Agenda, however, has been given clarity and, we hope, increased significance. The revised organization is the one that is seen in the Table of Contents of this document.

Comments Received During the Period for Public Review

From February 2012 to the end of October 2013, the Draft Mining Agenda was available on the NORA web site for public review and comment. Three such submissions were received, one only a comment and two with suggestions for amendments; the latter were incorporated into the Sector Agenda in preparation for its being made final. In addition, the National Mining Association released CoreSafety, its prototype safety management system, and that is acknowledged in sub-objective 5.1.4.

The comment came from Marty Lorkowski of Scott Safety, a manufacturer of respirators, who said that his company, among others, has a research and development division that could be helpful to the Mining Sector Council. An invitation has been extended for him to nominate a suitable member to the Council. The amendments came from Dr. Jürgen Brune, Research Professor of Mining Engineering at Colorado School of Mines, an incoming member of the Sector Council, and relate to the prevention of gas and dust explosions, and Dr. Jim Weeks,

Council member. Language based on Dr. Brune's comments is inserted into a new sub-objective, 1.4.

THE OBJECTIVES

OBJECTIVE 1: REDUCE THE LIKELIHOOD OF DISASTERS IN MINES

Before beginning the discussion of this objective, it is helpful to delineate several terms of reference. A disaster in mining is an accident that results in multiple fatalities, normally five or more. An investigation into the causes of mine disasters shows that they are one of, or a combination of, four things: fire, explosion, collapse of ground, and inundation. Disasters are usually, but not exclusively, associated with underground mining. A great deal of research has been dedicated over the past century to the prevention of mine disasters and there have been substantial rewards, in terms of the reduction of fatalities from disaster, from this research. Unfortunately, the recent downward trend in worker fatalities has reversed in the last few years. The topic of disaster prevention remains core to the agenda of research needed in mine safety and health.

Normally, surface mining or surface facilities associated with underground mining are not as prone to disasters as are underground mines. Nonetheless, in recent history, two of the worst disasters ever recorded occurred in surface facilities: Aberfan in Wales, UK, in 1966 and Buffalo Creek in West Virginia, US, in 1972. Both were due to the collapse of refuse piles compounded by improper management of surface water. A substantial reference work on proper construction methods was issued by the Mining Enforcement and Safety Administration, MESA, (the predecessor to MSHA) and it has been recently revised and re-issued (MSHA, 2009). The Sector Council members believe that the science and technology needed to build safe impoundments exists but that vigilance is needed to prevent the recurrence of such disastrous accidents.

This discussion recognizes that many of the objectives in the Sector Council's agenda are aimed at preventing disasters. Nonetheless, disaster prevention can be more effective when considered as a whole, rather than attacking individual pieces of the problem separately. The integrated report is more complete by allowing this redundant approach. Because the subcommittee looked at the problem in an integrated way, the sub-objectives in Objective 1. blend one into the other and need to be examined in the same integrated fashion in which they were created.

1.1 Develop Early Warning Systems, i.e. Mine-Wide Monitoring Systems to Prevent Mine Disasters

Various forms of monitoring systems are applied routinely in mining. Perhaps the oldest and most consistent of these is the interruption of electrical supply by circuit breakers and ground-fault interrupters when they sense electrical short circuits. Circuit breakers are designed to protect equipment from electrical overloads and ground fault interrupters protect workers from shock. The past several decades have seen the development of atmospheric monitoring systems (AMSs) including remotely monitored fire and carbon monoxide, CO, detectors. Remote monitoring is also routinely performed on the health of transportation systems, particularly of conveyor belts.

1.1.1 Identify steps to make Atmospheric Monitoring Systems reliable tools for the prevention of disasters.

A conservative attitude toward protecting miners from risk prevents major changes in ventilation circuitry from occurring while miners are underground. This means that current AMS normally observe (monitor) but do not react (control). The degree of intelligence built into current systems is primitive compared to other non-mining industrialized applications. Several coordinated research steps will be needed to make AMSs into reliable tools for the prevention of disasters.

1.1.2 Link monitoring data with interactive mine simulators.

The first research step is to link monitoring data with interactive mine simulators. This will allow the simulator to state whether the data are consistent with the model and, also, to predict the consequences when contaminants are detected in the ventilating air stream. An intelligent AMS should reduce risk.

1.1.3 Develop accurate and reliable AMSs that provide feedback on a real-time basis.

A related research task is to make AMSs accurate and reliable. We know that humans have a tendency to ignore warning signals if they have been exposed to a series of false positives. Humans do not want to be responsible for an expensive cessation of mining for what turns out to be a false alarm. Research is needed to drive opportunities for error out of the system and to create a strong sense of confidence in the system. A research goal is to have intelligent and reliable AMSs that give feedback on a real-time basis.

1.1.4 Develop rapid and error-free methods of data entry that provide real-time updates.

Mining systems are dynamic. Every day sees substantial changes in the structure of a mine. Intelligent AMSs need to have real-time updates in the various computer-based simulators that give them their intelligence. The system must have enough information to give real, not confusing, messages. Rapid and error-free methods of data entry are needed so that, should an alarm be sounded, the system correctly identifies the source of the alarm and predicts the correct steps to be taken to remedy the condition. Resolving the question of whether to fight a local fire or to withdraw personnel rapidly may hinge critically on the simulator knowing the actual configuration of entries around the fire. If express-delivery workers can enter and receive information instantly into hand-held data-entry devices, we should be able to create similar but intrinsically safe devices for mining.

1.2 Integrate Engineering (Technical) Controls into Mine Design to Reduce Risk.

The discussion written just above leads naturally into the concept of reducing risk by re-engineering the system. Major hazard risk assessment methods should be utilized to identify conditions that need attention. Two issues arise: the first is the question of the consequences of change, as above; the second is the limited opportunity to create equipment changes when so much mining is undertaken in existing mines or their expansions. The introduction of longwall mining in coal increased levels of safety at the coal-mine face but also introduced new forms of accidents. Automation of longwall face advance has caused injuries to workers who were in the wrong place when the face advanced. The topic of mine design for enhanced safety is pursued further in Objective 6 for issues of safety and health that, while significant, do not necessarily involve a disaster.

1.2.1 Research non-inhibitory ways to expand the intrinsically safe review beyond ignition sources into all sources of a disaster.

Usually, advances in technology are introduced by manufacturers to enhance the sale of their equipment. Researchers should be developing protocols to be used by equipment designers and manufacturers that compare technological developments to the causes of all major disasters and serious injuries. The subcommittee is aware that all new equipment for certain mining applications must be submitted for an assessment of its intrinsic safety against ignitions. It believes that research should be undertaken to find non-inhibitory ways to expand this review into other potential sources of a disaster.

1.2.2 Develop safety protocols for retrofitting old mines and for extending the life of existing mines.

Recent price rises in metals, both noble and base, has meant that there has been strong activity in re-opening old, previously abandoned mines. Increased material values also cause older and deeper mines to be kept in production. Extending the life of older mines requires different designs than do new mines. The research into re-engineering mine systems for improved safety should include protocols for retrofitting old mines and for extending the life of existing mines. The reactivation or extension of a mine should not expose workers to an increased level of risk.

1.2.3 Determine the handling characteristics of biodiesel fuels.

If advances in equipment design are routinely compared to the causes of disaster, then designers might avoid pitfalls. For example, the use of biodiesel fuels for their improved fume and smoke characteristics has led to increased incidences of equipment fires. Biodiesel is a solvent for rubber and has caused weakening of hoses and gaskets, which, in turn, leak fuel onto ignition sources. In parallel to the research into the health effects of biodiesel, there should have been research into its handling characteristics.

1.3 Determine the Impact of Depth on Mine Design

Life extension for mines includes the very real potential for going deeper and deeper. For a period in the history of mining, surface mining of massive low-grade deposits provided the expansion needed by the market place. While surface mining will continue unabated, projects such as Resolution Copper, slated to begin mining at 10,000 feet of depth, open up a whole new range of research issues. Whether intended for coal or for copper, future mines will be deeper, hotter, gassier, and have more ground-control issues.

1.3.1 Define the challenges and associated risks of mining at depth and, based on risk/benefit analyses, determine research that is needed to improve safety.

Coal mining, particularly in the west, is already going into depths that are greater than current systems can handle safely. The effect of depth is compounded by pre-existing tectonic stresses that create a complex ground-control problem. We know of one set of advancing longwalls that was tried in the United States. Advancing systems were used by the British National Coal Board to deal with depth impacts and the mitigation of subsidence. They were expensive and labor intensive. While we are tempted to suggest research programs for mining coal at depth, the subcommittee believes that the first research step should be to define the challenges of mining at depth, collect information on various technologies that respond to these challenges, define the risks associated with these challenges, and then, based on best risk/benefit analyses, determine the research that is needed.

1.3.2 Research potential heat and ground-stress conditions for block and panel cave zones that are deep enough to avoid singularities from the surface.

In hardrock mining, the subcommittee is concerned that there is little information about block and panel caving systems applied at depth. Previous systems were shallow enough that the cave zone intersected the surface. Research should be undertaken into the potential stress conditions for cave zones that are deep enough to avoid singularities from the surface. The reduction of heat in deep mines by ventilation controls, including cooling systems, has been prohibitively expensive and has led to the abandonment of mining in deep deposits such as Butte, MT, and at the Homestake Mine in South Dakota. Concerns exist related to the impact of high-levels of heat in the wall rock on the safety and efficacy of chemical explosives.

1.3.3 Identify the challenges of deep mining in metal and non-metal mining and then define the research needed to reduce hazards.

Similarly to the recommendation for deep coal mining, a research project should define the challenges of deep mining in metal and non-metal mining and then define the research programs needed to respond to these challenges.

1.3.4 Study the challenges of underground mining for thick coal deposits.

Finally, as we considered the questions of going deeper for the recovery of mineral deposits, we observed that some of our western coal deposits, now mined by surface methods, were much thicker than mined by traditional eastern U.S. coal-mining methods. A similar study of the challenges of underground mining for these thick deposits should be undertaken. The subcommittee knows that versions of top-slice mining have been developed for thick coal seams, also multiple-lift longwalls, and suggests that issues of ground control, ventilation, and worker safety should be submitted to a thorough risk-analysis review to produce an active list of needed research projects.

1.4 Reduce the Risk of Mine Explosions

Research is needed to reduce further the risk of gas ignitions and consequent dust explosions in underground coal mines.

1.4.1 Reduce the risk of methane ignitions in continuous miner development and production faces.

Continuing research is needed on face ventilation systems in continuous-miner sections including improved water sprays and the use of active water barriers mounted on the machine. Such barriers have been required in European coal mines and their efficacy in US conditions should be investigated.

1.4.2 Reduce the risk of methane ignitions in longwall production sections.

Research into improved ventilation around shearer cutting drums and improvements of water sprays for these drums should be undertaken to see if the incidence of ignitions on powered longwall faces can be lowered.

1.4.3 Reduce the risk of ignitions in gob areas.

Research into gas composition patterns in gobs along with ventilation flows in the gob might lead to better decisions on ventilating, sealing, or inertizing these gobs.

1.4.4 Reduce the risk of coal-dust explosions.

Current U.S. practice is to dilute and render harmless coal dust by adding low-silica, inert rock dust to at least 80 percent incombustible by weight of the total. A major issue is maintaining the dispersibility of the applied rock dust. Research on the efficacy of this 80-percent standard should be undertaken along with the benefit of the installation of water and/or rock-dust barriers in ventilating-air courses. Sampling methods for validation of the 80-percent standard should be reviewed and research into improvement of these methods undertaken if the review suggests that current methods lead to false results.

1.5 Reduce the Risk of Disasters through Health and Safety Behavioral Research.

Human behavior and organizational factors have contributed to accidents and disasters. That is why additional objectives, 5: Improve Health and Safety through Behavioral Research, 6: Improve Mine Design, Systems Operations, and Management Performance to Enhance Mine Health and Safety, and 7: Apply Ergonomics, Also Known as Human Factor Engineering, to Mining to Increase Health and Safety are included in this Research Agenda. Attention is directed to these objectives with the comment that they are relevant to all accidents including those that lead to a disaster.

OBJECTIVE 2: IMPROVE MINE DISASTER RESPONSE

In an introductory discussion of this objective, the Sector Council members realized that the topic of Disaster Response has, through recent tragedies, become highly politicized. They hope to be able to discriminate among the three broad concerns that will arise during the formulation of this objective: research needed, enforcement methods, and the political issues derived from recent mine disasters.

The discussion was dominated by underground coal-mining issues because that is where the recent disasters occurred. The group did not lose sight of the fact that metal and non-metal underground mines and surface mines of all sorts need to have input into this critical objective.

2.1 Improve Communications and Tracking Systems in Mines

2.1.1 Develop hardened communication systems that can survive any disaster in which workers can survive.

As a general conclusion, the most pressing area for research is a communication system that can survive any disaster in which workers can survive. A large-scale effort should be carried out to test various systems of communications and the methods to harden these communication systems against violent disruptions. Perhaps it will require cable embedded in a trench in the mine floor or roof or barrier pillars; perhaps it will require periodic hard links to the surface; however, if there is any single item that will improve nearly every aspect of disaster response, it is the ability to locate and communicate with potential survivors. A miner's ability to use these systems while escaping, navigating, and wearing breathing apparatus is necessary to take advantage of the technology advances.

2.1.2 Develop integrated communication systems and AMSs capable of sensing and relaying information in real time about the conditions existing in the mine.

Secondarily, such a communication system should be capable of sensing and relaying information about the conditions existing in the mine without providing additional ignition

sources. Research concerning what this information should be and what is needed to feasibly obtain it in both emergency and everyday operations should be considered.

2.1.3 Develop hand-held displays for communication systems and AMSs.

Repeatedly, we have said that reliable and current information about the status of a mine needs to be in the hands of miners. Research into MSHA-approved permissible or intrinsically safe hand-held displays that are linked to the atmospheric monitoring system and other such monitoring systems that might be developed, e.g. roof control, is important. If these devices can be integrated into normal operations, they will be maintained and comfort in their use will be obtained.

2.1.4 Develop real-time analytical programs for AMS data.

Development of real-time analytical programs for these data that will give up-to-the-minute condition reports for the mine is important.

2.1.5 Investigate inertial guidance systems to determine their utility for tracking.

Inertial guidance systems based on gyroscopes are being tested by at least one manufacturer for miner location devices. These need to be evaluated and prototype devices tested. NIOSH noted that they have a vigorous program to develop communications and tracking devices and the group supported this work while emphasizing device portability and survivability.

2.1.6 Study the feasibility of establishing a mine-wide emergency-response system that would provide the information needed by responders.

One component of a mine-wide information system during an emergency is a functioning mine-wide information system in normal conditions. Research should be conducted into the feasibility of establishing a mine-wide system that would provide the information needed by responders for the various types of disasters that might be encountered. The system could doubly function as a means of preventing disasters by informing workers of potentially hazardous conditions in parts of the mine not normally visited.

2.1.7 Identify unintended consequences that may occur with new advanced communication systems.

Research, development, and, indeed, implementation of advanced mining communications systems are well underway. Research is needed to identify unintended consequences that may occur with these new systems. For example, how well do they work, if at all, when the miner is wearing a Self-Contained Self-Rescuer (SCSR)? What maintenance and reliability complexity will be added to the overall mining system with these communication systems? The new communication systems are not passive; will their internal power requirements, often provided by batteries, create new challenges?

2.2 Improve Command and Control during Mine Disasters

During an emergency that has the potential to become a disaster (five or more fatalities), it is critical that the command and control structure be in place quickly and understood by all. Because of the number of entities involved: mining company, federal and State enforcement bureaus, local and State first responders, miners' representatives, media, and family members, the lines of authority and responsibility are not always clear. To be of value, research in this domain must be aware of current federal and State regulations that control activity during a disaster response; a summary of applicable federal regulations is provided here.

Current Federal Law and Regulations

Current federal mining regulations require that, on each shift, underground coal mines employ a Responsible Person who will take charge during an emergency, and who will have been trained each year in the following areas, as prescribed by MSHA's Office of Educational Policy and Development:

(i) Organizing a command center;
(ii) Coordinating firefighting personnel;
(iii) Deploying firefighting equipment;
(iv) Coordinating mine rescue personnel;
(v) Establishing fresh air base;
(vi) Deploying mine rescue teams;
(vii) Providing for mine gas sampling and analysis;
(viii) Establishing security;
(ix) Initiating an emergency mine evacuation;
(x) Contacting emergency personnel; and
(xi) Communicating appropriate information related to the emergency.

In addition, the Responsible Person is charged with having current knowledge of the assigned location and expected movements of miners underground, the operation of the mine ventilation system, the locations of the mine escapeways and refuge alternatives, the mine communication system, any mine monitoring system, locations of firefighting equipment, the mine's Emergency Response Plan, the Mine Rescue Notification Plan, and the Mine Emergency Evacuation and Firefighting Program of Instruction. The recently required tracking systems now provide the Responsible Person with the location of the miners at least up to the time of the disaster. The regulations further require that each miner is trained in evacuation procedures, including the donning of SCSRs in smoke at least once each year.

Each mine must also have a written Emergency Response Plan that is reviewed at least every six months by MSHA (MINER Act, 2006). This plan would typically include crucial telephone numbers of responders, and must include, for example, the phone number of a driller who has agreed to quickly respond to an emergency for the purpose of drilling an escape hole.

Comments on the Regulations

The current requirements form a sensible approach on how to be prepared for rare events. One primary problem is that a complete list of items can likely never be included in an emergency plan for two major reasons: (1) the widely varying nature of the emergencies; and (2) the volume of material would grow so large that it would be unlikely to be read during an emergency. Except for referring to phone numbers and a brief checklist, realistically it is unlikely that the entire emergency plan will be studied during an emergency in any case; thus the need for pre-training of the responsible persons and support personnel. Updating the information for the many contacts in the emergency plan is a further problem, partly because the information will change slowly and the changes will be easy to overlook.

MSHA has established three centers for Mine Emergency Operations (MEOs) located in Pittsburgh, Beckley, WV, and Price, UT to respond to mine disasters, nation-wide. These centers are equipped with specialized equipment for communications and mine-atmospheric sampling to quickly assess the nature of the disaster.

2.2.1 Create comprehensive operational protocols for emergency responses.

The MEO has organized a great deal of information about mine emergencies. There is a feeling among the Council, based largely on past experience, that research may be needed to create comprehensive and operational protocols that can be implemented quickly and assuredly at the time of an emergency and that are applicable to large and small mines. These protocols should clearly define, delineate, and systematize lines of responsibility and authority in both the mining company and the safety agencies such that the response may be implemented quickly at minimum risk.

Practically, during an emergency, a key issue is cooperation between the company personnel and regulatory personnel. MSHA issues a “103k or j” order, which gives them authority to approve all rescue activities to protect life. However, MSHA is not intimately familiar with the mine, thus the mine personnel must still be in charge of the rescue, but with the obvious need to confer with both federal and State regulators on key decisions. The company must also organize the key supporting functions: taking care of and updating the families, the security providers, the media; getting medical assistance and possibly coroners; organizing staging areas for rescuers; providing the needed maps and other information; providing general and specific instructions to rescuers both before and during the in-mine activity; obtaining needed equipment such as pumps or nitrogen tankers; and providing food and drinks for all of the above. While the Responsible Person is responsible for the workers in the mine, it is obvious that he or she will, at the very least, need staff support during the time of the emergency. As soon as the responsible person becomes aware of a reportable emergency, there are multiple tasks to accomplish in a very short time. A system for delegating duties and a local emergency response structure may be needed to address these tasks efficiently and develop a credible response plan.

2.2.2 Determine the benefits and effectiveness of comprehensive operation protocols.

A section of the protocol should be dedicated to communication with emergency first responders (local and State police, EMT’s, fire departments, etc.), also to family members, miners’ representatives, and representatives of the media. Moreover, simulations and drills will be needed to see if these protocols can be followed during times of stress. A critical part of this research will be to see if these protocols can improve on the existing system. Although a few regulations in the mine safety laws deal with how to proceed at the time of a disaster, the actual structure is often, by nature, *ad hoc* and this may lead to mistakes and delays. The panel is cognizant, as noted earlier, that long written protocols are unlikely to be read in the midst of an emergency, thus the challenge will be for the implementation to be ingrained in the entire response team by effective training before the emergency. New training, competency assessment, and exercise design methods may require research to perfect. The Responsible Person must lead the response until the command center is staffed and functioning.

2.2.3 Develop the Responsible Persons’ training needed for emergency responders.

How best to train and assess the competency of the Responsible Person during the stress of an actual emergency is another area that is open to research.

2.2.4 Identify the best methods for transferring decisions to rescue teams and keeping real-time records of these messages.

Emergencies may unfold over time such as when underground fire fighters find that they cannot control a fire and must evacuate. Others, such as structural collapse, inundations, or explosions, occur nearly instantaneously, yet knowledge and

understanding of the emergency may unfold only over time. Hence, the first problem for the Responsible Person is to recognize early that a potential disaster is in the making and that he or she needs to immediately call MSHA and the State agency, as required by law. Related to this problem is to plan a credible response that satisfies MSHA that all persons are being protected. While MSHA will issue a “k or j” Order and may take charge of the mine, more often the company, as owner of the mine and the entity first on the scene of the emergency, has a continuing responsibility for it and will name the executive(s) to fulfill this responsibility during the emergency. MSHA has authority to approve all response plans involving personal safety. Again, looking at recent past experiences, while there is a Responsible Person somewhere at the mine at the time of the incident, he or she may be superseded by a company official who becomes the lead person in the command center. During this time of uncertainty, key decisions may not be made or, if made, approved by MSHA and implemented in a timely fashion. Research into ways of streamlining this decision-and-approval process is needed. As noted earlier, cooperation between the company, federal, and State officials is key. Decisions must be made quickly and must be the consensus of all three groups. A further complication is that small mines may not have the capacity to mount a full-scale response and immediately need additional support. This is often true in establishing external communication systems because landlines become blocked by incoming calls.

As stated above, emergencies may take many forms and the protocols will need to be tailored to each major kind. Even though the protocol itself may be comprehensive, hence lengthy, its abstract into check lists must be brief and understandable in times of stress. Because needed contact data (telephone numbers and e-mail addresses) change so rapidly, there needs to be a regular verification and up-date checks. Studying the best methods for transferring decisions to command center participants, approval agencies, and rescue teams and keeping real-time records of these messages may be a worthwhile area of research.

2.2.5 Determine if electronic telephony can be used effectively in breathing apparatuses.

High-quality voice and data communications, utilizing electronic telephony to and within response teams from the operations command center, could reduce errors and speed reporting. At present, the practice is for someone from the command center to brief teams on their tasks and identified hazards before they enter the mine. Teams in the mine are reached by relaying information via phone to the fresh-air base, which, in turn, relays the information to the team electronically. There may be more efficient ways to effect this communication.

2.2.6 Improve the location and tracking of mine structures and the personnel within them to provide for rapid response during an emergency.

Research on improved location and tracking of mine equipment, infrastructures, and personnel is essential to provide low-risk rapid response during an emergency. Normal mine mapping needs to become real-time and verifiable. Mobile machinery and its operators need to be located at any time. If these developments can enhance normal operating conditions, they will be maintained so as to be available at the time of an emergency. Because refuge alternatives are designed to be moved from time to time, each move needs to be documented as it happens. Automating this process with survivable machine tracking may improve daily-operations efficiency and assist timely response planning.

2.2.7 Determine how emergency response drills can be enhanced by virtual reality technology.

Drills for emergency evacuation are a current coal mining requirement. Research is needed to see how these drills and emergency response scenarios can be enhanced by virtual reality technology. This research will need to be guided by assessments of effectiveness.

2.2.8 Assess the effectiveness of current mine rescue exercises and propose improved versions.

Mine Emergency Response Development (MERD) training may be provided to groups or as contests approved by MSHA for mine rescue teams. Research can assess the effectiveness of current exercises, degree of standardization achieved, and propose improved versions. Full-scale emergency drills that engage all potential responders are necessary to confirm emergency system functionality. Additional benefit may be achieved if independent audits and reporting on lessons learned and best practices are made available to the industry.

2.2.9 Assess the effectiveness of current mine emergency training program (MERITS) exercises and propose improved versions.

NIOSH has, in the past, developed a mine emergency training program (Mine Emergency Response Interactive Training Simulation or MERITS) in which participants from a mine act out a simulated emergency in a control-room setting using a computer program that responds to the actions of those in the exercise. The trainees are provided with information about a small coal mine, its emergency response plan and its communication system, and are then given information about an incident as if it was realistically unfolding. This software must be upgraded for modern computer operating systems so that it may be more widely applied. There may be opportunities to expand the number of scenarios modeled and expand it to include all Responsible Persons and staff each year.

2.2.10 Create guidelines for preparing comprehensive mine emergency response plans.

Mine emergency response plans are required for each coal mine and are meant to be a valuable resource during an emergency. The results of the various research recommendations should be written in a way that they can make these plans realistic, locally applicable, easily followed, and beneficial during an emergency. These plans need to consider each major type of emergency that may unfold for the mine in question.

2.3 Survivability

The group recognized that current mining technology cannot protect miners against certain kinds of high-impact emergencies, particularly explosions. Consequently, prevention of emergencies is an extremely high priority; it is noted that another subcommittee will be working on this topic.

2.3.1 Develop design protocols for mine planning that consider the types of emergencies that could occur in specific types of deposits and at the particular mine locations.

Mine designs and the consequent mine plans need to consider most carefully the types of emergencies that could occur in the type of deposit and geographic location: explosions, fires, major structural collapse, ventilation failure, and inundation. It is recognized that all mining operations are by nature adapting to changing geologic and

operational conditions; therefore, it is essential that when the mine plan is modified, the original design assumptions are reviewed by competent professionals before changes are instituted. One possible process for doing this is completing a Major Hazard Risk Assessment. This assessment should be connected to the real-time collection of mine-status data suggested in sub-objective 1.1.4. Develop rapid and error-free methods of data entry that provide real-time updates.

2.3.2 Develop rugged, redundant location and tracking sensors that can survive disasters.

The issue of survivability of personnel cannot be considered in isolation. Survivability of the mine structure, its infrastructure and its communication systems is a critical part of the discussion on refuge structures and evacuation and escape that will follow. Repeatedly, the group identified the need to know in-mine conditions during an emergency. Survival of sensors and monitors is a critical part of acquiring this knowledge (see sub-objective 2.1.1. Develop hardened communication systems that can survive any disaster in which workers can survive.). Intelligent and real-time analysis of the data that come from these sensors is also needed to assess the conditions during the emergency. Location, environmental, and tracking sensors that can survive an incident are needed. Design for ruggedness, low maintenance, intrinsic safety, and redundancy is a research topic. Equally, if a sensor fails, the time and cause of failure and, in the case of mobile ones, its location at the time of failure are data that can be analyzed in a simulator to produce useful information about the emergency.

2.3.3 Conduct research to improve the survivability of all of the elements of mine infrastructure.

If miners are to respond appropriately during or after an emergency, they will need power, water, ventilation, and communication links. Research into which structures are essential to the survivability of these elements and how infrastructure can be made more resilient is important.

2.4 Improve Refuge Alternatives and their Use

A refuge alternative is a structure, either fixed or mobile, close to the working face or spaced out along the escape route into which miners can go for survival during a disaster. Seeking refuge is a secondary alternative to escape. Their use is now mandated by federal regulation but many questions remain for which research is needed.

2.4.1 Identify requirements for the next generation of refuge alternatives.

Research is needed on the next generation of refuge alternatives; NIOSH and MSHA personnel are aware of this need. Refuge alternatives are required in both coal and metal/non-metal mines today and have been installed under emergency coal regulations. Apparently, there is no nationally approved alternative for the ones already installed, in part because they are difficult to test under full-scale conditions and because no protocols are available for manufacturers who wish to undertake the expense of testing and approval. One possible method for developing protocols would be to assemble a group of experts from government, industry, trade associations, and manufacturers who would conduct a consensus-driven process for the development of standards upon which these protocols may be based. The protocols can then be referenced by the approving agencies and used by the refuge-alternative manufacturers to complete the testing and approval process.

Mines have different refuge needs depending on their mining conditions, seam height or vein thickness, rates of advance, and number of expected refuge occupants; some may plan to use them as way stations along escape routes, which makes airlock sizing critical. Low-coal mines have other criteria that may make inflatable refuges more attractive. Mines with elevated ambient temperatures could face undesirable environmental conditions such as elevated temperatures inside of portable refuge alternatives, if adequate cooling is not provided. Post-disaster environments including smoke, limited visibility, the wearing of SCSRs, and presence of injured workers may make finding, deploying, and entering a refuge difficult. In addition, mine rescue teams may need additional training or improved protocols when refuge chambers are present including reaching the refuge within 96 hours and extracting groups of miners, some possibly injured, from a refuge. There are a number of design, operation, and occupation issues that have been identified and are in need of research as the next generation of refuge alternatives evolve. These include postural conditions, control interface, survivability, tolerability, mine rescue, training, and psychological issues.

This research should include the study of refuge alternatives that have been involved in recent mine emergencies. Recommendations for future design requirements should be based on observations, tests, and sound scientific research.

2.4.2 Assess criteria for deciding whether to remain in a refuge structure or to evacuate from the mine and evaluate their implementation.

Entering a refuge is a last recourse. It is a decision that should be based on good knowledge that evacuation and escape contains more risk than does barricading (in the structure) and awaiting rescue. The more knowledge that miners have about conditions during and after the emergency, the more likely they are to make a good decision about leaving or staying. It was noted that today's miners have doubts about using a refuge for protection. NIOSH has developed a collection of training material but research is needed in the effectiveness of the implementation of the criteria and the training material.

A secondary concern is how miners perceive approaching rescuers, how best to rescue multiple miners in a possibly hazardous atmosphere, and how to treat injured miners.

2.4.3 Develop survivable data displays and their supporting systems.

The development of survivable displays that will give miners information about conditions is also needed. These displays may be portable or fixed within the refuge alternatives (this recommendation links back to sub-objective 2.1.1. Develop hardened communication systems that can survive any disaster in which workers can survive).

2.4.4 Determine the optimal location for refuges and caches of safety gear.

Research is already underway on the optimal location and spacing of caches of rescue gear and refuges. It is clear that this research needs to be continued and expanded including an assessment of similar efforts in other countries that have underground mining.

2.5 Improve Evacuation and Escape Procedures

The alternative to seeking refuge is for workers to seek to escape the disaster site within the mine. This decision should be fact-based but also needs to consider human concerns about the unknown; a number of research issues are involved in making this decision wisely.

2.5.1 Determine if mine and ventilation plans needed to select escape routes can be built into tracking and communication devices that miners could wear.

Again, it is critical that workers involved in an emergency have information on the status of the mine and rescue plans, reinforcing the recommendations for research on location and tracking devices along with survivable atmospheric monitors. Based on information received from those who have escaped disasters, it is critical that miners know the mine and ventilation plans well enough to select alternative routes for escape if available. Perhaps research would be worthwhile to determine if this can be built into tracking and communication devices that miners would wear.

2.5.2 Identify effective forms of escape training.

Escape drills need to be made rigorous and comprehensive, incorporating situations where miners are challenged with decision-making, the necessity for team-building, change of leadership, and handling of stressful situations. Research into forms of varied drill simulation would enhance the effectiveness of the training. This is especially critical given the limited time for training and the wide variety of topics in which miners may be required to be trained.

Most agree that escape is the first option miners should try after an emergency. In the case when miners may be injured or unable to escape, they may need assistance. The first available miners for assistance are coworkers. This is referred to in Australia as “inseam assisted escape”. It is a natural response to want to help colleagues but training may not have taught miners how to protect their own safety first.

2.5.3 Develop technology to provide face-located or mobile displays of mine conditions that allow workers to evacuate even through obscurant fog.

Research to provide face-located or mobile displays of mine conditions would allow workers to evacuate even through obscurant fog.

2.5.4 Determine if existing devices that can see through obscurant fog can be made intrinsically safe.

Vision systems that can see through dust, fog, or smoke exist within the military. Thermal Imaging Cameras are used successfully in a variety of applications including coal-mine trouble shooting, rescue and firefighting. Research might be undertaken to see if these devices can be made intrinsically safe for application in the mine.

2.5.5 Investigate the escape and rescue functions that robots are better suited to accomplish than people.

The use of robots for locating, or removing workers from the mine should be investigated further. Exploration robots have been developed with mixed success. A review of available technology would serve to guide future research.

2.5.6 Investigate the use of trained animals including insects to assist escape and rescue operations.

A search-and-rescue dog has been trained to locate injured miners in advance of mine rescue teams. Other animals, including insects, may have characteristics that can be used to enhance the effectiveness of mine rescue.

2.6 Improve the Use of Self-Contained Self-Rescuers (SCSRs) and Filter Self Rescuers (FSRs) Used in Hardrock Mines

It was mentioned that most models of Self-Contained Self-Rescuers (SCSR) are not comfortable to wear or to use. Personnel in the midst of an emergency may never have experienced this discomfort over long periods of time and may misinterpret it to mean that the instrument is not working properly. Resistance to breathing and increased temperatures of the air could cause a miner to believe that the rescuer should be removed.

2.6.1 Develop improved SCSR simulators to allow miners to experience their use in an emergency.

Low-cost SCSR simulators are available but research is needed to allow miners to experience realistically what it is like to wear an SCSR during an emergency.

2.6.2 Develop SCSRs that are easier to use and that accommodate voice communication.

Subsequently, research should be undertaken to develop SCSRs that are easier to use and that accommodate voice communication by eliminating the mouth piece. For example, a transparent breathing hood or a full-face mask could provide protection and replace the goggles and nose clips, although such a device would also have to accommodate the wearing of a hardhat.

2.6.3 Study problems that might be encountered while removing and re-donning SCRSs.

Miners may need to change SCSR units in the midst of conditions such as smoke or highly noxious atmosphere. Studies of the problems that might be encountered while removing and re-donning the units are valuable.

2.6.4 Develop new technologies for the next-generation escape breathing apparatus.

Innovations in breathing apparatus technologies that improve efficiency of on-demand delivery; optimize the size-to-duration ratio; utilize new chemicals for oxygen generation or dosing; design dockable oxygen supplies, filters, and catalysts; and improve carbon dioxide scrubbers may lead to design improvements. Cryogenics (Liquid air and Liquid oxygen), compressed air breathing apparatus (CABA) and refill systems, chemical/biological/radiological/nuclear (CBRN) filters, and CO/CO_2 catalysts are examples of known technologies that could be applied to breathing apparatus in mining.

2.7 Understand the Impact of Fire on Normal Operations, Ventilation Changes, and Byproducts

In terms of disaster response, the group considered the special conditions of fire in creating changes to the ventilation system.

2.7.1 Develop ventilation simulators that can predict ventilation changes caused by the fire.

NIOSH personnel said the older computer simulator, M-Fire, was being brought up to date for use on portable computers. If research provided ventilation simulators with better input from the principles of fire dynamics, they might be able to predict likely changes that occur during a fire. This prediction could be based on information received from the atmospheric monitoring system during a real fire or it could be based on conditions that were input into the simulator by the mine ventilation system designers, initially and during any subsequent evaluation/modification. This also fits in with the

earlier recommendation that there be research into the feasibility of and requirements for a mine-wide monitoring system.

2.7.2 Create easily accessed, interactive ventilation models that can be used to model failure modes in ventilation systems.

Research is needed to create easily accessed, interactive ventilation models that could be used to model failure modes in ventilation systems. They could be used to evaluate alternatives such as location and direction of air moving along "neutral" splits or of pressures and velocities at various nodes and along various entries during both normal and abnormal operation of the mine.

2.7.3 Investigate the effectiveness of game-like ventilation and other emergency response simulators for the new generation of miners.

Research is needed on new learning methods such as ventilation or other emergency response simulators presented as competitive computer games. Such an initiative could introduce an entire new generation of better prepared mine workers into mining.

OBJECTIVE 3: PREVENT ILLNESS FROM OCCUPATIONAL HEALTH HAZARDS

Preventing occupational illness is an extensive objective that encompasses several categories of disease, including respiratory disease such as coal workers' pneumoconiosis, silicosis, asbestosis, chronic obstructive lung disease (COPD) and lung cancer, musculoskeletal disorders, and hearing loss. Even so, there turned out to be many cross-cutting sub-objectives and these are identified as they are presented.

3.1 Eliminate Exposures that Lead to Respiratory Diseases

The primary culprit in occupationally caused respiratory diseases in miners is dust. In this sub-objective, the Council considers ways to identify and then reduce, perhaps even eliminate the incidence of respiratory diseases in miners.

3.1.1 Eliminate Coal Workers' Pneumoconiosis (CWP).

Since 2000, the prevalence of CWP has increased among miners with longer tenure and miners are developing CWP at younger ages. Increases have been particularly prominent in Central Appalachia (Suarthana et al Occup Environ Med 2011). Several causes have been suggested, including increased exposure to silica and longer working hours. And, until recently, productivity (tons/hour worked) has increased also (NIOSH, 2011a). Research objectives include an evaluation of the relative contribution of these causes and development of new or improved means of reducing miners' exposure to respirable dust including silica dust. Evaluation of these causes depends on improved epidemiologic data concerning miners' exposures and associated burden of disease.

3.1.1a Use the PDM for assessment of miners personal exposure to respirable dust.

The Personal Dust Monitor (PDM) is a powerful tool for exposure assessment and should be used to evaluate exposure for the purposes of epidemiologic research.

3.1.1b Evaluate the PDM for use as an aid for reducing the concentration of respirable dust since it is a real-time instrument.

The PDM can identify specific dust sources in a timely fashion that could lead to measures that would reduce miners' exposure. Research may be needed to bring this concept to practice.

3.1.1c Develop new or improved means of reducing miners' exposure to silica.

Exposure to silica in coal mines likely contributes to the development of CWP. There is need for research and development of means of controlling not only respirable dust but also the respirable crystalline silica component of respirable dust.

3.1.1d Improve secondary prevention by increasing participation rates in x-ray surveillance.

Research is needed into ways to increase participation rates in the current voluntary x-ray surveillance program for coal miners. Similarly, research is needed into ways to increase utilization of x-ray surveillance for detection of occupational respiratory disease in miners generally. Participation increased with both the Miners Choice Program and the Enhanced Surveillance program and this suggests ways to increase participation.

3.1.1e Improve secondary prevention by enhancing radiographic techniques.

Research is needed into improved radiographic techniques. Digital chest images have been demonstrated to be an acceptable method of surveillance, produce results comparable to analog films, and are significantly easier to store and transmit. Their use should be encouraged (Franzblau et al., 2009; Laney et al, 2010; Laney et al, 2011; Mao et al, 2011; Sen et al, 2010). Also, the potential utility of modern image processing techniques such as rib shadow removal and coloration of opacities should be investigated.

3.1.2 Eliminate silicosis and other diseases related to silica exposure.

The predominant respiratory disease of hard-rock miners is silicosis. Exposure to silica also is associated with lung cancer, COPD, kidney disease, and some autoimmune disorders. While mining methods, including the use of water sprays on drills and isolation cabins on the jumbo drills can reduce exposure, there are still open questions, as to the occurrence of silicosis and other health effects in miners.

3.1.2a Establish the prevalence of silicosis in metal and non-metal miners.

The prevalence of silicosis in metal and non-metal miners is unknown. There is no systematic surveillance system that would provide us with an estimate of the prevalence of silicosis. It is difficult to evaluate prevention efforts without such a metric and we miss opportunities to prevent the progression of silicosis in its early stages. Estimates should be developed of the incidence and prevalence of silicosis in metal and non-metal miners. Because of the long latency between exposure and disease, retirees should also be evaluated.

3.1.2b Establish whether there is excess burden of silica-related diseases other than silicosis in metal and non-metal miners.

Whether metal and non-metal miners have an excess burden of diseases other than silicosis that have been related to crystalline silica exposure is unclear. Estimates should be developed of the incidence and prevalence of such

diseases (e.g., COPD, lung cancer, autoimmune disorders) in metal and non-metal miners. Because of the long latency between exposure and disease, retirees should also be evaluated.

3.1.2c Create accurate and reliable silica exposure monitoring systems to reduce the incidence of silicosis.

Work that has been done for monitoring coal dust needs to be performed for silica dusts. The PDM could be used as a real-time monitor for silica-containing dusts and, with knowledge of the dust silica content, could be used to monitor exposure to silica. Alternatively, new technology to measure directly respirable crystalline silica in real time would be highly desirable. This exposure information could be used to focus dust control methods. Prevention strategies, including the use of technology to prevent exposures and worker isolation, would be helped if there were silica-exposure monitoring systems for mining work places.

3.1.3 Eliminate the incidence of asbestosis, mesothelioma, and related diseases in mining.

While asbestos is no longer mined in the USA, mineral products such as vermiculite, talc, marble, dolomite, volcanic ash, dimension stone, roadstone, and clays continue to be mined and quarried. These products can contain asbestos, fibrous serpentine and amphibole minerals not included as asbestos, cleavage fragments of serpentine and amphibole minerals, or other elongate mineral particles (e.g., mordenite, erionite, and palygorskite). In addition, fibrous minerals and elongate cleavage fragments may occur in association with metallic minerals. Exposure to asbestos also may occur as a result of other activities such as vehicle maintenance and use of asbestos for electrical insulation. The research that is needed to investigate the potential hazards posed by various elongate mineral particles and to reduce the risks of possible disease in these situations has been summarized in the NIOSH Current Intelligence Bulletin 62: Asbestos Fibers and Other Elongate Mineral Particles: State of the Science and Roadmap for Research (NIOSH, 2011b). In addition, population-based surveillance of mesothelioma, taking into account geographical areas where exposure may be an issue, should continue. In this, the acquisition of job and industry information about mesothelioma cases is essential in order to identify occupational risk groups.

3.1.4 Reduce Diesel Particulate Matter (DPM) Exposure in Mines.

Research is underway on the impact of diesel particulate matter (DPM) on miners. With a continuing regulatory effort to reduce DPM exposure, this research is important and should be continued. For example, operators will be seeking the most cost effective means for compliance with the 160 $\mu g/m^3$ total carbon standard. At present, compliance is being met with good maintenance, ventilation, and the use of biodiesel fuel. However, research is needed to determine the biological responses to biodiesel or fuel additives such as Cerium. Field observations suggest that there is less emphasis on the use of filters of various types. Ventilation for dilution of DPM concentrations below the allowable threshold is most important. Eventually, EPA Tier IV off-highway vehicles will be available for surface mines and their engines will be available for underground vehicles. These will have installed filters. As they become available and old diesel equipment is phased out in mines, the Tier IV vehicles will become more commonplace. Despite the improvement that should result from equipment substitution, there are research sub-objectives that define work needed on the issue of DPM and health.

3.1.4a Clarify the influence of carbon interferences on accurate DPM determinations when using NIOSH Method 5040.

Although the regulations and practices for control of diesel particulate matter, DPM, in underground coal mines are not too controversial, a controversy persists over the Permissible Exposure Limit, PEL, and best implementation for controls for DPM in underground metal and nonmetal (M/NM) mines. At present, the majority of underground M/NM mines are complying comfortably with the 200 $\mu g/m^3$ DPM (160 $\mu g/m^3$ total carbon) standard; however, some are not. It appears that the controversy persists over carbon interferences with the accurate determination of DPM. More research is needed to clarify the influence of carbon interferences on accurate DPM determinations when using NIOSH Method 5040. Also, a cost-benefit study on the use of different combinations of control technologies in maintaining DPM concentrations comfortably below the standard would prove useful.

3.1.4b Survey the implementation of DPM control technologies in metal and non-metal mines to determine current levels of DPM and the percent reduction from past levels.

A study to determine the level of implementation of new control technologies for DPM, including the introduction of Tier IV vehicles, and their impact on miner health would be useful. This survey of what technologies are being used and the results of the implementations (level of DPM and percent reduction) can be used to determine future research directions in DPM reduction.

3.1.4c Determine the effect of biodiesel, cerium oxide additives and filters on exhaust characteristics and human toxicity.

Preliminary data suggest that the mix of contaminants in engine exhaust change with substitution of biodiesel. Biodiesel usage can modify particle size distribution and aldehyde generation. In addition, nanoparticle counts increase with the use of exhaust filters and certain fuel additives. The nature of these exposures and their associated health effects should be investigated.

3.1.4d Characterize the impact of improved engine pollution-control systems on workers.

As diesels are tuned to create lower mass amounts of particulates per horsepower, an unwanted side effect may be the creation of unwanted emission products or of emission particulates that are finer, hence more reactive, than before. Research should be undertaken into this potential consequence.

3.1.5 Eliminate lung cancer from uranium mining.

An increased global interest in generating electricity from nuclear sources means that there is a concomitant increase in uranium mining. Thus, research to study the control of radon gas and to eliminate lung cancer from uranium mining will be needed.

3.1.5a Determine the extent to which in-mine radon exposures cause lung disease.

With exposure to the radioactive decay products of radon gas comes the potential for lung cancer. We need to apply contemporary exposure assessment methods, including real-time methods, for more sophisticated understanding of exposure to radionuclides in the radon and thoron decay series in mines and the associated risk of lung cancer in order to develop preventive strategies.

3.1.5b Improve the ventilation skills needed to protect miners from radon gas.

Ventilation research and dissemination of current best practices are needed to devise improved preventive technologies in the underground uranium mine. This would include studying the control of radon gas so as to inform new mine operators on best practices to control radon exposures of miners.

3.1.5c Determine whether uranium surface miners are at risk from radon gas.

Industrial hygiene research is needed to see if surface miners for uranium are at risk from radon gas. If they are found to be at risk, a new sub-objective for their protection will need to be written.

3.1.5d Consider undertaking an updated risk assessment to develop a new recommended exposure limit to radon and its progeny.

The current limit for radon exposure (30 CFR 57.5037 et seq) is dated (1973) and poorly documented. Although the ANSI N13 Committee has been reactivated, they are considering not recommending an exposure limit in a revised standard. Mixed exposures involving alpha radiation, diesel exhaust, and respirable dusts should be investigated. Improved monitoring devices for alpha radiation may prove to be useful.

3.1.6 Identify, reduce or eliminate hazards from airborne chemicals found in the mining work place.

3.1.6a Characterize the impact of airborne oil aerosols used in the lubrication of pneumatic drills and hand-held equipment.

There are concerns, hence the need for research, on the impact of fine oil aerosols used in the lubrication of pneumatic hand-held equipment, such as jack-leg and sinker drills, in confined underground operating environments. Studies are needed to determine the toxicity of rock drill oil, dose-response relationship, and potential contribution to disease. Potential health effects, based on research on machinists exposed to metal working-fluid, include chronic bronchitis, emphysema, asthma, and hypersensitivity pneumonitis (Jaakkola et al, 2009; Godderis et al, 2008; Bracker et al, 2003).

3.1.6b Determine if fugitive dust liberated from the wear of mechanical contact tools and equipment wear surfaces represents a health concern.

Numerous new alloys, crystalline and composite materials, and coatings are being used in the fabrication of mechanical contact tools, such as bits, ripper tips, and disc cutters, and wear surfaces, such as haul truck beds and the buckets of excavators. In most cases, little consideration or analysis has been devoted to assessing the possible health implications associated with fugitive dust created as a consequence of material wear. A number of physical metallurgists have raised concerns given the physical characteristics and chemical composition of some of these materials. Research into inimical metallogenic species such as manganese, associated with engine wear, that are found in DPM is related to this objective.

3.1.6c Determine the toxicity and respiratory health impacts of welding fumes.

The toxicity of welding fumes is not completely understood and neither is exposure in the mining environment, where pulmonary and systemic (cardiovascular, neural, and immune) effects should be studied. This is of

particular concern in confined environments associated with activities like maintenance/repair, construction, and/or mobilization/demobilization of equipment, facilities, and infrastructure. In addition, the relative potency of fumes generated by different welding processes and types of electrodes and base materials should be determined. Supporting this research aim, NIOSH has identified two sets of research needs associated with welding fumes. The first is the continuation of epidemiological studies to better understand the role these fumes play in immunosuppression, lung cancer development, neurotoxicity, and reproductive disorders. The second involves toxicology studies to examine key biochemical reactions to welding fumes at a molecular level in hopes of establishing insights into ways in which subtle genetic and cellular changes might lead to tumor formation, nerve damage, and other adverse changes in tissues and organs.

3.1.6d Determine if there are other health impacts from blasting fumes.

The gaseous products of blasting are normally dissipated in surface mining, but may be confined in high concentrations inside underground mining environments. In addition, blasting gases can also be confined in the muck piles generated through activities such as underground drift development and stoping. In these situations, the muck degasses over time and can contribute to exposures in workers not assigned to production areas. These blasting gases vary as a function of the specific explosive products being used and the operating conditions of the blast round (e.g., oxygen balance, hole diameter, presence of water, etc.). In most applications, these gases include very high but short-lived concentrations of oxides of nitrogen (NOx), which are known irritants that can create pulmonary inflammation and edema with acute exposure, as well as loss of lung function after long-term exposure (Mainiero, 2011; Wang et al, 1999; Bakke et al, 2004; Bakke et al, 2001), carbon monoxide which is an asphyxiate, and respirable and non-respirable dusts, which may contain silica. Chronic disease outcomes associated with worker exposure to blasting gases are poorly reflected in the MSHA accident/illness database. As such, research is needed to assess the chronic, as well as acute, impact of these fumes on miners.

3.1.6e Determine whether by-products of blasting at mining operations, including coal dust, gases, and residual explosive compounds, represent a health risk to the general public.

From an environmental perspective, research is needed to determine if blasting by-products and gases generated at mining operations represent a health risk to the general public and surrounding communities. In most mining applications, water-soluble blasting agents are used that have the potential to degrade and enter surface waters and subsurface aquifers used for municipal and agricultural purposes. In addition, fugitive blasting gases are routinely liberated after large surface blasts and through ventilation shafts in underground mining, particularly if water is present or the oxygen balance of explosive detonation is poor. Under certain atmospheric conditions, gas clouds can form and travel large distances before dissipating. Research is needed to quantify these potential hazards.

3.1.6f Research the health risks to mechanics associated with the removal and exchange of welded wear plates and liners.

The removal of wear plates and liners from mobile and fixed equipment exposes mechanics and other personnel responsible for repair and maintenance to a host

of different chemical and dust exposures associated with the processes themselves, such as air-arc cutting, as well as the wear materials being replaced. The impact of this activity on worker health needs to be studied while alternative methods of removal and replacement need to be devised.

3.1.6g Develop improved mobile equipment cabins to protect operators from airborne particulates and gases.

Data show a continued overexposure of miners to coal and silica dust, as well as high temperature environments that have the potential to result in heat stress. The Health Subcommittee recommends to the Mine Design and Systems Improvement subcommittee (see sub-objective 6.5.5) a strong push for research into improved operator cabins. While the implementation of engineered cabins has demonstrated a tremendous potential in facilitating disease prevention and improving overall safety, significant research is necessary to overcome challenges associated with limited visibility and operator awareness of environmental indicators of potential hazards (e.g., air blasts, sound/noise, smells, and changes in ventilation).

3.1.6h Determine the full suite of chemicals used in mills, concentrators, and preparation plants.

A survey is needed to determine information on all chemicals used in processing facilities and preparation plants. The methods to control worker exposures can then be determined based on MSDS information for the identified chemicals and possibly the European Union REACH data. As survey information identifies new chemicals in use, the extent and level of workers' exposures need to be determined through subsequent research.

3.1.7 Use surface chemistry and toxicity research to better characterize the human toxicity of mine dusts.

The surface reactivity of a dust may have a great deal of impact on its disease causation. Research is needed to determine if variation in surface reactivity correlates to toxicity or the incidence of disease in humans. If it does, then research should be undertaken into the reactivity of the various dusts that could reasonably be found in mines. This could be done by, for example, comparing the exposure-response relationships for health effects or disease surrogates of short latency on truck drivers or bulldozer operators (assumed exposed to stale dust) to that of driller or crusher operators or those exposed to abrasive blasting (assumed exposed to fresh dust with more surface activity). Significant amounts of research are underway on the impact of nano-sized particles on humans and, as much as possible, findings from this research should be transferred to mining.

3.1.8 Refine Recommendations for Personal Protective Equipment Related to Atmospheric Control: Respirators, Positive-Pressure Face Masks, Etc.

3.1.8a Investigate the application of positive-pressure airstream helmets or face masks and their compliance with the new respirable dust standards.

If a 1.0 mg/m^3 respirable coal mine dust standard is implemented by MSHA, research may be needed to determine the appropriate role for positive-pressure airstream helmets and face masks. The research should delineate the advantages and disadvantages of this technology as well as the feasibility of its adoption.

3.1.8b Study if respirators should be used in areas that are not in compliance.

In settings where specific over-exposure conditions occur, is it appropriate to use respirators until engineering controls can remedy the exposure? Research is needed to make recommendations.

3.2 Reduce Noise-Induced Hearing Loss in the Mining Workplace

3.2.1 Identify and determine methods for reducing noise exposures from existing and emerging technologies and processes.

A review of the current incidences of non-compliance with 30 CFR Part 62.140 for those exposures that have been determined to be technologically infeasible (P-code given by MSHA) should lead to research and/or development on new noise-control technology methods.

3.2.2 Determine the benefit of reducing the threshold of noise exposures for action from 85 to 80 dBA.

The medical opinion in the subcommittee was that nothing will be done to reduce the loss of hearing until the threshold for action is reduced from 85 to 80 dBA. Research is needed into the consequences of this action including the likelihood of compliance.

3.2.3 If the threshold for action is reduced from 85 to 80 dBA, conduct research to redesign or repower much of the underground mining machinery.

Since achieving this reduced standard implies a quantum reduction in sound-pressure levels, research will be needed to redesign or repower much of the underground mining machinery. The discussion above, in objectives 3.1.6a and 3.1.6b, of substitutes for pneumatic machinery is particularly germane to the protection of hearing.

3.2.4 Ensure sufficient visual and aural feedback for safe operation of equipment with improved cabins or other forms of tele-operation.

In creating technologies that remove miners from noisy environments, such as using isolation cabins, research will be needed to ensure sufficient visual and aural feedback for safe operation. This is particularly true if the cabins are armored to protect operators from falling objects or from roll-over accidents.

3.2.5 Develop personal hearing protectors that inherently work well no matter how they are donned.

Individual hearing protectors can be effective if they are fitted and used properly. Research may be needed to obtain personal hearing protectors that work well inherently no matter how casually or carefully donned.

3.3 Reduce Toxic Exposures of a Non-Respiratory Nature (Trans-Dermal and Ingested)

Past experience has shown that a variety of skin-related diseases stem from direct and indirect contact (through saturated clothing) of chemical contaminants, naturally occurring minerals, and mine water.

3.3.1 Survey the mining industry to update the list of chemicals being used including end products and the extent of use.

There appears to be much unknown about the level of usage of many ‘new’ chemicals in mining. A survey is needed to update the inventory of new chemicals being used, including reaction end products, and their level of use.

3.3.2 Determine whether there are unknown substances in the mine environment that can cause diseases and, if so, devise preventive measures.

Investigatory research is needed to see if there are other substances in the mine environment that can cause diseases and, if there are, to devise methods of prevention.

3.3.3 Determine the hazards that may be associated with the bacteria used in biological reactors.

The development of biological processes to pre-treat ores for leaching and biological reactors to treat acid-rock drainage means that workers will be exposed to the various strains of bacteria that oxidize iron or sulfur. Research should be undertaken to determine the hazards that may be associated with these bacteria.

3.3.4 Investigate prolonged exposure to the chemicals used in mineral beneficiation plants to determine if there are exposures not discussed in the MSDSs.

Any number of exotic and common chemicals is used in solvent-extraction electro-winning (SX/EW) mills. While Material Safety Data Sheets (MSDS) exist for them, research into prolonged exposure is needed to see if there is a threshold for disease not discussed in the data sheets. Comparison could be made with the European Union REACH program (Registration, Evaluation, Authorization, and Restriction of CHemical substances).

3.3.5 Identify methods to safely use and dispose of cyanide.

Cyanide used in gold mills is a topic of major concern for both environmental and occupational health. Research into its safe use and disposal is needed now unless we want to accept the moves to ban its use entirely.

3.3.6 Investigate the impact of cold on mining chemicals to extend the range of MSDS information to polar and sub-polar regions.

In deep, arctic cold, diesel fuels and hydraulic fluids can be harmful if touched to the skin. Research on the impact of cold on mining chemicals is needed to extend the range of MSDS information to polar and sub-polar regions.

3.4 Reduce Stress-Based Diseases

Much of the occupational stress-related research underway today is extremely significant in mining. Activities leading to musculoskeletal disorders (MSD), such as those of the back, knee, and neck, are being examined by current research projects.

3.4.1 Investigate the implications of an aging workforce on the likelihood of developing MSD.

One concern in this domain is for the impact of MSD on an aging work force. Moving the social security retirement age to 70 may have a great impact on the incidence of this disease if prevention methods are not found.

3.4.2 Investigate thermal effects in mining: Heat in deep mines; Cold in Arctic mines.

In the realm of physical stressors such as heat and cold, much research needs to be done. Mining is moving to more extreme environments and methods of cooling or warming miners, as the case may be, need to be evaluated against potential health and safety hazards.

3.4.2a Determine the extent of miner exposures and related accidents/ illnesses in arctic and other cold-area (polar and sub-polar) mines.

A study to determine the extent of miner exposures and related accidents/illnesses in arctic and other cold-area (polar and sub-polar) mines would be useful. The study could also delineate best practices in dealing with cold weather.

3.4.2b Determine the extent of miner exposures and related accidents/ illnesses caused by heat in large southwest open-pit mines and in deep mines.

Heat exposure issues exist in large open pit mines in the southwestern U.S. A study is needed to determine whether it poses an exposure problem, and, if so, what controls are used to protect workers from heat exposure. Although, there are very few deep mines in the U.S., heat stress is still a topic deserving of research. The mines in the Silver Valley (Idaho), approximately 5,000- to 6,000-ft deep, appear to have adequate ventilation at present. As they go deeper, issues of heat and its amelioration will need to be researched.

3.4.2c Develop methods of cooling or warming miners to prevent thermal stress in the workplace.

For exposures to cold, extra-thick clothing is used to keep a worker warm, but it also reduces mobility. For exposures to heat, low-cost and environmentally friendly methods to cool ventilating air are needed. Isolation of workers in atmospherically controlled cabins may be needed but then the workers will need to have aural and visual sensors provided as substitutes for their own ears and eyes.

3.4.3 Investigate the human willingness to take risks to create effective training programs that reduce risky behavior.

Mental stress arising from the nature of potentially hazardous tasks performed in mining – roof control, blasting, moving machinery through confined spaces, etc. – has the potential to dull alertness or to cause miners to take risks. Further research into the human willingness to take these risks may be an important step in the creation of effective training programs to prevent these risks.

3.4.4 Redesign the work place or the work tasks to minimize risk taking.

Equally, this research into the willingness to assume risk may help in the redesign of the work place or of the work tasks to minimize risk taking. Repetitive performance of these tasks also dulls alertness. This topic is explored further in sub-objective 5.1., Safety Culture.

3.4.5 Study the impact of longer shifts or variable-length work weeks.

The safety and health impacts that arise in variations of the working shift or of the work week are uncertain and therefore, research should be undertaken on these issues. These include longer work days, for example, four days of ten hours each or three of twelve hours, as a substitute for the traditional eight-hour, five-day work week. We do not know if there are mental stresses, fatigue, and task overload associated with longer work days nor do we know if there are disease impacts associated with longer exposures and shorter recovery periods.

Extended work shifts also extend a miner's exposure to respirable dusts and other chronic hazards (e.g., diesel particulate matter) over a short period of time, particularly if

they work consecutive days, reducing the time available to clear retained particulate matter. Existing threshold limit values all assume an eight-hour shift. With longer shifts, exposure limits need to be examined in light of extended exposure and shorter recovery periods.

3.4.6 Study the implications of fly-in/fly-out arrangements.

In fly-in, fly-out arrangements, workers go for extended work periods followed by a number of days away from work. The implications of these arrangements for both safety and health need to be studied also.

3.5 Improve Behavior that Impacts Health

Behavioral traits demonstrated on and off the job and not necessarily under the direct supervision of management may have substantial impacts on worker safety and health. In this section, we discuss the health impacts of harmful behavioral traits; in Objective 5 we discuss similar concerns for safety. Research is needed to translate national healthiness campaigns for miners.

3.5.1 Promote wellness by investigating life-style issues.

3.5.1a Tailor anti-smoking campaigns to miners.

The number one problem associated with wellness is smoking. Anti-smoking campaigns need to be tailored to miners to help them to understand that smoking, even if only done outside of the work place, substantially alters the threshold for the onset of respiratory diseases.

3.5.1b Investigate the impact of effective educational programs on obesity in the mining communities.

The United States has seen issues of obesity, associated with diet and nutrition, in the news. This issue is particularly important for miners because the diseases associated with obesity, diabetes, cardiovascular problems, stroke, and heart attack can be particularly troublesome to workers undergoing the physical stress of mining. Research into effective educational programs is needed.

3.5.1c Investigate distracting elements of behavior: fatigue, anxiety, anticipation of a vacation or break, or return from an extended lay-off.

The subcommittee on worker behavior will separately examine the issues of worker attitudes and ways to reduce risky behavior while enhancing safe work practices. Nonetheless, the health subcommittee noted that laxness toward personal safety can be associated with fatigue, with anxiety, with anticipation of a vacation or break, or with return from an extended lay-off and suggest that research into this element of behavior be undertaken.

3.5.2 Reduce substance abuse.

Whether of controlled (illegal drugs) or of non-controlled substances such as alcohol or prescription drugs, the presence of a worker under their influence is a risk to himself or herself and to surrounding workers. While the data may be more anecdotal than statistical, there is a suggestion that substance abuse is a huge problem in some mining regions.

3.5.2a Develop education programs to reduce abuse of controlled and uncontrolled intoxicating substances.

Research is needed into the education methods and materials needed to reduce substance abuse in the mining demography.

3.5.2b With respect to substance abuse, research from other venues may need to be transferred into mining.

Since some of these substances are addictive, research from other venues may need to be transferred into mining circumstances so as to provide help to workers who are unable to stop the use of drugs by themselves.

3.5.2c Assess the performance of newly developed educational programs.

Research is also needed to assess the outcomes of these educational programs.

3.6 Improve Health Surveillance in Mining

Data on the health of miners have been collected through the various programs such as voluntary x-rays or audiograms done for hearing conservation. Unfortunately, these data bases are held at individual clinics and health facilities and, therefore, are not unified nor in consistent format. Even if they were uniform, privacy issues have intervened to prevent their use by researchers.

3.6.1 Determine whether the move by the health-care industry to digital data records can be used to create privacy-protected data bases that can improve health surveillance in the mining industry.

If we are to make substantial advances in protecting the health of miners, we will need statistically valid data on disease incidences and associated working conditions. Risk-based standards such as are used in Australia have the potential to reduce the incidence of disease below what prevails today. Research is needed to see if the move by the health-care industry to digital data records can be used by mining researchers to create privacy-protected data bases that can be queried to find answers to the questions posed above.

Eventually, we will need to know as much about the health of miners as we do about their accident histories. Comprehensive data bases that can be accessed by the public and by researchers will help move mining into healthier realms.

OBJECTIVE 4: IMPROVE ATMOSPHERIC CONTROL (VENTILATION) IN MINES

4.1 Improve Air Quality and Quantity in Mines: The Threshold Values for Safe and Healthy Mining

MSHA standards on air quality and quantity are explicit for most mine gases and aerosols, regardless of mine type and commodity. Revisions, through rule-making, of stricter permissible exposure levels for respirable asbestos, crystalline silica (alpha quartz), and coal dust are planned. *(This sub-objective complements Objective 3: Prevent Illness from Occupational Health Hazards)*

4.1.1 Determine the best mix of cost-effective and efficient ventilation control technologies for each regulated pollutant to comply with standards.

It is clear that revised standards on permissible exposure levels, PEL, would impact both the quality and quantity of air in mines. In general, supplying more air will reduce the

concentration of air pollutants; increasing air quantity, however, may not be the most effective choice for reducing concentrations. Thus, research on the best mix of control technologies for a given pollutant is needed to achieve compliance in a cost-effective and efficient way.

4.1.2 Review mine ventilation plans to determine fan applications, single versus multiple, the level of air leakage found in the different fan applications, and the impact of various practices on maintaining effective mine ventilation.

There seems to be fewer shafts, but with larger-diameter boreholes, used for mine ventilation today as compared to past practices. This practice leads to longer escape routes to mine exits during an emergency and larger amounts of air leakage throughout the mine. It is not uncommon now to have main ventilation fans three or more miles from active workings. The extent of the use of multiple fans vs. one fan, the level of air leakage in the different applications, and the impact of various practices on maintaining effective mine ventilation need some study. A survey to determine what is the current state of fan usage and what are the most cost-effective (capital and operating costs over the mine life) practices would be useful. The practices will likely vary by size of company, mine areal extent, seam thickness, and other factors. For example, more frequent use of multiple fans is likely to be more common in large companies while there is more likely to be only one fan used in small mines; the practice in medium to somewhat large mines is less certain.

It is noted that NIOSH researchers have proposed a new Metal and Non–metal, M/NM, ventilation initiative that would focus on the use of other fan technologies, i.e., booster fans and controlled recirculation in M/NM operations, to improve air quality and quantity. Determining the extent of use of these alternative fan applications would be useful for technology transfer.

4.2 Reduce hazards associated with Explosive Gases and Atmospheres

In the recent coal mine disaster at Upper Big Branch in West Virginia, a possible methane inundation from a lower reservoir has caused some concern. Also, in 2001, a large emission of gas from a stratum above the coal seam was involved in a disaster. Consequently, we are recommending research into sudden gas releases.

4.2.1 Study available histories of large gas emissions coming from strata above or below the production seam to determine the potential extent of the problem.

Histories of large gas emissions may be studied to reveal the potential extent of the problem in future mining, particularly as mines become deeper. It is noted that NIOSH is considering a proposal to do this now.

4.2.2 Investigate the potential for de-gasification systems to control large methane emissions.

Because deeper and more complex mines are likely to have higher gas concentrations, research is needed on de-gasification systems. The goal of this research would be application guidance on when and to what extent de-gasification systems should be used to control strata gas.

4.2.3 Determine when nitrogen inertization systems could be most effectively implemented in gassy, abandoned areas of a mine.

Because sudden barometric changes can result in the emission of large volumes of methane-containing air from exhausted sections of an underground mine, there is

increased interest in the use of nitrogen inertization in sealed gob areas in Eastern underground mines. It is recommended that this practice be studied for costs versus benefits and to determine if it will maintain long-term effectiveness.

4.2.4 Study positive-pressure chambers as an alternative to inert atmospheres for controlling methane emissions.

An alternative to nitrogen inertization of entire sealed areas would be the use of positive pressure chambers to eliminate in-gassing and out-gassing; a study is needed on which system would best control the problem and be the most cost effective.

4.2.5 Investigate the effective use of a tube bundle system for monitoring nitrogen inertization.

A complementary study on the most effective use of a tube-bundle system in association with a nitrogen-inertization system would be useful. Tube bundles provide a means to sample air in zones that are sealed to entry by mine personnel.

4.3 Real-Time and Intelligent Monitoring and Control of Ventilation

New legislation has been proposed for mine safety reform. If passed, the use of mine-wide atmospheric monitoring systems, AMSs, to monitor carbon monoxide and methane more broadly in an underground coal mine would be required. The Mine Safety Technology and Training Commission recommended an expanded use of mine-wide monitoring systems that are based on the results of mine-specific risk assessments.

4.3.1 Study the cost-benefit analysis of the expanded use of mine-wide atmospheric monitoring systems, AMSs.

A study is needed on the cost-benefit analysis of expanded use of mine-wide atmospheric monitoring systems, AMSs. This research should identify the conditions (risk level) for which a greater use of AMSs would be justified. The study should include also an assessment of the use of a tube-bundle system for monitoring air quality behind sealed areas under conditions of high risk. The threshold of risk should also be determined by the research program.

4.3.2 Investigate the survivability of mine-wide atmospheric monitoring systems, including the survival of existing components and improving the durability of new and proposed systems.

The survivability of existing mine-wide atmospheric monitoring systems and the development of new, more durable and permissible ones are very important goals for monitoring the mine atmosphere post-fire or post-explosion. Research is needed to estimate the period of survival for existing mine-wide monitoring systems during fires and explosions. This research can also be directed toward defining the vulnerabilities that reduce survival times. From this research, further work to develop permissible systems with improved survival characteristics can be undertaken.

4.3.3 Study the rapid adjustment of ventilation in response to real-time monitoring.

With greater implementation of mine-wide atmospheric monitoring systems, real-time changes to mine ventilation can be made, so long as the regulatory limitations are followed. A study on what scenarios and conditions are appropriate for AMS-driven, real-time change of ventilation is needed for all underground mines. It is noted that NIOSH is presently considering a proposal on ventilation on demand as an M/NM mine initiative. A similar study for underground coal mines, however, would need to consider existing regulations for ventilation system stability.

4.3.4 Investigate the further expansion of mine-wide atmospheric monitoring systems to include real-time monitoring of air velocity at strategic locations, dust concentrations at work places, and other ventilation-related parameters not now measured.

Further expansion of mine-wide atmospheric monitoring systems to include real-time monitoring of air velocity at strategic locations, dust concentrations at work places, and other ventilation-related parameters not now measured should be explored. The use of such strategic sensors could minimize risk to miners from potential deleterious exposures if the appropriate displays and read-outs are developed.

4.3.5 Determine how wireless-based sensor technologies can be implemented.

Wireless-based sensor technologies have many attractions for AMSs in routine and emergency use. Research into the use of wireless sensors should parallel the development of wireless communication systems in underground mines.

4.4 Improve the control of Chemicals and Reagents that May Enter the Working Atmosphere of a Mill or Preparation Plant

Research is needed into best practices for ventilating mills and preparation plants. These best practices should be based on achieving air quality that is below the thresholds for the different chemicals used in preparation. A survey of current practices for ventilating mills would provide a good basis for this research.

4.5 Improve the Performance of Stoppings and Seals

One recommendation of the Mine Safety Technology and Training Commission (http://www.coalminingsafety.org/) was to conduct research on improving the integrity of stoppings used to isolate emergency escapeways. This issue remains one that should be pursued.

4.5.1 Investigate and develop ways to improve the integrity of stoppings used to isolate emergency escapeways.

A study is needed to delineate the best practices in constructing stoppings for the best possible integrity, particularly during a mine fire. At issue is the survivability of stoppings against fire and over-pressure (explosion). A survey to get good information on best practices for stopping construction may provide the basis for further research.

4.5.2 Study the extent and conditions under which monitoring of the atmosphere behind sealed and other abandoned areas should be undertaken.

As noted earlier in this objective, there should be a study of the extent and conditions under which monitoring of the atmosphere behind sealed areas is needed. The recommended way to monitor the atmosphere behind sealed areas should be addressed. The extent to which monitoring is undertaken of the atmosphere at strategic locations in coal-mine bleeder entries and other abandoned but unsealed areas should be studied as well.

4.5.3 Determine the variation of methane levels with distance from the face.

Research is needed to determine the variation of methane levels behind longwall shields at various distances into the gob. The extent to which changes in barometric pressure impact the movement of methane into and out of the active longwall gob should be determined as well. A similar study should be done on active gobs in continuous-mining, pillar-retreat sections.

4.6 Improve the Performance of Face Ventilation and Scrubbers

Recent NIOSH research specified best practices to control respirable dust generated during deep cuts in continuous mining sections; however, a follow-up research effort is needed to continue the work and to disseminate the research results broadly.

4.6.1 Investigate and develop methods to back-flush scrubber filters.

Research and development of methods to back-flush scrubber filters would be useful. One inquiry to NIOSH sought the integration into scrubbers of an ultrasonic anemometer that would monitor scrubber airflow. This innovation may form a research and development initiative that could be useful. The air-delivery capability of scrubbers has been compromised at times. Recent NIOSH research gives guidelines on best practices to maintain the air delivery of scrubbers; however, the information needs to be disseminated broadly through a translation project.

4.6.2 Delineate the optimal ventilation parameters for controlling methane migration from longwall gob areas onto the face.

If methane levels immediately behind longwall shields are elevated, then there is a partial pressure that could drive methane back onto the face. Research is needed to delineate the optimal ventilation parameters for control of methane migration to the face area.

4.6.3 Identify the optimal ventilation parameters to maintain compliance with forthcoming reduced respirable dust standards.

Another significant research issue relative to face ventilation is the identification of optimal ventilation parameters for compliance with forthcoming reduced respirable dust standards. Questions that may need to be resolved are how do these parameters vary by type of mining, seam thickness, percent quartz in dust, etc.?

4.6.4 Study the design of face ventilation and filtration systems for ease of filter exchange and maintenance.

NIOSH research has found that continuous miner operators can experience high silica levels, depending on the amount and type of rock cut, but bolter operators can often see higher levels. NIOSH looked at the use of disposable dust bags, a canopy air curtain, and mist drilling to control dust levels. This problem appears to be a maintenance issue, i.e.., maintaining the vacuum system: dust box cleaned, filter checked and seated properly, pre-dump use, etc. Research into the design of systems for ease of maintenance should be continued.

4.6.5 Disseminate best face-ventilation practices by developing a Best Management Practices Manual, BMP, for Face Ventilation.

A comprehensive study to compare the dust control practices of highly compliant mines with those of troubled mines would help give broader dissemination of best practices. A corollary benefit of such a study would be to use MSHA data to target mines that need help to improve their dust control; however, it is best that disinterested researchers do this work.

4.7 Improve Deep Coal Mine Ventilation

4.7.1 Define health issues related to deep, coal-mine ventilation in Alabama, Utah, southwestern Virginia, and southern West Virginia.

Besides possible improvements on de-gasification, additional health issues need to be defined relative to deep coal mine ventilation in Alabama, Utah, southwestern Virginia, and southern West Virginia. The issues defined should be related to those identified in Objective 3: Improve the Health of Miner. However, there could be additional unforeseen health issues involved with deep coal mining. Additional research would be conducted to determine ventilation controls specific to deep coal mines that could mitigate the health issues defined.

OBJECTIVE 5: IMPROVE HEALTH AND SAFETY THROUGH BEHAVIORAL RESEARCH

Research into miners' behavior was deemed by the Council and the assigned subcommittee to be a critical element in the search for accident reductions. What elements of the workplace or of work organization lead miners to an increased awareness of their responsibility for safety and health and what is it that encourages some to take risks?

In an editing exercise done to reduce redundancy among the objectives, it was decided to move five sub-objectives from the original Objective Six to Objective Five; these were named originally as 6.1, "Improve Education and Training," 6.2, "Worker Behavior,", 6.6, "Develop Risk-Based Systems that Provide Goal-Oriented Versus Means-Oriented Approaches to Safety," 6.9, "Quantify the Impacts of Variation in Shift Length, Shift Rotation, and Days Worked Versus Days of Rest on Safety and Health," and 6.10, "Determine the Best Forms of Managerial Intervention to Reduce the Incidence of Substance Abuse by Mine Workers." These five sections have been edited and re-numbered to fit into Objective Five with much of the duplication removed. The fact that two of the working subcommittees reached similar conclusions suggests strongly that they are important and the removal of duplication should not be construed to imply that they are not significant. The balance of Objective Six was also moved to other Objectives.

5.1 Improve Safety Culture in the Mining Industry

Becoming aware that the subject of safety culture applied to the entire realm of mining, the subcommittee discussed the role and responsibility of management in encouraging and inculcating a positive approach to safety in the work force. A positive safety culture is one in which every member of the workforce pushes for and is encouraged to push for safe operation in the mine; a negative one would encourage risk taking and inappropriate short cuts. Anecdotally, many circumstances were given of large companies that showed leadership in developing a safety culture. Equally, anecdotes were given of poor behavior in small-company operations that might have had a high percentage of non-English speaking personnel or that relied on a high percentage of contract employees.

5.1.1 Conduct a comprehensive survey into best practices that encourage a positive safety culture, including a statistical examination of the benefits of these practices.

The subcommittee agreed, however, that no one sector had an absolute lock on a positive safety culture and recommends that research be undertaken into best practices along with a statistical examination of the benefits of these practices.

5.1.2 Determine if there is a correlation of best safety culture with size of mine and the size of the owning entity.

Such research would define the nature of the problem with respect to the maintenance of a safety culture and determine if there is a correlation to size of mine and size of the owning entity. Examples should be gathered of best practices.

5.1.3 Compare training methods for best safety culture practices and develop standardized outcome assessments.

Equally, the best education and training exercises that are designed to encourage a safety culture should be gathered. The notion of best training is demonstrated by the educational effectiveness that they have as measured by standardized outcome assessments. One such assessment, of course, is the incidence of accidents in the mine unit. Another that may be more subjective but is still measurable is the retention by miners of the lessons learned in the training moments. Independent observation of operations and worker behavior therein is another form of assessment. The research into this subject could result in a best practices manual for outcome assessments of safety culture training.

5.1.4 There should be research into safety and health management systems for mining that would include the development of a model Safety and Health Management System (SHMS) and examination of its prototype application in a mine.

Several members of the subcommittee mentioned that a safety and health management system, SMS, would help to build a safety culture. Independently, the National Mining Association has developed and released "CoreSafety," a prototype mining safety and health management system (http://www.coresafety.org/, web site accessed on Feb. 4, 2013). These systems parallel environmental management systems and are based on a "Plan-Do-Check-Act" cycle of continuous improvement. Significantly, they place responsibility on all members of the system for successful implementation of the system. Individual miners would be charged with a sense of "if you see something, say something." Research into safety and health management systems for mining should include the development of a model SMS and examination of its prototype application in a mine.

5.2 Optimize Work Behavior and Scheduling of Work to Improve Worker Health and Safety

The subcommittee quickly shifted its conversation away from the original title of this sub-objective and, furthermore, consolidated two sub-categories of Objective 5 into one discussion of shift length and shift rotation. Indeed workers' attitudes toward safety are such an important feature of research into mine safety and health that it appeared in Objective 5 and the now-amalgamated Objective 6. In sub-objective 5.2, a key concern is with research into managerial methods that encourage safety and a culture of safety.

Longer shifts are becoming the norm at some truck-based operations. Time lost with driver changes, the acceptance by workers of 12-hr shifts, and the supervisory benefits of two shifts instead of three per day have led many surface mines to employ this length of shift. To maintain some sense of equivalence with a 40-hr work week, work schedules are augmented with appropriate times away from work. Having large blocks of leisure time is a reason for worker acceptance of these shift schedules. Where workers are transported to a work place such as in the arctic or other remote locations, longer shifts are also employed.

The health subcommittee recognized that shift scheduling and duration could have health impacts as well as safety and managerial ones. Sections 3.4.5, 3.4.6, and 3.5 are related to Section 5.2. In the sub-objectives that follow, we highlight elements of behavioral traits that can cause safety impacts.

5.2.1 Safe Worker Behavior

5.2.1a Study the roles of management to determine what encourages safe behavior.

If management's role for encouraging a positive safety culture is broader than installation of a safety management system, then research is needed into all of the roles of management that encourage safe behavior: potential examples of these roles include empowerment of the workers to take responsibility for the workplace, reinforcement and reward from management, delineation of effective workplace policies and standards, and, perhaps therefore, the formal incorporation of these elements into a safety management system.

5.2.1b Evaluate the effectiveness of rewards for safe behavior.

Research into the effectiveness of rewards for safe behavior is needed. How sizable must an award be to be effective; are there differences evident in how the reward is given?

5.2.2 Promote a positive safety culture.

5.2.2a Determine how to formulate managerial attitudes and approaches that foster the continuous search for safety improvements.

If the work defined in 5.1 leads to observations about the impact of the management system on a positive safety culture, then research can help to formulate managerial attitudes and approaches to the continuous search for safety improvements.

5.2.2b Formulate safety culture training for different kinds and sizes of mines.

Again, if the work suggested in 5.1 leads to finding a significant difference in safety culture between small and large mines, then research can help to formulate such systems for different kinds and sizes of mines.

5.2.3 Quantify the impacts of variation in shift length, shift rotation, and days worked versus days of rest on safety and health

There are safety-and-health issues with both shift length and shift rotation. Research is needed to quantify these impacts and to determine if there are optimal costs and benefits associated with such things as longer-than-eight-hour shifts and, consequently, fewer shifts per week or with the swinging of shifts through day and night assignments. Longer shifts have the attendant health impact of longer exposures to such things as noise and dust with shorter recovery periods before the return to the work environment (see 3.4.6).

5.2.3a Identify and quantify the potential for a decline in worker health and safety when shift duration and rest days are altered.

The subcommittee noted a host of problems that could develop with these working arrangements and suggests a research program to identify the magnitude of the problem and potential solutions.

5.2.3b Identify changes in attentiveness and alertness that come with longer shifts, more shifts between rest days, and larger numbers of rest days.

Problems with attentiveness and alertness come high on the list of potential problems associated with novel shift assignments. One line of inquiry would be a correlation of reportable accidents against elapsed shift time.

5.2.3c Longer shifts lead to an increase in repetition of tasks and research should identify if this repetition has an impact on alertness.

Repetition of tasks over a 12-hr shift, such as might be experienced by the driver of a large haul truck in a surface mine can lead to dangerous loss of attention and an injury-causing accident. Keeping limbs in a fixed and tensed position such as might occur with hands on a joy stick used to control bucket functions on an excavator may lead to muscle and tendon injury. Research could help to correlate these types of accidents and injuries to elapsed shift time in 12-hr shifts.

5.2.3d Improve operator control configurations and develop relaxation exercises, if a correlation between shift length and alertness is established.

Research into improvements in control configurations plus development of relaxation exercises may be appropriate if the reviews and studies do demonstrate a link between shift duration and scheduling and accidents and injuries.

5.2.3e Develop appropriate rest period and work rotation schedules and work responsibility guidelines to enhance alertness.

Similarly, the development of appropriate rest periods and of rotation of work responsibilities might improve alertness.

5.2.3f Determine whether respiratory recovery associated with longer shifts and shorter rest periods is sufficient for the maintenance of respiratory health.

Another wellness issue that was also discussed by the Health subcommittee is respiratory recovery associated with longer shifts and shorter rest periods. If the threshold for exposure to potentially inimical dusts and gases is based on an eight-hour shift followed by a 16-hr recovery period, then we need to know if that threshold value is still valid for 12-hr working shifts.

5.2.3g Conduct research to determine if the rotation of shifts, day to afternoon to night, etc., has an impact on safety.

Finally, for this sub-objective, the subcommittee considered the question of shift rotation: a week or two of days followed by the same length of afternoons followed by the same of nights. Conjecture suggested that this practice was developed to accommodate the workers' interest in one shift and dislike of the other. Fairness, therefore, developed the rotation. Of course, we also considered the presence of differential pay and how this might stimulate an interest in rotation. The question that research needs to answer is whether or not this rotation has an impact on safety. Are there more accidents after the weekend on which rotation occurs? If so, does the risk of accidents outweigh the benefits provided by the rotation?

5.3 Improve Training and Education

The subcommittees that created Objectives Five and Six (incorporated here) recognize that a tremendous amount of research is underway in The United States on effective means of teaching in Science, Technology, Engineering, and Mathematics (STEM) and encourages the mining research groups that are engaged in this sub-objective to stay in touch with efforts reported by the American Society for Engineering Education (ASEE), the National Science Foundation (NSF), the Higher Education Research Institute (HERI) at UCLA, and others engaged in research on learning effectiveness. The publishers, Jossey-Bass, have an extensive catalog of books on education. The ASEE has both a Council and a Division dedicated to Engineering Technology and their publications and conferences are relevant to research in training. The American Society for Training and Development (ASTD) brings together experts and practitioners in the realm of training.

Despite this volume of published research, the subcommittee recognized that education and training dedicated to mining are essential to the development of a safe mine and so discussed areas applicable to mining that could be helped with good additional research.

5.3.1 Investigate effective means of presenting safety training and of assessing the impact of these educational means.

A critical issue for a continued reduction in the incidence of accidents and industrial diseases is effective training. The subcommittee notes that training must engage the participants and create a sense of responsibility among the students for their on-going job performance. Research into effective means of presentation such as active learning, virtual reality (VR) simulators, responses to varying attention spans, use of alternative and distance-education modes that are coupled with research into effective means of assessing the impact of these educational means are integral parts of an on-going research agenda into safety training. Perhaps even more important is education into critical responses to emergencies and the development of assessment tools for emergency responses.

5.3.2 Identify best distance educational practices for training miners for safety, wellness, and job skills.

With many mining communities being remote, the use of distance-education techniques seems a natural for education in mine safety. If these lessons are transmitted into a mine-based facility such as a training room, attendance and participation can be controlled. On the other hand, if distance education subject matter is not carefully prepared and validated by beta-test groups, then its effectiveness may be diminished.

The subcommittee felt that an impartial research organization should take the lead in identifying best distance-educational practices and assembling them into packages that could be distributed to mines and miners.

5.3.3 Improve educational methods along with assessment methodology for mandated and suggested training.

There are routine efforts today to teach such varied elements as miners' rights and the donning of Self-Contained Self Rescuers (SCSR). Because these, and many other things taught to miners, are critical to their well-being, continuing research is needed on improved educational methods along with assessment methodology.

5.3.4 Develop methods of presenting innovation during training that lead miners to embrace new technology.

We have mentioned that participants should be engaged in their training. Stimuli for engagement such as active and pro-active training methods are needed. A sense of empowerment needs to be inculcated into the participants. If they are responsible, at the first level, for safety, they need to have the authority to improve the system. Such authority is integral to a safety management system (SMS) discussed later. Innovations in methods and technologies have been responsible for great advances in safety improvements, yet there are clear examples where an innovation has led to a retreat in safety. Research into methods of presenting innovation that lead to a responsible embrace of innovation is necessary.

5.3.5 Develop methods of reinforcing lessons that are engaging and assessable.

Finally, research into methods of reinforcement of lessons that are engaging and assessable is necessary to keep the message of safety before the participants. Renewal training can be boring if it is presented routinely. As part of a well-considered safety management system that rewards workers for improvements in safety practices and statistics, renewal can be fun, stimulating, and productive.

5.3.6 Improve educational methods used by contract trainers and develop assessment methodology.

Safety training is provided today both by the mining companies' staff (in-house) and specialty consultants and companies (contract). Research is needed on improved educational methods along with assessment methodology that might be used by contract trainers.

5.3.7 Integrate safety analyses into skills training, develop improved job simulation methods, and develop the means to assess the effectiveness of virtual-reality (VR) training.

Much of what is written above about classroom safety training applies also to job and skills training. The use of virtual reality (VR) simulators to raise skill levels in a safe and cost-effective manner is an important development in job training. Integration of safety analyses into this training, development of improved simulation methods, and means to assess training effectiveness are all part of a research agenda into training.

5.3.8 Develop computer simulations of safety circumstances that resemble video games to enhance learning among new miners.

Given the leisure-time activity of today's young people, the use of computer simulations of safety circumstances that look like video games should be examined.

5.3.9 Study the benefits of collaborative learning groups for health and safety training.

Research into methods that enhance learning, such as collaborative learning groups, should be undertaken.

5.3.10 The development of methods to reinforce safety-training lessons while personnel are at work would be useful.

Researchers should look for simple but effective ways to reinforce safety-training lessons while personnel are in the work environment. Reinforcing safety training taught in the classroom helps to assure miners of the lesson's validity.

5.3.11 Assess the effectiveness of health and safety training requirements and methods that are found in the mining industry.

Researchers should examine ways to assess the benefit of health and safety training. These assessments should lead naturally to improvements in the training regime.

5.3.12 Assess the benefits of MSHA Fatalgrams and safety shares for improving the safety culture of miners.

From experience in the mines, members of the subcommittee asked if today's research teams knew the benefit of several practical techniques used in today's mines to encourage safe behavior. The first was the use of Fatalgrams to illustrate recent accidents, with the hope that such a review would prevent a similar accident at the site. The second was the use of a "safety share," where each member of the group would provide one anecdote or idea that illustrated good and safe behavior. Research is needed to assess the benefits of Fatalgrams and safety shares and to improve them if necessary.

5.3.13 Assess on-line professional renewal learning systems for their effectiveness in the mine industry.

Extending this research agenda into improvements in higher education, credit and non-credit, for professionals may be beyond the scope of this research agenda. Nonetheless, mining will be enhanced by educational delivery systems that are responsive to work schedules and locations of mining personnel. On-line learning systems should be assessed for their effectiveness in the mine environment.

5.3.14 Evaluate hazard training for contractors and visitors, identifying best practices for hazard training, model training programs, and methods of assessment.

Finally, the subcommittee recognized the increased incidence of contractors, customers, and suppliers who go onto or into the mine site and who do not have the same attitude toward safety as the permanent employees. Research into easily deployed safety training for visitors is necessary. This implies an examination into current methods of hazard training for visitors, identification of best practices, development of model programs, and assessment of their use.

5.4 Promote Risk Management in the Mining Industry

Risk management involves independent assessments of the pitfalls that could befall miners from the design of machines and physical systems (objects) or from actions that they must take to operate these machines and systems. An inventory of objects and actions is made for any particular system or sub-system and each component is assigned a value for the harm that could be caused by it. The greater the predicted harm, then the more urgent would be the research needed to reduce or, even, remove this harm. Risks can be organized by a hierarchy of potential harm. Risk management includes an assessment of benefits that arise from redesign of the object or from re-education in operating it.

In quantifying these benefits, risk managers assign a high order to self-actuating or autonomous controls and a lower order to those that require operator/ human intervention and control. A hierarchy of desired reactions and responses to risks becomes the desired control structure within risk management.

5.4.1 Research standards of competence; determine what level of skill competence and expertise is needed to make risk assessments.

If there is no self-actuating control available and human intervention will be required in case of a sudden appearance of risk, then one very real concern of the subcommittee is how can we ensure that the person who intervenes is competent to do so? Research into standards of competence needs to be undertaken so that there are national standards for expertise as well as standards of expectation of knowledge of the mine system or sub-system that is to be controlled by the competent person. Intervention should be undertaken only by someone who is completely aware of the mine system and of the consequences of altering it.

As an example, the subcommittee is concerned that design decisions are being made about ventilation systems by people whose level of experience and expertise is less than optimal. Ventilation designs may be assigned to junior engineers whose experience level is modest; a new respect for the role of ventilation design needs to be inculcated. While consultants can provide needed maturity of expertise, they are not always around to revise and update designs as the mine develops. A review of submitted and approved ventilation plans has found substantial errors that could prove to be misleading in a risk-management assessment. This observation reinforces the need for standards on competence.

5.4.2 Identify and quantify risk factors used in a risk assessment.

A broad research objective is to identify and quantify risk factors in such a way that independent analyses will produce similar results from the same identified risks. This means assigning statistically valid values for the probability of failure that are based on observations in mines that are similar in structure, geology, or modes of operation. Risk management needs to learn from experience and to share rapidly the lessons learned. Many design algorithms, such as for slope stability, depend upon a predicted factor of safety.

5.4.3 Investigate the substitution of probability factors for safety factors when making risk assessments.

Research into the substitution of probability factors for safety factors (F/S or factors of safety) should be undertaken with the goal of improving model reliability. The probability factors should be given by experts and only placed on a Likert Scale (a scale of 1 to 5, where 1 is sure failure and 5 is sure stability) if they are not quantifiable. This approach to observational systems has been used in rock mechanics to predict the stability of openings and tunnels: rock-mass classifications and rock-mass ratings. It can be used more broadly to predict the probability of failure in many mining systems.

5.4.4 Research the consequences of changing a system to prevent failure so as to prevent unintended consequences.

Finally, research should be undertaken in the consequences of changing a system to prevent failure. We should be able to predict the consequences of any change so as to avoid the so-called “unintended consequence.” As an example, fatal accidents have been caused by continuous-miner operators in an underground coal mine running themselves over with tele-operated machines. The tele-operation (either by umbilical tether or by radio) was designed to remove the operator from the risk of roof failure and, instead, increases the risk of harm from the machine. The balance, in risk management, between determining the likelihood of an event and the cost of the consequences of this

event should always be kept in view so that research achieves a reduction in the product of the two values, not in just one or the other.

5.4.5 Develop effective training programs for risk assessment.

The subcommittee began with the premise that risk management was the approach needed to reduce risky behavior and was uncertain how this differed from the topics discussed above. It rapidly became clear, however, that risk management implied a statistically driven means to improve safety. If workers can be trained to recognize risk while managers are shown how to identify risks from statistical data on safety, then risky behavior can be reduced. Research into effective training programs needed for risk assessment would be beneficial.

5.4.6 Study the mine safety and health enforcement system to determine if there are alternatives that might deliver better health and safety performance in mines.

While not discussed at any great length, the subcommittee also considered an enforcement regime that was risk based. If the enforcement system were able to identify those operations and those behaviors that lead to a higher incidence of accidents, then the mine could concentrate on their reduction. Coupled with a SMS-approach to safety, workers would be engaged in safety rather than treating it as something belonging to an external enforcer. Recently obtained data show that the almost monotonic improvement in mine safety has come to an end. Some numbers have merely reached a plateau while others, such as fatalities from disasters, have shown an unhealthy reverse. The subcommittee believes that research is needed to study the enforcement system and see if there are alternatives that might deliver better performance in the mine.

5.4.7 Develop risk-based safety systems that provide goal-oriented versus means-oriented approaches to safety.

The concept of risk appears in several of the major objectives in this Agenda. The subcommittee is very concerned that the current system of regulation does not focus its priorities on a data-driven risk assessment or risk analysis. At one time, mine-safety regulation was very goal oriented and merely suggested that safe behavior was a virtuous objective and left industry to determine what this meant. An insufficient reduction in accidents led to a substantial increase in means-oriented regulations, i.e., specific guidance on machinery and methods. Today, we have a substantial body of data on accidents and a system for continuous updating of this data. Research may be able to show us if accidents can be correlated to the risk of their occurrence thereby giving guidance on the need for regulation and the assignment of responsibilities for compliance. The research might continue into the realm of the safety culture mentioned previously inasmuch as a clear definition of risks and responsibilities could stimulate active compliance.

5.4.8 Evaluate the effectiveness of risk management programs in reducing injuries and illnesses.

Risk-management programs were implemented in Australia following changes in their federal regulations. A study has shown a temporal association of risk-management-program implementation with a reduction in lost-time injuries in Australian coal mines. Further research is necessary to determine the effectiveness of risk-management approaches in the U.S. mining industry.

5.5 Employee Assistance Programs: Substance Abuse, and Counseling

5.5.1 Identify best practices in Employee Assistance Programs, EAP, for identification and treatment of substance abuse.

The subcommittee recognizes the existence of employee assistance programs, EAPs, which are voluntarily joined by employees who have behavioral problems, such as addiction, that they would like to overcome. What the subcommittee could not identify is whether or not EAPs are effective. Similarly to the members of the Health subcommittee (see 3.5.2), this group recognized that substance abuse is a tremendous problem in some mining regions. Research is needed to review the ways that the mining industry handles these problems and identify best practices for identification and treatment of abuse. Whether or not an EAP represents best practice is something that should be examined.

5.5.2 Determine the Best Forms of Managerial Intervention to Reduce the Incidence of Substance Abuse by Mine Workers.

Abuse of alcohol, controlled drugs, and tobacco has known impacts on the quality and cost of work performed by mine personnel. Research is needed on the best forms of managerial intervention to reduce the incidence of substance abuse. Considering the cost of replacing workers, research might be able to demonstrate preferred forms of employee assistance programs in lieu of strict enforcement of sanctions and terminations.

5.5.3 Conduct an independent examination of the use of sanctions for appearing at work under the influence of drugs and alcohol.

Many companies practice mandatory drug and alcohol testing and the subcommittee was uncertain as to the fairness of the practice. Failure of a drug test can lead to a non-appealable termination. The question is whether or not this is the best approach toward maintaining a safe workplace. On the whole the subcommittee thought that it was but suggested that an independent examination of the problem was worthwhile.

5.6 Develop training programs that address obesity in haul truck operators

A wellness issue that this subcommittee recommends to the health subcommittee is the potential for obesity involved in truck driving, which is essentially a sedentary job (see 3.5.1b). Food can become a diversion, which is consumed to reduce boredom, and consumption can lose any correlation with need.

OBJECTIVE 6: IMPROVE MINE DESIGN, SYSTEMS OPERATIONS, AND MANAGEMENT PERFORMANCE TO ENHANCE MINE HEALTH AND SAFETY

6.1 Systematic Safety Management

Similarly to an Environmental Management System, a Safety Management System inventories aspects and impacts within the system, lists objectives for improvement that are based on the inventory, lists all laws and regulations that affect the system, creates a policy that guides the system, defines management's role in guiding the system, and sets up an archive for all documents created within the system. It makes all members of the system both responsible and empowered to propel the system toward its objectives.

6.1.1 Develop safety management systems for mining.

Safety management systems have been formalized through various standards by, for example, the United Kingdom, Australia/New Zealand, ILO, and ISO, and have been used for 10 to 20 years. They have not yet been adopted broadly in the U.S. Research is needed to guide the adoption and modification of such standards for the U.S. and to determine their potential effectiveness in consideration of the U.S. regulatory approach to mine safety. The program in CoreSafety recently developed by the National Mining Association (http://coresafety.org/) presents an opportunity to study the effectiveness of a safety management system intended for mining.

6.1.2 Determine whether the 18001 culture (BS OSHAS 18001:2007) can be adapted for mining.

The British Standards Institute (BSI) encourages use of its standards for occupational safety management. It was originally called the "Occupational Safety and Health Assessment Series, OSHAS," but now only uses the initials. Inasmuch as this safety management system exists and has a history of application to mining, research can determine if it will fit into U.S. mining with ease.

6.2 Regulation

The United States and its respective mining-oriented individual states have some of the toughest approaches to mine safety that can be found in any regulatory code. Yet, although relatively good, the statistics on mine safety have not continued to decline in recent years and several prominent disasters (Sago, Upper Big Branch, and several smaller ones) have demonstrated that the regulatory mode needs reexamination to maintain or increase effectiveness.

6.2.1 Conduct impartial research to improve our regulatory system in mining.

Disinterested and impartial research may help us to improve our regulatory system in mining.

6.2.2 Demonstrate that effective regulatory requirements are scientifically sound and that future requirements are science based.

What approach to regulation and enforcement works best? At present, we have a mixed system that is predominantly guided by a strict operating code and a system of inspection and penalties. Research is needed to show that the current requirements are scientifically sound and that future requirements are science based.

6.2.3 Determine whether a specification-by-permit system, such as exists in mine reclamation, can increase the involvement of all personnel in a mine unit.

Research is also needed to see if a specification-by-permit system, such as exists in mine reclamation, can increase the involvement of all personnel in a mine unit. The statements made above about Safety Management Systems need to be examined in terms of their utility for regulation and inspection. Other major mining countries rely on codes of practice and descriptions of Best Management Practice (BMP).

6.2.4 Compare the effect of alternative codes of practice and best management practices to determine their effect on mine safety experiences.

Research is needed to see if the adoption of other codes of practice or management practices into U.S. mining would enhance or degrade our mine safety experiences.

6.2.5 Compare the effect of alternative systems of regulation on mine personnel attitudes toward safety.

Research is also needed to see if the adoption of alternate systems of regulation into the U.S. would improve or degrade mine personnel attitudes toward safety. The psychology of compliance may be determined by the nature of the regulatory system. Mine workers should be working toward a goal of safety not one of besting the system of inspection.

6.2.6 Conduct research to determine if managerial systems affect workers' attitudes toward safety.

Many mine management systems work in a hierarchical, authoritarian fashion. Research is needed to see if managerial systems affect workers' attitudes toward safety. If there is a culture of silence, rather than one of safety, then there may be ingredients for an increased incidence of accidents. Research into management systems, including safety management, may help to create an environment of collaboration instead of fear.

6.3 Integrate Operational Management into Advances in Engineering Design to Improve Health and Safety

The near future has the potential for substantially different technologies to be implemented in mining: autonomous vehicles, mine-monitoring and control systems, advanced mechanization in extraction systems such as longwalls and continuous miners, and so forth. The implementation of any one of these advances should be accompanied by managerial methods that specifically consider the impact of these systems on miners' safety and health. Managerial improvements will need to accompany the technical ones.

6.4 Develop Working Prototypes for Inserting Exploration Data into Geological Models and Mine Designs

It is anticipated that, as the technologies of exploration continue to be developed, data gathered during deposit exploration will be able to be integrated into mine designs as rapidly as the data are collected, i.e., in real time. Also, exploration data should soon be able to guide mining equipment. These data may come from pre-mining exploration programs, in which case they can help with initial mine design as well as be pre-loaded into machine guidance systems. Alternatively, they are gathered from on-board exploration equipment and the data would be used to refine these guidance systems.

NIOSH personnel would like to develop the science and technology of seismic tomography so as to obtain a better picture of mineral deposits and the ground that surrounds them from readily available geophysical tools. Exploration data can go into global and regional models that help to locate and delineate target deposits within their place in the earth's crust; they can also go into local models to help refine mine plans and to guide machinery. Research is needed to convert these concepts into real prototypes.

6.5 Improve the safety of Automated and Mechanized Mining Equipment

The subcommittee considered the broad topic of automation as applying to both production efficiency and safety improvements. It was agreed that NIOSH's charge was confined more to safety but that productivity and safety were linked. Moreover, the NORA Agenda was to be national, not just for NIOSH. Consequently, it was agreed that safety and health would be the first considerations but that relevant ideas would not be excluded because they appeared to enhance production. The discussion of automation sub-objectives that follows is slightly modified from the list produced in our meeting in Phoenix.

6.5.1 Develop reliability software for locating and tracking face workers on automated longwalls.

Automation of shield advance based on shearer location needs to have more reliable software. The system also needs to be able to locate all personnel and determine their risk for harm before moving shields. Software aberrations – glitches – have caused unwarned and unprepared movement of heavy equipment to the potential harm of face workers. Research is needed into software reliability as well as continuous identification of face workers and their location.

6.5.2 Develop reliable self-diagnosis systems to protect maintenance workers while working on automated face equipment.

The failure of autonomous equipment has its own risks to maintenance workers. If electricians and mechanics enter a section after the equipment fails or shuts down to prevent a catastrophic failure, then they were not present to hear or otherwise sense the symptoms of failure, consequently, they may have difficulty in diagnosing the problem. If the failure was due to a software glitch, the machine may well malfunction again during the period of repair. Research into reliable self-diagnosis systems would help to protect maintenance workers.

6.5.3 Improve proximity detection around equipment in mines.

6.5.3a Develop a reliable, intelligent proximity system for detecting workers around any piece of automated equipment.

MSHA approval of proximity warning systems does not guarantee functionality, only intrinsic safety against a methane gas ignition. At present only three proximity-detection systems are approved. One good research target is an intelligent proximity system that would create a hazard zone that is responsive to the shape and functions of various automated equipment. It would also identify people entering into the hazard zone and distinguish between those who should be there and those who should not. This recommendation is coupled to one first found in 1.1.4.

6.5.3b Develop reliable proximity-detection systems for continuous miners.

Continuous miners, with their multiple degrees of freedom, are good targets for further development of reliable proximity-detection systems.

6.5.4 Coupled with the development of proximity detection systems, develop guidance systems that protect the operator from inadvertent harm.

Related to proximity-detection systems are autonomous guidance systems. As we consider the increased use of remotely operated continuous miners, either through an umbilical tether or by a radio system, we note that there have been cases of operators being run over by their own machines. Deep-cut remote control has led to a new class of accidents. In cooperation with the research on proximity systems, there should be research into guidance systems that protect the operator or that allow the operator to be sufficiently far from the machine to avoid being run over. An intelligent guidance system will know where all personnel are located at all times.

6.5.5 Develop improved mobile equipment cabins to protect operators from airborne particulates and gases.

In keeping with the recommendation from Health sub-objective 3.1.6k, research should be undertaken into improved operator cabins that increase the protection from airborne

particulates and gases. A connected objective for these cabins should be increased comfort levels leading to increases of alertness and awareness of safe equipment operation.

6.6 Improve Ground Control in Mines

Ground failure of roof and pillar in underground mines and of slopes in surface mines is a substantial cause of injuries and fatalities.

6.6.1 Continue to develop numerical models that exceed the current empirical systems in efficacy.

Research in the area of ground control should continue to search for numerical models that exceed the current empirical systems in efficacy. These models should be based on universal design considerations rather than trial and error methodology. Exploration data should be input into the model before the simulation is initiated and then the model should self-modify, or "learn," based on in-mine monitoring or other additional data. To be practical and to guide the ongoing research, the modeling should start with localized ground-control models that can later be inserted into a larger framework.

6.6.2 Improve methods for determining the rock mass characteristics that form one of the critical independent data sets for a numerical model.

Numerical models based on commercially available finite-element and boundary-element codes have had some success in modeling ground-control conditions accurately. Research is needed in the key material characteristics that become one of the sets of independent data for a model; geometry of the openings is the other. These are well-studied elements in the laboratory but are less reliably measured *in situ*. Independent parameters of rock strength and yield function need to be developed for semi-infinite rock masses. Rock-mass characterization is an observational technique that attempts to give accurate values to *in situ* rock strength and stability and should be developed further. Geostatistics should be applied to rock-mass characterization to increase its predictive value. We should be able to identify weak ground in advance of its appearance at the mine face. Moreover, quantification of the term "weak" may help to improve the validity of ground-control models.

6.6.3 Develop "smart" roof-control drills for continuous detection of roof stability data.

Research should develop "smart" roof-control drills that gather information about rock strength and roof stability as they drill holes for the emplacement of roof bolts. These data should go directly in real time into the ground-control models.

6.6.4 Develop methods for rib reinforcement and reliable rib-roll warning devices.

Rib failures are already responsible for about one-half of the recent ground-control fatalities in underground coal mines. As coal mines go deeper (see 1.3) into the underground environment, this condition will only worsen. Research should resume into rib reinforcements and rib-roll warning devices.

6.6.5 Conduct investigations to discover relevant predictive seismic signals.

Coal-mine bumps and rock bursts in hardrock mines will become more prevalent as mines go deeper. Research should concentrate on finding relevant predictive seismic signals to be used as real-time warnings. Earlier research into this topic was stymied by the large volume of signals that were produced by stressed ground. Improved data analyses and artificial intelligence models make resumption of this work beneficial.

6.6.6 Search for rib-control technologies that reduce the incidence and impact of bumps and bursts.

In addition, rib-control technologies and pillar design that reduce the occurrence and impact of bumps and bursts should be investigated.

6.6.7 Improve seismic monitoring systems for mine safety and to guide mine design.

Because of the rapid advance of underground coal mines with the concomitant rapid change in ground-stress conditions, seismic surveying has not been very successful in identifying impending bumps. The pace of coal mining outruns the ability of a seismic network to provide meaningful data. The slower pace of mining in hardrock mines means that we have had some success in using seismic surveys to identify impending rock bursts. Research into improved seismic monitoring systems is essential. These include mobile three-dimensional seismic arrays. Seismic information, even if it arrives too late to predict an imminent failure, can still be used to improve mine design. Trials of various geometries can be observed by their seismic activity with the lower being the better.

6.6.8 Develop easy-to-use surface-mine drilling systems that include automated guidance to drill parallel holes in a single plane.

On the whole, the research response to past failures has led to a sufficient reduction in fatalities to reduce interest in further research in this topic. For example, as discussed in the beginning of the research agenda, devastating accidents with disastrous loss of life can occur if impoundments are not built correctly. This does not imply, however, that we do not know how to build correctly; rather, it is a matter of vigilance to see that they are built to design.

In the particular case of blasting in surface mines, we would like to see more use of controlled (smoothwall) blasting to reduce highwall failures and falls of rock from untrimmed highwalls. The research should be directed toward easy-to-use systems that include automated guidance to drill parallel holes in a single plane or that use multiple drills on a track to achieve the same result. Expert systems might be applied to blast design such that design occurs in real time. These systems should be designed to prevent overbreak and flyrock. They should also predict the appropriate amounts of explosive to be used to achieve optimal fragmentation. All of these measures will reduce instability of the highwall.

6.7 Transportation Systems

Many elements of mine transportation have been studied extensively for their impact on safety and health and, thus, the potential to reduce incidence of accidents. Nonetheless, potentials for improvement remain.

6.7.1 Revise surface-mine haulroad design manuals to accommodate autonomous vehicles.

If autonomous vehicles become more prevalent, haul roads will need to be constructed more carefully and more uniformly. The current design manuals may need to be revised to include features that allow for smooth operation of these vehicles. Additionally, if either wire guidance or wireless broadcast is part of the autonomous system, there will need to be design protocols and installation instructions for the guidance systems.

6.7.2 Develop effective methods of detecting the proximity of personnel around conveying systems.

Slips and falls of personnel around and under conveyor belts is still a major source of accidents. Research into effective methods of detecting personnel proximity should be undertaken. These are meant to be more effective and reliable than the current pull-cord system of emergency stopping. If mine design can find ways to separate personnel from conveyances, it would help also.

6.7.3 Develop better systems for locating personnel in complex underground mines.

Tracking and location of personnel is an issue raised in several of the objectives and research on better location systems is necessary. At present, resolution detail in the various tracking systems is not fine enough for them to be used as a proximity detector. The subcommittee thought that radio-frequency identifiers (RFID) would work but were uncertain about their acceptance by mine personnel. Research into better location systems should include social elements of worker acceptance.

6.8 Improve Power Systems Safety

Accident data reveal that mines still have problems with arc flash and burns. Shock injuries and electrocutions also still occur.

6.8.1 Investigate proper grounding design, as well as education and training material to reduce risky behavior when working with power systems.

More research is needed on proper grounding design as well as education and training material to reduce risky behavior.

6.8.2 Develop fail-safe lock-out mechanisms.

The failure to lock-out electrical supply boxes or cables when work is being done by electricians is still a leading cause of electrical accidents. Fail-safe lock-out mechanisms should also be considered for research.

6.8.3 Research should be considered on self-actuated diagnostic devices in power systems.

As suggested in the sub-objective on automation, electricians may be called on in the future to repair systems that failed when there was no human observation. Consideration should be given to research on self-actuated diagnostic devices. Protocols for maintenance and repair of autonomous equipment should be developed.

6.9 Improve Blasting and Explosives Safety by Investigating the Risks Inherent in Electronic Initiation Systems

The introduction of electronic blasting systems adds a new source of risk into blasting. The subcommittee is certain that much work has been done to ensure that new systems are safe but suggests that prudence would ask for independent research into the risks inherent in electronic systems. Can stray radio waves initiate such a system?

6.10 Improve the Health and Safety of Mining in Arctic Regions

Recent rises in the price of gold suggests that underground mining for it will increase in the next few years.

6.10.1 Translate information on mining in arctic conditions from the Russian archives into English.

It is known that the Russians have mined extensively in cold regions and have done a lot of empirical research into mining in arctic conditions. This work has been published in Russian and a technology-transfer project should be undertaken to translate it into English and make it available to miners in Alaska, Northern Canada, and other arctic regions. Once this literature is available, the safety and health elements in it can be emphasized.

6.10.2 Obtain relevant de-classified information that can be applied to arctic mining from the U.S. Army's Cold Regions laboratories.

Similarly, the U.S. Army's Cold Regions laboratories have done research into working in arctic environments but much of it is classified. An effort should be made to obtain relevant de-classified research from the Army that can be distributed to the northern mining community. Again, the word "relevant" implies that emphasis will be placed on safety and health implications.

6.10.3 Develop compromise approaches that optimize conflicting applications of infrastructure in arctic-condition mines without jeopardizing mine safety and health.

The subcommittee learned that underground mining, particularly of placer materials, in permafrost has a combination of problems arising from the use of common supporting mechanisms. Research should be undertaken to develop compromise approaches that optimize as much as possible applications of infrastructure without jeopardizing mine safety and health. For example, ventilation air will be frigid. Heating it to provide comfort to underground workers will cause thawing and softening of underground pillars that provide roof support. If the roof is also a gravel layer, thawing will cause its collapse.

6.10.4 Develop dust control methods that work in underground placer mines at temperatures below freezing.

The creation and control of dust is also very different in these placer mines. Inasmuch as the indurating agent for the silts and fine sands is water, in the form of ice, heating at the face will melt the ice and cause fine particles to enter into the ventilation stream. As long as air temperatures remain at freezing or below, water sprays for the control of dust will be ineffective; they will produce ice crystals or artificial snow. Research is needed into forms of dust control that work in underground placer mines at temperatures below freezing.

6.10.5 Develop effective social-support systems and methods to increase familial contact through electronic media for fly-in/fly-out mining operations.

Issues raised by other subcommittees about the stress of long shifts and fly-in/fly-out operations are as valid in arctic conditions if not more so. Alcohol and substance abuse is common. Family stresses are high as is the incidence of divorce. Prolonged absences of workers from their home residences exacerbate these stresses. Research into means for increasing familial contact through electronic media should be undertaken. Also, research into effective social-support systems is needed.

6.10.6 Develop cold-resistant metals.

Cold embrittlement of metals leading to abrupt fracture is a problem. Sudden fracture can directly hurt a worker or, by failure of a structure, indirectly. Research into cold-

resistant metals along with the development of internal heating devices would help to create machinery that can survive this environment.

6.10.7 Develop cold-weather lubricants.

Equally, lubricants should be effective in intense cold or else lubricated surfaces should be heated effectively and inexpensively. Research is needed in these lubrication issues as well.

6.11 Assign Wireless Frequency Bands to Respective Device Types to Prevent Safety Hazards

It was noted during some of the early discussions about the use of wireless systems in mining that there was little control of the assignment of frequencies to particular uses. The subcommittee believes that recommendations, based on valid research, be made for the assignment of frequency bands to particular categories of use in mining.

6.12 Improve Health and Safety for Small-Mine Operators

A continuing challenge to mine safety is the higher incidence of accidents found in units operated by small enterprises. They rely on designs done by others, outside consultants, or they copy designs of nearby mines and there is potentially a disconnect between mine design and operation. Because of their small size, the share of overhead cost assigned to permitting and mine design is inherently greater than for larger units.

6.12.1 Determine how intrinsically safe designs can be shared among small mining enterprises in cooperative collaborations.

Research is needed to see how these designs can be shared in cooperative collaborations.

6.12.2 Improve our methods of technology transfer into small mining enterprises.

Research is also needed to improve our methods of technology transfer to ensure that small mine units take advantage of the lessons already learned. Publications, whether in print or on-line, are a “push” methodology when what we need is for these mine units to want to “pull” the information into their operations.

OBJECTIVE 7: APPLY ERGONOMICS, ALSO KNOWN AS HUMAN FACTOR ENGINEERING, TO MINING TO INCREASE HEALTH AND SAFETY

The subcommittee recognized that future mining systems will include substantially more elements of automation and robotics than heretofore. While it is believed that automation will be installed as a cure that alleviates the risk of harm to workers, it is recognized that harm to workers can come as an unintended side effect. The deliberations of this subcommittee are aimed at identifying potential hazards in the mining system of the future and recommending research to reduce these hazards. In general, the subcommittee also found that physical ergonomics and prevention of cumulative, trauma-type injuries will continue to be an area of research needed for the mining industry.

7.1 Enhance the Safety of Workers Who Maintain Equipment

7.1.1 Develop design protocols as well as training programs for electricians and mechanics to understand and use software-based diagnostic tools.

Putting maintainability as a first principle in equipment design after functionality will locate parts in such a way that worker strain is minimized during the exchange of parts in the field. Parts that have the potential to fail from wear and use will be designed for ease of replacement. Parts that are likely to be exchanged should be designed so as to be as free as possible from sharp edges and inaccessible fasteners. Well-maintained equipment is safe equipment; poor machine design inhibits both routine and repair maintenance, which leads to the use of unsafe equipment. Maintenance support systems need to get parts to a machine rapidly and this requires an accurate diagnosis done quickly so that parts can be ordered for a “just-in-time” delivery. Once again, thoughtful equipment design will integrate self-diagnostics into the machine allowing for swift diagnosis and repair. Research that leads to design protocols as well as training programs for electricians and mechanics to understand and use these diagnostic tools will help in maintaining safe equipment.

7.1.2 Develop predictive maintenance procedures for new models and new types of equipment.

A long-desired goal is to have equipment that will signal, in advance, an impending failure. Maintenance can then be done at a convenient time with a minimum of downtime and at optimum cost; such a process is known as predictive maintenance. As new forms of equipment are developed, research should continue into predictive maintenance procedures for them. The boon to safety is obvious; catastrophic failures, such as of braking systems while on a hill, are avoided; maintenance workers can operate safely and at times when they least interfere with other operations. Hastily performed jobs intended to bring failed equipment back on line quickly, but which increase the potential for injury, can be avoided.

7.1.3 Apply the lessons learned from research on the maintainability of preparation plants to other mining systems.

Coal preparation plants have on-going research into maintainability. Lessons learned from this research should be applied to other systems. Equally, work done on maintainability in other industrial sectors should be transferred to mining.

7.1.4 Investigate the implications of an aging workforce on the safety of maintenance workers.

As the retirement age for social security is moved up, consideration should be given to an aging maintenance workforce: capacity losses, longer recovery times, etc.

7.2 Improve Worker-Machine Interfaces

7.2.1 Continue to apply human factor engineering, particularly when new machines are introduced, to mining equipment.

As machinery becomes more and more automated, it is essential that there remains a cognitive mesh between the operator and the machine, even if the operator is in a remote location. Automating everything means that the operator becomes dulled and, potentially, cedes thought to the machine. We know from disasters, such as the failure of the cooling system at the Three Mile Island nuclear power plant, that operators will frequently ignore warning signs if their main control unit fails to signal. There is a

parallel here to the initial introduction of computers. Users would give answers that were patently absurd saying that, "the computer says….." without first checking the algorithm to see if the computer program contained major errors. A portion of the concern for alertness factors (sub-objective 7.3) should include the loss of mental engagement when responsible for an autonomous machine. Research should continue on human factor engineering, particularly when new machines are introduced.

Elsewhere (sub-objective 6.5.3), we indicated that proximity detection is a significant part of the human-machine interface. So is the atmosphere in which the operator is found. Heat and humidity are significant sources of alertness deterioration. A social issue is off-site behavior of workers. If they come to work tired or recovering from binge drinking, they will certainly not be as alert as if they arrived fresh.

7.2.2 Training programs for contractors should be developed.

Similar problems may be found with contractors, whose employees may not be subject to training requirements. The supervisory line for contractors may be unclear. Training programs for contractors should be developed as well as model organizational structures for the use of them.

7.2.3 Link human-factor behavior with psychology.

Continuing research effort is needed to link human-factor behavior with psychology. We need to understand better how equipment operators make decisions. What drives their decision making: ease of behavior, regulatory compliance, or some other factor? Studies may be able to determine if behavior-intervention teams can be effective in reducing unsafe behavior.

7.2.4 Find ways to stimulate and enforce good behavior through safety culture modification.

NIOSH has a safety-culture study underway. This line of research should be encouraged among all mining research entities to find ways to stimulate and enforce good behavior. Protocols should be developed for concerted, continuous education that is based on outcome assessments.

7.3 Alertness Factors: Shift Duration, Multiple Assignments and Tasks, Fatigue

There is an overlap among human factors research and that of health (see sub-objective 3.4.5) and worker behavior (see sub-objective 5.2). The Council agreed that the topics in this section were important and benefitted from reinforcement.

7.3.1 Create a guidance manual on best practice for shift rotations and extended shifts.

Coupled to the issues of worker-machine interfaces are those of operator alertness. The impact on safety of shift rotation has been studied elsewhere. Research is needed that assembles the known research into a report or monograph and produces a guidance manual on best practice for shift rotations and for extended shifts.

7.3.2 Develop safety guidelines for extended work schedules.

We do not know, but should, the impact of long shifts on alertness. If they are working for an extended period in difficult environments, e.g., cramped, hot, or humid areas, operators may become fatigued and, thus, less alert. Since there is a move to longer shifts, i.e., greater than eight hours, research into the safety elements of these schedules should be undertaken. Mention has been made of the health concerns for

longer exposures to dusts and noise during long shifts. Off-site behavior leading to fatigue or of post-alcohol impacts ("hangover") certainly affects worker alertness.

7.3.3 Determine whether education and safety-culture reinforcements reduce the incidence of unsafe behavior away from the work site.

Studies should be undertaken, within the education protocols dedicated to safety culture, that determine whether education and safety-culture reinforcements reduce the incidence of unsafe off-site behavior.

7.4 Investigate the Effects of Vibration on Operators and Develop Duration and Intensity Thresholds

NIOSH personnel are currently studying the effect of vibration on haul-truck operators. There is a sense, however, that the impact of whole-body vibration on workers' balance and stability is under-studied. Data suggest that the vibratory effect on drivers in light vehicles may be negligible but this may not be so for big vehicles. Research into the effects of vibration on operators should include the development of duration and intensity thresholds. The parameters would include frequency and amplitude of the vibration, its duration, and the benefit or, conversely, risk of intermittent operation. These studies would be companions to those on the impact of longer shift durations for truck drivers.

7.5 Study the Safety Characteristics of Alternative Lighting Systems and Develop Technology to Make Them Intrinsically Safe

Many technologies, such as Light-Emitting Diodes, LEDs, are available for use in mining. LED lighting provides an improved view of the underground work place. Research or, more realistically, development of the safety characteristics of these alternatives and steps needed to make them intrinsically safe should be undertaken. On-board lighting systems are being developed by the manufacturers and research personnel should undertake cooperative development work with them.

7.6 Prevent Slips and Falls

Improved lighting should reduce the incidence of slips and falls in underground mines and in the night shifts of surface mines. House-keeping and cleanliness of ladders and walkways are important factors in the reduction of slip-and-fall accidents. These are a matter for the observance of a positive safety culture by workers. Research into the safety culture should include house-keeping factors.

7.7 Investigate the Safety and Health Impacts of Changing Materials Handling Technologies

The concern with the development of improved materials handling equipment parallels the concerns written above for the safety impacts of automation in general. A continuous line of research will search for the safety and health impacts of changing technology and this is particularly true for materials handling. Improvements are needed in monitoring instrumentation and, as written before, proximity detection coupled with safe shut-down in the event of a worker straying too close to the conveyance.

7.8 Increase the Use of Guards on Equipment

Guarding is a well-studied topic, however educational programs are needed to persuade workers to maintain guards and to not use equipment with faulty or missing guards. We need to

understand why workers would knowingly work without guarding or, worse, would remove it during operation.

7.9 Improve the Efficacy, the Fit, and the Ease of Donning of Personal Protective Equipment

Personal protective equipment (PPE), particularly respirators designed to protect workers from dusts and protectors for hearing conservation, needs to be worn correctly. Lessons in donning these two items in particular have helped to reduce the introduction of dust into the lungs and damage to the ear. Continuing research is needed in the ease of donning, comfort, and, particularly, the ability to communicate while wearing respirators (see sub-objectives 2.2.5, 3.2.5, and 5.3.11). The weight of this equipment has a consideration for worker comfort when it is worn over an entire working shift.

References

Bakke et al, 2001, Effects of blasting fumes on exposure and short-term lung function changes in tunnel construction workers, Scan J Work Environ Health, 27(4):250-7, abstract in PubMed: www.ncbi.nlm.nih.gov/pubmed/11560339.

Bakke et al, 2004, Cumulative exposure to dust and gases as determinants of lung function decline in tunnel construction workers, Occup Environ Med, 61(3):262-9, abstract in PubMed: www.ncbi.nlm.nih.gov/pubmed/14985522.

Bracker et al, 2003, An outbreak of hypersensitivity pneumonitis at a metalworking plant: a longitudinal assessment of intervention effectiveness, Appl Occup Environ Hyg, 18(2):96-108, abstract in PubMed: www.ncbi.nlm.nih.gov/pubmed/12519684.

Franzblau et al., 2009, Comparison of digital radiographs with film radiographs for the classification of pneumoconiosis, Acad Radiol, 16(6):669-677, abstract in NIOSHTIC-2: www2a.cdc.gov/nioshtic-2/BuildQyr.asp?s1=20035481&View=f.

Godderis et al, 2008, Exposure to metalworking fluids and respiratory and dermatological complaints in a secondary aluminium plant, Int Arch Occup Environ Hyg, 81(7):845-53, abstract in PubMed: www.ncbi.nlm.nih.gov/pubmed/17999077.

Jaakkola et al, 2009, Respiratory symptoms and conditions related to occupational exposures in machine shops, Scan J Work Environ Health, 35(1):64-73, abstract in PubMed: www.ncbi.nlm.nih.gov/pubmed/19190832.

Laney et al, 2010, Comparison of storage phosphor computed radiography with conventional film-screen radiography in the recognition of pneumoconiosis, Eur Respir J, 36(1):122-127, abstract in NIOSHTIC-2: www2a.cdc.gov/nioshtic-2/BuildQyr.asp?s1=20037100&View=f&.

Laney et al, 2011, Intramodality and intermodality comparisons of storage phosphor computed radiography and conventional film-screen radiography in the recognition of small pneumoconiotic opacities, Chest, 140(6):1574-1580, abstract in NIOSHTIC-2: www2a.cdc.gov/nioshtic-2/BuildQyr.asp?s1=20038894&View=f&.

Mainiero, 2011, ISEE Blaster's Handbook, 18th edition, International Society of Explosives Engineers, Cleveland, Ohio.

Mao et al, 2011, Comparison of digital direct readout radiography with conventional film-screen radiography for the recognition of pneumoconiosis in dust-exposed Chinese workers, J Occup Health, 53(5):320-326, abstract in NIOSHTIC-2: www2a.cdc.gov/nioshtic-2/BuildQyr.asp?s1=20039806&View=f&.

MINER Act, 2006, The Mine Improvement and New Emergency Response Act of 2006, www.msha.gov/mineract/mineractsinglesource.asp.

MSHA, 2009, Engineering and Design Manual: Coal Refuse Disposal Facilities, Second Edition, Mine Safety and Health Administration, www.msha.gov/Impoundments/DesignManual/ImpoundmentDesignManual.asp.

MSHA, 2011, Injury Trends in Mining, Mine Safety and Health Administration, www.msha.gov/MSHAINFO/FactSheets/MSHAFCT2.HTM.

NAICS, 2007, North American Industry Classification System: Introduction to NAICS, www.census.gov/eos/www/naics/.

NIOSH, 2011a, Current Intelligence Bulletin 64: Coal Mine Dust Exposures and Associated Health Outcomes - A Review of Information Published Since 1995, National Institute for Occupational Safety and Health, www.cdc.gov/niosh/docs/2011-172/.

NIOSH, 2011b, Current Intelligence Bulletin 62: Asbestos Fibers and Other Elongate Mineral Particles: State of the Science and Roadmap for Research, National Institute for Occupational Safety and Health, www.cdc.gov/niosh/docs/2011-159/.

NORA, 2013, The National Occupational Research Agenda (NORA), www.cdc.gov/niosh/nora.

Sen et al, 2010, Comparing film and digital radiographs for reliability of pneumoconiosis classifications: a modeling approach, Acad Radiol, 17(4):511-519, abstract in NIOSHTIC-2: www2a.cdc.gov/nioshtic-2/BuildQyr.asp?s1=20036687&View=f&.

Suarthana, et al, 2011, 1 Coal workers' pneumoconiosis in the United States: regional differences 40 years after implementation of the 1969 Federal Coal Mine Health and Safety Act, Occup Environ Med, 68(12):908-913, abstract in NIOSHTIC-2: www2a.cdc.gov/nioshtic-2/BuildQyr.asp?s1=20038885&View=f&.

Wang et al, 1999, Clinically important FEV declines among coal miners: an exploration of previously unrecognised determinants, Occup Environ Med, 56(12):837-844, abstract in NIOSHTIC-2: www2a.cdc.gov/nioshtic-2/BuildQyr.asp?s1=20000897&View=f&.

Note: All web pages were accessed on 12 April 2013.

Appendix A: NORA Mining Sector Council Membership

Role	Name	Organization
Program Manager	Jeffery Kohler	NIOSH
Co-Chair	Mike Jenkins	NIOSH
Co-Chair	Lee Saperstein	Missouri University of Science & Technology
Member	Sukumar Bandopadhyay	University of Alaska
Member	Christopher Bise	West Virginia University
Member	Jefferey Burgess	University of Arizona
Member	Mark Ellis	Industrial Minerals Association - North America
Member	Arthur Frank	Drexel University
Member	Samuel Frimpong	Missouri University of Science & Technology
Member	John M. Gallick	Alpha Natural Resources
Member (resigned Nov. 2012)	R. Larry Grayson	Penn State University
Member	John S. Hayden	formerly National Stone, Sand & Gravel Association; now Society for Mining, Metallurgy, and Exploration
Member	William Hustrulid	Consultant
Member	David Kanagy	Society for Mining, Metallurgy, and Exploration
Member	Jessica Kogel	Society for Mining, Metallurgy, and Exploration
Member	George Luxbacher	Society for Mining, Metallurgy, and Exploration
Member (resigned April 2010)	Richard Maxwell	Freeport McMoRan Copper & Gold, Inc.
Member	Hugh Miller	Colorado School of Mines
Member	Tom Novak	University of Kentucky
Member	Susan Patton	Agapito Associates
Member	Mary Poulton	University of Arizona
Member	James Sharpe	Sharpe Media
Member	Joseph Sottile	University of Kentucky
Member	Eileen Storey	NIOSH
Member	Stanley Suboleski	Consultant
Member	Richard Sweigard	University of Kentucky
Member	Jim Weeks	US Department of Labor Mine Safety and Health Administration
Member (deceased)	Linda Zeiler	US Department of Labor Mine Safety and Health Administration
Assistant Sector Coordinator	Randy Reed	NIOSH
Corresponding Member	Dan Alexander	NIOSH
Corresponding	Thomas Barczak	NIOSH

Member		
Corresponding Member	Eric Bauer	NIOSH
Corresponding Member	Mike Brnich	NIOSH
Corresponding Member	Jay Colinet	NIOSH
Corresponding Member	Gerritt Goodman	NIOSH
Corresponding Member	Joel Haight	NIOSH
Corresponding Member	Samuel Harteis	NIOSH
Corresponding Member	Peter Kovalchick	NIOSH
Corresponding Member	Anu Martikainen	NIOSH
Corresponding Member	Susan Moore	NIOSH
Corresponding Member	Robert Peters	NIOSH
Corresponding Member	Floyd Varley	Yukon Zinc Corporation
Corresponding Member	Eric Weiss	NIOSH
Corresponding Member	Jeff Welsh	NIOSH

Appendix B: Differences between MSHRAC and the NORA Mining Sector Council

	MSHRAC	NORA Mining Sector Council
Authority	• Federal Advisory Committee Act – Public Law 92-463, as amended (5 U.S.C. App. 2)	• Internally created by NIOSH – cannot provide advice to NIOSH.
Mission	• Advises the Secretary, HHS; the Director, CDC; and the Director, NIOSH on the conduct of mine health and safety research including offering grants and entering into contracts for such research.	• Develops and maintain a mining-specific research strategic plan for the nation to address the most important mining safety and health problems. • Maximizes impact through partnerships by promoting widespread adoption of improved workplace practices based on research results.
Function/Guiding Principles	• Evaluates the degree to which mine research conforms to standards of scientific excellence appropriate to Federal scientific instruction in accomplishing objectives in mine safety and health. • Evaluates mine research activities, along or in conjunction with other known activities inside and outside of NIOSH • Addresses currently relevant needs in the field of mine safety and health. • Evaluates the results produced by the research in addressing important research questions in mine safety and health, both in terms of applicability and translation of the research findings.	• Seeks broad stakeholder participation in identifying the most important problems, developing the goals, conducting research, and translating/sharing results. • Practices transparency by displaying its inputs and results of its decision-making publicly. • Establishes and periodically updates sector-specific research goals. • Promotes high quality research. • Promotes effective partnerships. • Hosts reviews and tracks progress on goals.
Structure	• Consists of 10 appointed members, including the Chair. • Consists of individuals from the following federal agencies: Assistant Secretary of Labor, Mine Safety and Health Administration; Director, National Science Foundation; and Director of the National Institutes of Health; individuals knowledgeable in mine safety and health research and dissemination of scientific research findings and currently practicing in their profession; individuals representing mining labor organizations; and individuals representing the mining industry.	• Co-chaired by the NIOSH Sector Program Manager or a designee and by a stakeholder representative. • Membership guidelines encourage broad and diverse participation with such categories as trade associations, labor groups, government agencies, and professional organizations. • Consists of researchers, safety and health professionals. • Membership consists of full members and corresponding members.

Appendix C: Major Subcommittees of the NORA Mining Sector Council

In the following table, the major objectives and Sector Council members who are linked to these objectives are identified. In the body of the report on the Research Agenda, sub-objectives are identified and explained. Research recommendations are made for each sub-objective; these are put into a master summary table in the Executive Summary of this report.

Title	Membership
Health	Bise, Burgess, Frank, Miller, Storey, and NIOSH Corr. Mbrs., Colinet, Haight, Kovalchick
Behavioral Research	Hustrulid, Poulton
Disaster Prevention	Patton and Corr. Mbr. Varley
Disaster Response	O'Dell, Suboleski and Corr. Mbrs. Alexander, Bauer, Harteis, Varley, and Weiss
Mine Design and System Improvements for Normal Operations	Bandopadhyay, Sottile, Sweigard and Corr. Mbr. Barczak
Ergonomics (Human Factors Engineering)	Frimpong, Kogel, Sharpe and Corr. Mbr. Haight
Atmospheric Control and Ventilation	Grayson, Luxbacher and Corr. Mbrs. Goodman and Martikainen
Operations and Management	Ellis and Corr. Mbrs. Brnich, Peters, and Welsh