Figure 1: *Left* - Sandia researcher Matt Higgins conducts a propagation experiment at the Sago. *Right* - Sandian Dawna Charley (left) and a Sago mine worker prepare a vehicle before it enters the mine.

Measurement and Modeling of Electromagnetic Propagation of Lightning Energy into the Sago Mine

Sandia team verifies that lightning could have caused 2006 explosion.

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On January 2, 2006, a methane gas explosion killed 12 miners at the Sago underground coal mine in West Virginia. Lightning was quickly considered a possible cause of the accident. Eyewitness accounts describe strong thunderstorm activity above the mine at the time of the blast. More incriminating were the simultaneous recordings of cloud-to-ground lightning in the vicinity of the surface above the mine, a spike in carbon monoxide inside the mine (indicating an explosion), and seismic activity of the blast. While the circumstantial evidence was strong, a scientific explanation was missing of how lightning could propagate into the sealed area 300 feet underground and 2 miles from the mine entrance.

A Sandia team, working at the mine with the Mine Safety and Health Administration (MSHA), took measurements to characterize electromagnetic propagation through the earth and via metallic penetrations (coal conveyor, rails, and power and communication lines) into the mine (Figures 1). Measurements were made in the frequency range typically seen in natural lightning strokes. Each metallic penetration into the mine was characterized over this frequency range at various points from the mine entrance to the sealed area, 2 miles away. While these penetrations did not breach the sealed area where the blast initiated, they were conduits for electrical energy into the mine.

For measuring propagation of lightning energy from the surface to the mine cavern 300 feet below, the drive signal was applied to a long wire stretched on the surface. Directly below, inside the sealed area, an antenna received the transmitted signals. Electric field and voltage measurements were mapped and compared favorably to analytical models simulating lightning propagation through the earth. They then were combined analytically with mathematical representations of natural lightning strokes to calculate induced voltage on an

abandoned pump cable in the sealed area. The conclusion was that lightning near the surface above the sealed area could have generated sufficiently high voltage on the pump cable to create a spark that initiated the methane explosion.

This pivotal work led MSHA to set in motion changes in mining operations to reduce the probability of such a catastrophic event occurring in the future. Mine safety can be improved with a better understanding of this phenomenon in the variety of scenarios seen in the U.S. mining system.

Sandia National Laboratories

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