

**Geophysical Technologies for Detecting Underground Coal Mine Voids
An Interactive Forum**

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**Overview of
MINING INDUSTRY OF THE FUTURE
Industrial Technologies Program
Energy Efficiency and Renewable Energy**

DOE Organization

The Department of Energy's single, overarching mission is to enhance national security. Responsibility for accomplishing this mission is shared between four principle program lines:

- National defense
- Energy programs
- Environmental programs
- Science programs

To achieve this, the DOE has many offices. Beneath the Under Secretary of Energy, Science and Environment is the Office of Energy Efficiency and Renewable Energy. It is within this office that the Office of Industrial Technologies, Mining Industry of the Future performs its research.

The mission of the Office of Energy Efficiency and Renewable Energy (EERE) is to strengthen America's energy security, environmental quality, and economic vitality through public-private partnerships that:

- (1) promote energy efficiency and productivity,
- (2) bring clean, reliable, and affordable energy technologies to the marketplace;
and
- (3) make a difference in the everyday lives of Americans by enhancing their energy choices and their quality of life.

EERE Programs

To achieve its mission, EERE has been organized into programs. They are:

- Biomass Program
- Building Technologies Program
- Distributed Energy & Electric Reliability Program
- Federal Energy Management Program
- Freedom CAR & Vehicle Technologies Program
- Geothermal Program
- Hydrogen, Fuel Cells, & Infrastructure Program
- **Industrial Technologies Program**
- Solar Program
- Wind & Hydropower Program
- Westernization & Intergovernmental Program

OIT Organization

The mission of the Office of the Industrial Technologies Program (OIT) is to partner with key, energy-intensive industries to conduct a balanced program of technology investigation, validation, and dissemination that will lead to the increased use of energy efficiency and pollution prevention technologies, as well as renewable energy resources, in the U.S. industrial sector. These efforts assist in reducing the nation's dependence on foreign energy resources, the energy intensity of our economy, and the environmental impact of our industrial processes, while achieving cost-effective product quality enhancements and improving our competitiveness in the global marketplace.

Mining Industry Vision

The mining industry developed the Vision, *The Future Begins with Mining*, in 1998. Goals listed in the Vision are:

- Low Cost and Efficient Production
- Superior Exploration and Resource Characterization
- Safe and Efficient Extraction and Processing
- Responsible Emission and By-Product Management
- Advanced Products
- Positive Partnership with Government
- Improved Communication and Education

Roadmap R&D Areas

From this Vision document, targeted Technology Roadmaps were developed that describe pathways of research to achieve the Vision goals.

The first Roadmap, developed in February 1999, was the *Mining Industry Roadmap for Crosscutting Technologies*. This Roadmap applies to all minerals and all aspects of exploration, mining, and processing technologies.

The second Roadmap, developed in September 2000, was the *Mineral Processing Technology Roadmap*. This Roadmap focuses on methods used to clean, separate, and prepare coal, metals, and non-metallic minerals from mined material into final marketable products.

The third Roadmap, *Exploration and Mining Technologies*, focuses on the method used to locate and mine minerals.

Mining IOF Evolution

Since the beginning of the Mining IOF, the Technology Roadmaps developed by industry have been the basis for R&D development and have led to partnerships between industry, laboratories, universities, and government. The Mining IOF would now like to take those partnerships and transition to high-impact, high-value R&D or an industry “Grand Challenge.” This R&D will be performance-based rather than technology-based. The goal is to develop the next revolutionary concept in mining.

Outlook for the Mining Industry of the Future

Mining IOF organized its portfolio around the energy-intensive nature of the mining process. The energy consumption in the three opportunity areas are:

- Materials Handling, which consumes 42% of the total energy used in mining
- Beneficiation & Processing, which consumes 39% of the total energy used in mining
- Extraction, which consumes 19% of the total energy used in mining.

Current Research

The current portfolio in these opportunity areas consist of:

Extraction: Ten projects

Materials Handling: Six projects

Beneficiation and Processing: Twelve projects

The portfolio is soon to grow from 28 to 33 projects with a total DOE cost-share in excess of \$18 million. These additional projects are Beneficiation and Processing technologies that respond to the Mineral Processing Technologies Roadmap and have a value in excess of \$3 million in DOE cost share. The program has been funded since FY 1999 and has grown to a level of \$5 million/year.

Grand Challenge Focus

To move to performance-based R&D, an energy analysis was performed to highlight the largest opportunities for energy savings in mining. They are:

- Reduce energy consumption in Materials Handling
 - Diesels accounts for 87% of energy used in Materials Handling
- Reduce the energy consumption in Beneficiation & Processing
 - Comminution activities account for 75% of energy used in Beneficiation & Processing
- Reduce the energy consumption and increase recovery efficiencies in Extraction
 - Improvements in Extraction will reduce energy use in Materials Handling & Beneficiation and Processing: Target improve Extraction efficiencies

Current Research Partners

The Mining Industry of the Future has awarded 28 cost shared projects from three rounds of solicitations, ten from round one, 16 from round two, and 2 from round three. Round one and two were based on the *Mining Industry Roadmap for Crosscutting Technologies*. Round Three was based on the *Mineral Processing Technology Roadmap*. These projects are being carried out by 151 project partners in 28 states.

Partners are scattered across the U.S. giving the Mining Industry of the Future a wide range of experts from all areas of mining. The following are several ongoing Mining IOF Projects related to detecting underground mine voids:

Wireless Mine-Wide Telecommunications

Goal: To develop and apply high-temperature superconductors in underground communications to improve safety, productivity, and energy efficiency. The use of superconducting materials in communication equipment will increase the range of through-the-earth communications and make underground wireless networks commonplace in underground mining operations. The high-temperature Superconducting Quantum Interference Devices (SQUID) system can increase underground mining production by allowing better communications, and orientation and position information, which can benefit both an individual miner and a mining machine. This system also improves underground mining safety through wireless communications. The best approach to underground communications systems is to use low-frequency electromagnetic waves that can deeply penetrate into the earth. The existing low-frequency receivers are relatively insensitive to low frequency magnetic fields when configured into small packages and used over a wide bandwidth. Receivers based on high temperature SQUID technology are far more sensitive to low frequency magnetic fields, and can be placed in small packages easily carried by miners moving in an underground environment. The SQUID receivers possess the sensitivity and bandwidth to carry voice and data in a configuration that is easier to install and maintain than hard-wired technology. The first successful field test of a two base station combination was conducted at the Molycorp, Inc. facility in Questa, NM. The standard base station antenna is now an inexpensive copper loop that can be cable-tied to the tunnel mesh. A nearly identical antenna was built to establish two-way base station communications.

Partners:

Hecla Mining Company, Coeur d'Alene, ID
CONSOL Inc., Library, PA
Cyprus Amax Minerals Company, Englewood, CO
ASARCO Incorporated, Sahuarita, AZ
Phelps Dodge Mining Company, Morenci, AZ
Raton Technology Research, Raton, NM
Harris Communications, Rochester, NY
Waste Isolation Pilot Plant, Carlsbad, NM
Colorado School of Mines, Golden, CO
RAG Coal, Baltimore, MD
Stolar Horizon, Tucson, AZ

Wireless Mine-Wide Telecommunications Technology, Transtek, Inc.

Goal: To develop a two-way, real-time, wireless communications system for use in underground mines. This technology will lower the cost of mining by increasing productivity as well as the safety of miners. Project partners will design and test a comprehensive wireless mining communications system that will allow two-way communications among underground personnel and between underground and surface personnel. The wireless system will not require any dedicated cable inside the mine or between the mine interior and surface. This technology will increase system reliability and simplify the installation process making it considerably less disruptive to mining operations. Two methods of signal transmission will be studied. The methods differ in formatting approaches. The studies will center on evaluating the results of these approaches in terms of differences in product cost, clarity of signal, and freedom from interference. The chosen system will be optimized for performance and reliability. In-mine voice capability was developed. The through-the-earth voice technology capability has been expanded. Also, digital data transmission capability has been developed. The team will now develop tracking sensors and beacons and test the entire wireless telecommunications system.

Partners:

University of Pittsburgh, Pittsburgh, PA
National Institute for Occupational Safety and Health, Pittsburgh, PA
CONSOL, Inc., Library, PA
Gateway Commerce Center, Wampum, PA
Victor Products USA, Cranberry Twp, PA

Imaging Ahead of Mining

Goal: To use the Internet, instrumentation advances, and newly developed modeling and analysis software to accurately image the volume of material ahead of mining, thereby improving the quality of mined ore, reducing wear of mining machinery, facilitating mine operations, and reducing costs. RIM is an electromagnetic (EM) system that was developed to detect and map anomalous geologic conditions far in advance of the mining

face. The elements of RIM are deployed on each side of the ore seam of interest that forms a natural waveguide for transmission of electromagnetic waves. Until recent hardware improvements, it was not possible to use a superior imaging algorithm with it. This project will analyze actual RIM data with a sophisticated finite difference imaging scheme and traditional tomographic methods. This new imaging scheme will accept data from RIM to produce an image of the distribution of electrical resistivity. This graphical map can delineate the interface between bounding rock and an ore seam, or show the presence of an anomaly within the seam ahead of the mining face. This project will also examine the possibilities of using the Internet to allow mining engineers to determine the applicability of RIM with the new software for specific geologic situations. By allowing mining operations to see beyond the mining face, this technology will improve mine planning, increase energy efficiency, decrease equipment wear, and produce a better quality product. The electronics and packaging are complete for both the In-Mine and Down-Hole RIM-IV Systems. MSHA certification (for flame-proofing and intrinsic safety) is in process. In-Mine RIM-IV has been tested ten times in an underground environment. Tomography images have been generated for five sites. Latest field tests show RIM IV system capable of 2000 feet range with phase stability greater than three degrees. There are now seven imaging frequencies available. The In-Mine system can be mechanically reconfigured for Down-Hole use with only an antenna and fiber-optic change. RIM In-Mine and Down-Hole versions of RIM IV are being produced in small quantity at Stolar.

Partners:

CONSOL Inc., Library, PA
Kennecott Exploration, Salt Lake City, UT
West Virginia University, Morgantown, WV
Stolar Horizon, Incorporated, Raton, NM

Horizon Sensing™

Goal: To test remote sensing and imaging technology on the cutting edge of mining equipment to make real-time measurements of mining conditions. Researchers hope to develop a cutting-edge sensor that will improve worker safety, by preventing worker exposure to rock outbursts in deep mines and by allowing greater remote control of equipment, while improving the efficiency of mining operations. This project will demonstrate the feasibility and benefits of real-time horizon sensing and bit drag and side force measurements on cutting drums of longwall shearers and continuous mining machines. The sensing technology can also be applied to boring machines, front-end loaders, and drag lines. The application of cutting-edge technology to mining machines will reduce dust exposure to machine operators; enable mining of clean-coal, trona, and potash; minimize waste rock; increase energy-efficient recovery and yield; and enable automation of machines mining metal and nonmetal deposits. The HS physical assemblies are holding up very well to mining condition, impact/abrasion, and use from personnel. Parts have needed to be replaced to date due to normal usage, wear, or misuse. A dual frequency sensor system has been developed to further the sensitivity, resolution, and depth of penetration of the HS. An accelerometer-based circuit has been developed

to control the measurement triggering of the roof and floor. This has provided cleaner measurements and improved signal-to-noise ratios. "Forward-looking" capabilities are being developed that will allow the HS (HS-RADAR) to detect anomalies in the coal seam ahead of mining, such as dikes, faults, and abandoned mine workings. The HS-RADAR prototype is being tested using a salt wall to simulate 25 feet of unmined coal seam. During a recent HS-RADAR demonstration for an audience of MSHA technical representatives: 1) a wall of salt was used to simulate a coal seam for HS-RADAR experiments, 2) Stolar successfully proved HS-RADAR could detect air voids through 23 feet of salt blocks, 3) the salt wall is considered a worse-case condition due to its block-like construction, and 4) the HS-RADAR results were confirmed by MSHA.

Partners:

Colorado School of Mines, Golden, CO
Los Alamos National Laboratory, Los Alamos, NM
Mine Safety and Health Administration, Pittsburgh, PA
CONSOL, Inc., Library, PA
FMC Corporation, Green River, WY
Lee Ranch Coal Co., Grants, NM
RAG American Coal, Plateau Mining Corp., Price, UT

Other Opportunities

Mining Industry of the Future solicitations announcements can be found on the OIT Web site.

- Concept Solicitations
- R&D Solicitations

Other ways to participate in the Mining Industry of the Future are:

- Inventions and Innovation – Provides assistance for establishing technical performance and conducting early development of innovative ideas and inventions. Ideas that have a significant energy-savings impact and future commercial market potential are chosen for financial support through a competitive solicitation process. In addition to financial assistance, this program offers technical guidance and commercialization support to successful applicants.
- BestPractices – Consists of many programs that can help manufacturers of all sizes become more productive through efficient use of motor, steam, compressed air, and combined heat and power systems.
 - Upcoming BestPractices workshops sponsored by NMA: May 15-16 Reno, NV; June 24-25 St. Louis, MO; July 22-23 Pittsburgh, PA; August 18-19 Denver, CO; September 22-23 Charleston, WV; October 20-21 Macon, GA
- SBIR solicitation - Goes out once a year as a DOE-wide solicitation. However, each office (FE, EERE, etc.) submits its own topics, which come

from its programs. These are get added to other office topics and the solicitation is released as a DOE solicitation. SBIR has three phases:

- Phase I is for innovative concepts to see if your idea has merit.
- Phase II is the actual R&D based on a successful Phase I.
- Phase III provides no DOE money but helps you team and commercialize the product.
- The EERE SBIR contact is: Charlie Russomano,
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