Proven Benefits of Target Drilling, Inc.'s In-mine Directional Drilling Technology for Abandoned Mine Verification

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ABSTRACT

Target Drilling, Inc. (Target), based 12 miles south of Pittsburgh, PA, has directionally drilled over 1,200,000 feet of in-mine horizontal borehole for coalbed methane recovery, coalbed exploration, abandoned mine verification, and water drainage since spring 1995, applying its real-time directional drilling techniques using its DDM MECCA (downhole drill monitor utilizing modular electrically connected cable assembly). This includes an in-mine horizontal longhole directionally drilled to 5,045 feet and fifty-nine (59) boreholes directionally drilled to greater than 4,000 feet in length.

The purpose of this presentation is to briefly describe Target's directional drilling procedures applied to Abandoned Mine Verification Boreholes including 1) wellhead control; 2) monitoring changes in directional drilling parameters indicating if a mine void is intercepted; 3) borehole placement accuracy and 4) obtaining borehole roof and floor markers to verify coal seam thickness. Target's presentation will provide actual case study results at several coal mines where Target has directionally drilled Abandoned Mine Verification Boreholes to establish that a safe coal barrier exists relative to future mine development with the borehole serving as a known boundary and where abandoned mine workings were intercepted to accurately establish a safe coal barrier.

Application of True Reflective Tomography and 2-D and 3-D Seismic Tomographic Imaging to Location of Mine Works

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<u>*ABSTRACT*</u>

Geotechnical engineers have struggled for years with the difficult task of characterizing geologic and past mining conditions that affect the design, stability, and safety of both civil and mining constructions/operations. Commonly, underground developments (mines, tunnels, foundations, etc.) are based on surface or underground investigative drilling programs that may not characterize the true character or three-dimensional continuity of the material/strata present, and may also not detect the presence of prior excavations (old mine works) or localized structural discontinuities (faults, shear zones, etc.). Geophysical techniques such as seismic reflection, seismic refraction, and ground penetrating radar have been used with some success to expand the knowledge of subsurface conditions prior to excavation; however, these techniques often interfere with the construction process and are time-intensive in terms of data collection and interpretation.

To improve the quality, continuity, and timeliness of geotechnical data for site characterization, NSA Engineering, Inc., has developed an imaging system known as TRT™ ("True Reflective Tomography"). Whereas past structure mapping applications relied on seismic velocity and/or attenuation tomography within an enclosed seismic source and receiver array, recent developments in TRT™ have expanded the application of this technology considerably. For example, in-seam TRT™ seismic reflection may now be used to image structures and/or old workings from within an active mine (e.g. face areas of mains and panel developments) well ahead of planned developments – potentially eliminating the need to probe-drill on regular intervals.

Seismic tomographic imaging, based on the same principles as a medical CAT (Computer Aided Tomography) scan, has been used for many years in the oil industry for large-scale subsurface stratigraphic characterization, and has been applied to various structure- and stress-related problems in the coal industry.

This presentation demonstrates the application of 2-D and 3-D seismic tomographic imaging to (1) the location of old works in Appalachian room-and-pillar operations, and (2) the identification of anomalous zones ahead of mining/tunneling developments. These applications demonstrate the state-of-the-art in seismic ground imaging using reflective, velocity, and attenuation techniques (and combinations thereof), and further illustrate the flexibility of data acquisition from a variety of mining and tunneling settings. Recent examples are presented from projects in the United States, Europe, and Japan.

Horizontal Drilling for Advance Exploration in Underground Mines

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ABSTRACT

Twenty years ago, CONSOL Energy Incorporated completed the development of a horizontal drilling technology for de-gasification of underground coal mines. The system can drill precisely controlled, horizontal boreholes up to 3000 feet long and stay in the coal seam. Besides de-gasification, these boreholes can be used to de-water the mines or do advance exploration in areas where an active mine is approaching old mine workings. This technology can also be used to measure coal seam thickness and to map a sand channel intrusion in the coal seam. The engineering details of the drilling rig and techniques of advance exploration shall be discussed.

Directional Drilling – It's What's Up Front that Counts"

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ABSTRACT

Longhole directional drilling is a valuable tool available to the underground coal mining industry for the prevention of inundations. This technique is a proven and acceptable alternative by MSHA under CFR 75.388. The roots of this technology were started through methane drainage applications. The reliability and accuracy of directional drilling has been developed and improved over the past twenty years. Longhole directional drilling is commonly used for pre-mining methane drainage, water drainage, and various exploration applications.

REI Drilling, Inc. ("REI"), with over twenty years of experience, has six longhole directional drill units that operate in various coal mines across the United States. A longhole drill unit generally consists of a permissible, high thrust drill and power unit, drill rods, hydraulic driven downhole motor, water pumps, and steering tools. These tools coupled with experienced operators allow the accurate placement of long, horizontal boreholes.

Coal mine operators have used REI services to directionally drill long in-seam boreholes in advance of projected mine workings to delineate the absence of old workings. This presentation will review the tools of our trade, case history applications, and results of the projects.

Surface Geophysical Methods for Detection of Underground Mine Workings

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ABSTRACT

The presentation is titled "Surface Geophysical Methods for Detection of Underground Mine Workings". It will cover the traditional surface geophysical methods including microgravity, seismic, DC resistivity, Electromagnetic (EM) methods, Ground Penetrating Radar (GPR), and
magnetics. Case histories will be presented to demonstrate results of the more useful methods. A similar presentation was made at the Association of State Dam Safety Officials, Tailings 2002 Conference. The authors expect to present a few case histories on seismic methods that were not included in their Tailings 2002 paper.

Horizon Sensing and Radio Imaging Method (RIM™) for Detecting and Imaging Underground Barrier Pillars, Mine Voids, and Water.

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ABSTRACT

Given the inundation of the Quecreek Mine in Pennsylvania, considerable attention is being directed to the question of how new technology can be used to prevent such accidents in the future. Not only is the breach of barrier pillars between old and active works a concern, but given the Martin County flood from the failure of a tailing pond impoundment, underground detection and imaging of geology and structures is a critical need.

This presentation will address two technologies that enable underground detection and imaging to prevent – or act as early warning systems of – pillar and impoundment failures. The first technology, the Radio Imaging Method (RIM™), has been commercially used in the industry since the early 1980s. RIM has been used to survey old mining works to confirm the location of barrier pillars. RIM technology can also be used to detect water seepage beneath dams and tailing pond impoundments. A paper on this subject was presented on September 9th at the annual meeting of the Association of State Dam Safety Officials.

The second technology, Horizon Sensors™ (HS) has become available commercially this year. Mounted on the cutter drum of a continuous miner (CM) the HS can detect the coal seam boundaries of the roof and bottom rocks, shale, clays, etc. The first HS unit in the United States has been in continuous operations on a Joy 12CM at the Monterey Mine #1 in Carlinville, Illinois since February. With minor adjustments, the detection capability of a HS can be re-directed in a forward mode to detect coal thickness ahead of mining. In such a mode, the HS can act as an early warning system for potential breach of a barrier pillar. The detection signal can be used to shut down the CM if a barrier yield thickness is near.

Both Stolar technologies have been developed and enhanced under the DOE-NMA Mine of the Future program. In partnership with DOE-NETL, Stolar has prepared a proposal to demonstrate the use of HS for detecting barrier pillar thickness. Stolar has already demonstrated this capability at its development facility in Raton, NM. The management of Monterey has agreed to accommodate the use of the HS on its Joy CM to facilitate an underground demonstration.

This presentation will address the underlying science of both RIM and HS, and more important, their applications to enable detection and imaging for the purpose of preventing mine and tailing pond floods.

Robotic Mine Mapping and Accident Response

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ABSTRACT

Our coalfields are vulnerable to breaches, inundations and entrapment, since complete, accurate maps do not exist for many mines. Submergence, roof fall, rotted timbers and water seals prevent human access for re-mapping, and they motivate the use of robots. Robots offer unique capability relative to complementary mapping technologies, and future robots will exhibit further technical, safety and cost advantages for mapping abandoned mines. The presentation will describe what mine robots are, how they build maps, how they know where they are and where they are going. A robot map will be compared to a human-surveyed map to illustrate the distinctions of the new technology. The presentation will exhibit live mapping of a mine by a robot to convey the power of the technology in action. We will view a robot from our symposium in Charleston, while it maps a mine from another state. We will share the experience of exploration and mapping to graphically understand the principles and capabilities offered by the technology.

Technical advantages of robotic mine mapping include: (1) Physical presence by a robot inside underground cavities guarantees the existence of void (2) Direct observation of the surface of an internal cavity is superior to complementary approaches that only make inference from external observation (3) Robotics offers survey quality mapping versus approximation of location (4) Robotics models 3-D surfaces like roof, walls and floors versus approximation by a centerline (5) Small robots will be developed to access confined voids undetectable by complementary approaches

Safety considerations for mine mapping robots include: (1) Use of robotic machines precludes people from harm's way (2) Robots can be certified for operating in the circumstances of abandoned mines

Roles of abandoned mine mapping robots, present and future, include: (1) Premapping perimeters adjacent to proposed new mines to audit old maps for fidelity (2) Operating during accident response to search, communicate and deliver (3) Exploring post-breach events to tie all maps of old workings together (4) Exploring from boreholes and breaches to fill mapping gaps, if any (5) Exploring from boreholes and breaches to confirm perimeter as safety assurance for future mining

The technical agenda for robotic mine mapping is: (1) Develop mineworthy mapping robots (2) Create new physical forms of mapping robots like minefish and amphibots (3) Invent robotic mapping sensors specialized for coal mines (4)Create technology for mine robot exploration autonomy (5) Develop methodology for creating complete mine maps from selective access (6) Create interfaces to facilitate ease of use in field operations

Opportunity and charter for the mining community to fulfill robotic mine mapping: (1) Lead the world and support robotic mine mapping (2) Grant variances to enable robotic mapping of abandoned mines, at least for R&D (3) Resolve technical standards for certifying robots and ops in abandoned mines (4) Support research enabling robotic mine mapping operations (5) Support enterprise enabling commercialization and support of robotic mapping services to the mine industry

Current Research in Mining Geophysics at Virginia Tech

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ABSTRACT

The Department of Mining and Minerals Engineering at Virginia Tech is actively involved in the practical application of geophysical methods to solving challenges in mining. Funded research projects focus on developing borehole seismic sensors and on improving the ability to image stress-induced physical property changes around mining.

A project funded by the Department of Energy, Industries of the Future program seeks to improve ground-imaging capabilities. Seismic tomography has been used successfully to monitor and evaluate geologic conditions ahead of a mining face, however a primary limitation to existing technology is the placement of sensors. The goal of this project is to develop an array of intrinsically-safe seismic sensors which are capable of being mounted in either a vertical or horizontal borehole.

The National Science Foundation has provided funding for a project focused on prediction of rock failure through high-resolution tomographic imaging. The specific tasks associated with the research include generating time-lapse three-dimensional tomographic images to observe relevant alterations to the fabric of rock samples loaded to failure, and comparing generated images with numerical modeling results. The images will be obtained for unconfined compression and diametrical tension (Brazilian) tests of both isotropic and anisotropic rock types of four different diameters.

A Protocol for Selecting Appropriate Geophysical Surveying Tools, based on Geotechnical Objective and Site Characteristics

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ABSTRACT

Engineering geophysical tools are generally non-invasive and can provide qualitative/quantitative information about the physical properties of an abandoned/active mine or other geotechnical site. The mining engineer responsible for site characterization should ensure that the geophysical technique(s) employed provide useful and cost-effective information about physical properties of interest at the required levels of spatial resolution and target definition.

As an aid to the mining engineer, we present tabularized information about ten commonly employed geophysical methods and a generalized approach for evaluating their utility as site characterization tools. Our discussions are intended to be informative - not exhaustive. The audience is referred to the selected bibliography for more rigorous treatments of the geophysical techniques. The mining engineer engaged in geophysical survey design is strongly encouraged to work with a knowledgeable geophysicist.

Radio Imaging Method (RIM™) for Detecting and Imaging Underground Barrier Pillars, Mine Voids, and Water

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<u>*ABSTRACT*</u>

Given the inundation of the Quecreek Mine in Pennsylvania, considerable attention is being directed to the question of how new technology can be used to prevent such accidents in the future. Not only is the breach of barrier pillars between old and active works a concern, but given the Martin County flood from the failure of a tailing pond impoundment, underground detection and imaging of geology and structures is a critical need.

This presentation will address the Radio Imaging Method (RIM™), which has been commercial in the industry since the early 1980s. With new innovations in instrumentation and tomography algorithms to increase resolution, RIM has been used to survey old mining works to confirm the location of barrier pillars. RIM technology can also be used to detect water seepage beneath dams and tailing pond impoundments.

A key benefit of RIM is that it can be used from the surface to image coal seams and other geology to identify voids such as old works, and it can detect water and/or air gaps. From the surface, RIM transmitters and receivers are lowered down boreholes. Given the range of the signals, RIM can eliminate the need to drill on close centers when trying to locate old works. The reduction of boreholes is a significant cost savings. Also, RIM can be used in-mine, in horizontal holes, and cross well to detect water filled entries and voids, as well as water and anomalies within the coal seam structure.

RIM is a technology offered by Stolar Horizon, Inc., and it has recently been enhanced under the DOE-NMA Mine of the Future program, in which WVU participated as well as leading mining companies such as Consol and Peabody.

The presentation will address at a high level the underlying science of RIM, and more important, its applications to enable detection and imaging of old works and underground water for the purpose of preventing mine and tailing pond floods.

The National Institute for Occupational Safety and Health (NIOSH) Research Program for Detection of Abandoned Mines and Mine Voids

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ABSTRACT

In 1996 the mining health and safety research mission of the former U. S. Bureau of Mines (USBM) was transferred to the National Institute for Occupational Safety and Health (NIOSH). NIOSH was created by the 1970 Occupational Safety and Health Act to ensure safe and healthful working conditions for the nations workers through research, training, and making recommendations for the prevention of work-related illnesses and injuries. NIOSH conducts the bulk of its mining safety research at its Pittsburgh, PA, and Spokane, WA, research laboratories, which were former USBM research centers. NIOSH through its congressional mandate to conduct mining health and safety research and through its history, including that of the USBM, has done various investigations into technologies that were either aimed at detecting mine voids or could be applied to that goal. A brief review of some of these techniques investigated in the past will be given, including long hole directional drilling, and various radar techniques, such as a frequency domain radar device and more traditional pulse-type ground penetrating radar (GPR). Past and ongoing work utilizing seismic techniques will also be reviewed. Discussed will also be our view of NIOSH's role in and plans for future research to develop technologies that can be applied to the problem of locating abandoned mines or mine voids. NIOSH through its past work in this area; its staff of scientists and engineers; its unique facilities, such as it labs and research mines; and its knowledge of mining, especially relative to this particular issue, is uniquely positioned to conduct or manage research aimed at developing technologies to address the detection of abandoned mines and mine voids.

Using Geographic Information Systems to Map and Model Underground Mines

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ABSTRACT

Geographic Information Systems (GIS) provide mine operators and mining regulators with powerful tools to map, model, analyze, and predict surface and subsurface aspects of modern underground coal mines. GIS also enables mining engineers and regulators to effectively combine and study data from many sources and divergent time periods. Current information, extracted directly from surveying and mine modeling applications, can be quickly combined with scanned or vectorized maps of prior operations to show relationships of abandoned mines to proposed or active mining. The modeling and 3D visualization power of GIS helps to identify potential problems and issues before they become critical.

A study of the Leyden underground coal mine, located northwest of Denver, CO, will be presented. The Leyden model shows how paper mine maps, dating back nearly 80 years, can be combined with modern engineering, topographic, and cultural data. Once registered and analyzed, early mining data builds relationships between early mining and present activities, especially relating to safety and concerns of regional growth.