Mining coal from underground tunnels has been practiced for more than 100 years. Underground coal mines, by nature, can be dangerous places, and many people have lost their lives over the years. Governments have responded to such fatalities by enacting safety regulations to make the workplace safer. These regulations have driven new operational procedures to monitor the condition of the environment (roof supports, atmospheric gas checks etc.), equipment (periodic equipment inspection etc.) and adoption of new technologies to positively impact the accident rate. This article will review the positive safety impact communications and tracking systems have, and also explore the operational benefits they can bring.

Technology overview
One of the technologies that has improved miner safety, and is required in underground coal mines in some countries, is a communications network installed in the escapeways, which remains operational after a mining incident/accident occurs so that miners underground...
can communicate with others in the mine and with personnel on the surface. A complimentary capability is a tracking network that provides the location of all personnel underground at all times, and provides last known location after the incident has occurred.

The terms ‘wired’ and ‘wireless’ are often used as system descriptors of these networks and do not necessarily mean the same things to everyone. In this article, ‘wired’ means when infrastructure devices communicate with each other over wire (twisted pair, coaxial cable, fibre), and ‘wireless’ means the infrastructure devices use radio frequency (RF) to communicate and do not have a wired connection.

Different technologies have been applied to provide communications and tracking. For communications, wired mine ‘page’ phones were installed in several locations along the escapeway, and allowed a miner to walk to the phone and call the surface (older readers can think of pay phones at phone booths). Then, RF push to talk radios (VHF or UHF), which communicate along a ‘leaky feeder’ coaxial cable, were deployed to provide more continuous communications along the escapeways. Most leaky feeder systems in use are analogue systems, although newer digital versions are now available.

More recently, digital technologies developed for use on the surface were adapted for use underground. The definition of communications has also evolved to include texting, driven by the widespread adoption of cellular/mobile phones. Some of these surface technologies have been directly applied, such as Wi-Fi, while others have been adapted specifically for the difficult underground environment, such as mesh networking.

Tracking capability has also evolved. In the beginning, ‘manual’ tracking was used, whereby a miner called out his location to the surface and the location was entered into a log book. Then, RFID readers were used to electronically detect a person wearing a tracking tag, passing by the reader and sending the information over the wired network to the surface and displaying on a map. This technology is called ‘zonal’ since the tag-bearing miner’s location is only known when within range of the reader. The only knowledge is where the miner has been, not where he is currently. The next technology step has been ‘continuous’ tracking, which operates much like GPS on the surface, such that location information is always available as long as the person is within range of the network. Solutions using Wi-Fi can provide continuous tracking, depending on the system implementation (some actually have used RFID). Mesh networking technologies also provide this continuous tracking capability.

**Safety benefits of communication and tracking**

All communication and tracking technologies enhance safety in mines that use them, both in day to day operations and in post-accident situations. The ability to communicate with a miner underground and know his/her location substantially improves safety. This is fairly obvious. What is somewhat less obvious are the safety benefits of one system/technology vs another.

**Robustness**

The various wired technology systems have a single point of failure where all devices on one side of the break are down until repaired. Fibre repair requires a clean environment and great precision, which often contributes to repair delays due to getting qualified personnel to that area. In the case of leaky feeder coax, even if the cable is not completely damaged, repaired cable is subject to noise and performance degradation.

Systems that are ‘wireless’ are more resilient and less susceptible to failure due to roof falls or impacts with machinery. Today, wireless systems utilising wireless mesh networking technology offer the greatest resiliency for coal mine deployments. That is because mesh technology is ‘self-healing’ and automatically reroutes its signals around blockages or failure points. Figure 1 depicts how wired technologies are impaired by a roof fall or some other incident that damages the wire, while wireless mesh systems are not. Coal mines can take full advantage of the redundant nature of mesh systems when mesh infrastructure devices are installed in more than one entry/tunnel.

**Ease of use**

Voice communication systems are easier and simpler to use than systems that only provide texting. This is certainly true in normal day to day use, but especially beneficial in an emergency situation. In a post-accident, smoke-filled environment, voice communication is the only viable option.

**Case study**

The IWT SENTINEL™ communication and tracking system provides voice communications and tracking in one system.
SENTINEL was installed in a mine to replace a previously installed text and tracking system. Within months of its installation, a miner working underground started having chest pains and was able to call for assistance. Because of having continuous tracking, his exact location was quickly determined and the EMT was able to get to him quickly. The EMT maintained constant voice communication with the surface, providing patient vital signs and condition. When ambulance personnel arrived, they were fully informed and prepared to provide immediate medical treatment.

Coverage
In mines that have multiple, parallel entries, systems that provide voice coverage in entries adjacent to the escapeway entry/tunnel in which the system is installed, further enhance the safety of those miners who work there, since they spend less time without communications capability.

Continuous vs zonal tracking
Knowing where a person actually is, vs knowing he is somewhere between point A and point B, is clearly a benefit. This is called continuous tracking, and systems utilising Wi-Fi or mesh networking technology provide this capability.

Communications and tracking in one system
Having one system that provides both communications and tracking might not immediately seem like a safety advantage. But, when considering learning and staying up to date on the unique aspects of each system, as well as the labour requirements of maintaining two separate systems/networks for often overworked maintenance crews, system performance can degrade and negatively impact overall safety.

Operational benefits
Although the purpose for deployment of communications and tracking systems has been safety-related, their benefits extend to improved production.

Most systems will enhance productivity due to tracking, or communication, or both. But not all systems can deliver increased productivity to the same extent. And the costs to realise these productivity gains can also vary. Let’s examine some examples.

Wired vs wireless systems
This article previously reviewed how wired systems are more susceptible to failure than wireless systems and the impact on safety. There is also a corresponding impact on costs and productivity. The comparative costs – both labour and material – of maintaining and advancing wired vs wireless systems can be substantial.

Case study
The comparative costs for materials and labour for two mines using longwall mining techniques are shown in Figure 2. The wired systems used were leaky feeder for communications and RFID tracking. The wireless system was the IWT wireless mesh system. The results are displayed in percentage but the dollar savings were in the hundreds of thousands.

The productivity impact is more difficult to measure, as it relates to additional hours spent maintaining the wired
system and potential lost production when the system is down.

Communications: voice vs text
Communication systems that support voice yield far greater productivity improvements, simply because talking is much more efficient communication than typing out a text. IWT has deployed its mesh networked, voice-capable communication and tracking systems in more than 90 underground coal mines in the US, many of which only had wired page phone systems previously installed. These customers indicated up to a 20% improvement in productivity after the IWT system was installed.

When comparing production from a mine with a voice system vs text system, the production impacts are still significant.

Case study
When replacing a texting system with a voice communication system, a dramatic production increase can result. Figure 3 shows the quarterly production levels with the texting system (through 2014) with those once the IWT voice system was installed (from 1Q15). Many factors can influence production output of course, but the before/after production data from several mines consistently shows an increase.

When translated into revenue, the impact is very significant. This particular mine showed a dramatic production increase, but even a few percentage point increases for a mine that produces a few million tonnes per year ends up translating into millions of dollars.

Zonal vs continuous tracking
The operational benefits derived from continuous vs zonal tracking systems is not easily quantified. However, customers have stated that the ability to see where resources — both human and material — are located helps them manage their operations more efficiently. Also, the ability to review historical data of where people and assets were at specific times has helped them determine bottlenecks and change processes and procedures to remove them.

Conclusion
Communications and tracking systems have clearly impacted underground coal mining operations with improved safety and enhanced production. Some technologies are inherently more robust and better suited to the harsh realities of underground coal mines than others. All digital systems can be leveraged well beyond providing communications and tracking and support additional capabilities, such as gas monitoring, to reduce the number of independent networks deployed in the mine. With the addition of sensors of various types, these systems can be used to carry other types of data that can further improve productivity.