At Orica, we’re focused on developing long term partnerships which reduce total cost of mining, improve productivity and enhance your licence to operate. We combine the progressive thinking of our Global R&D and Technical networks to find solutions to the challenges you face every day.

Blasting Systems | Ground Support | Mining Chemicals

orica.com
Our range of services, blasting systems, ground support and mining chemicals is uniquely positioned to deliver results in underground mining.

**BLASTING SYSTEMS**

**Services**

Orica's service delivery model ensures your charging productivity is maximised in both development and production and your complex blasting challenges can be overcome to achieve optimal blasting results.

Our team of mining engineers, blasting technicians and product support specialists are enabled by a comprehensive range of design, modelling, measurement and survey tools as well as sophisticated delivery systems.

**Bulk Systems**

Our Bulk Explosives offer the broadest range of energy in the market, with systems ranging from less than half, to almost triple the Relative Bulk Strength of ANFO. Subtek™ Control is a bulk emulsion system designed specifically for underground mining and provides a range of energies in a single face. It is an enabler of smooth wall blasting methods and faster mine development.

**Electronic Blasting Systems**

Our Next Generation of Electronic Blasting Systems harness the latest developments in blasting technology to ensure greater control of energy in the rock mass. i-kon™ II is the benchmark system for use in high value and complex blasts and eDev™ II is designed specifically for underground development.

**Initiating Systems**

Orica manufactures and distributes the widest range of conventional electric and non electric detonators, boosters and detonating cord globally. Our Initiating Systems provide the highest level of safety, reliability and ease of use. They’re backed up by a global network of manufacturing and assembly plants to ensure reliable supply.

**Packaged Explosives**

Our extensive range of Packaged Explosives provides outstanding product performance. With excellent shock and heave energy, Orica’s Packaged Explosives are safe, easy to use and reliable.

**GROUND SUPPORT**

Through an extensive Ground Support offer, Orica works with you to overcome the challenges of mining productivity and safety in a wide range of geological conditions.

We focus on roof and ground support, ventilation control, cavity filling, slope stabilisation and water and gas stopping. Our offer includes a range of services, resin capsules, injection chemicals, bolts, mesh, powders and resin grouts.

**MINING CHEMICALS**

Orica is a leading global provider of sodium cyanide and mining chemicals. We also strive to reduce your onsite costs and increase plant efficiency, while ensuring safe chemical handling to protect your employees, the environment and your reputation.

Dedicated manufacturing facilities, sound contingency planning, 24/7 emergency response, technical advice and mine staff training programs underpin our commitment to safety and efficiency.

For further information visit orica.com/contact and we will connect you with your regional customer solutions specialists.
CASE STUDY
CONTROLLING OVERBREAK IN DEVELOPMENT MINING
MMG LIMITED, GOLDEN GROVE MINE, WESTERN AUSTRALIA

The Golden Grove mine in Western Australia was extending operations beyond 1000 metres below the surface. At these depths increasing alteration and intense foliation had degraded the rock mass quality. Intense fracturing and persistent jointing led to an increasing volume of overbreak in development – in some cases exceeding 30 per cent of the design volume.*

Management recognised that the overbreak was impacting on operating costs, and began working with the mining contractor and Orica to find a solution to the problem.

SITE PROFILE
Golden Grove is a polymetallic mining complex owned by MMG Limited. It comprises the Scuddles and Gossan Hill underground mine and processing operations. The site is in the mid-west of Western Australia, approximately 450 kilometres north-east of Perth and 280 kilometres east of Geraldton.

MMG Golden Grove produces concentrates of zinc, copper and high precious metals (HPM) which are exported to smelters in China, Korea, Japan, India and Thailand via the Port of Geraldton.

The Scuddles underground mine uses the sub-level open stoping method of mining and operates at depths of 1,000 metres below the surface.

TECHNICAL SOLUTIONS
To address the overbreak problem, Orica recommended a demonstration of Subtek™ Control bulk emulsion for development mining. A trial plan including a benchmarking phase to establish current performance was drafted.

Orica and the mining contractor scheduled two headings for conversion to Subtek™ Control while an Orica Technical team were on site to monitor and support the demonstration. A 3D camera system was used to measure the post blast volume of all headings.

THE RESULT
Drive profile data results showed a significant reduction in overbreak enabling the Orica Technical Team to graphically demonstrate the advantage of using Subtek™ Control in the development headings. In some cases overbreak was reduced to just five per cent.

The delivery of Subtek™ Control enabled the following average results over the 10 headings:
• A 50 per cent reduction in average overbreak;
• A 50 per cent reduction in scaling time; and
• Positive feedback about Subtek™ Control from the mining contractor.

KEY OUTCOMES
– REDUCED AREA TO BE MECHANICALLY SCALED, VENTILATED AND MAINTAINED
– REDUCED THE AMOUNT OF BROKEN ROCK TO BE BOGGED AND HAULED
– REDUCED MESHING AND BOLTING TIMES

*Data was sourced during benchmarking phase.
**The image depicted above is for illustration purposes only and is not the Golden Grove mine site.
Sub Level Cave (SLC) Mines have the most intensive blasting process of all the mining methods, as generally, one or two rings are fired at a time at each draw point in order to maximise recovery and reduce dilution. The charging process can be made more efficient by pre charging, which is charging rings well ahead of those to be fired, such that the charging operation is kept away from the choked brow.

**SAFETY ISSUES FOR SOLUTION**

The brow, the edge of the intact rock and the broken rock mass, is the area where many safety hazards are present and is the area where hook-up operations for blasting rings are carried out. The major hazards are:

1. Unstable rill of material moving causing impact and slip trip injury
2. Unstable brow causing rock fall causing impact injuries and damage
3. Wear of the brow causing back break thereby causing limited or no access to the next ring
4. Unstable body of fill causing ejection into the draw point
5. Blast damage cutting off the holes in the next blast ring
6. Rework processes to mitigate safety concerns at blast hook-up time (bunds, shotcrete, and extra ground support) is a cost and reduces draw point availability.

The rill of material at a sub level cave draw point is inherently unstable as it is the flow of material after broken ore has been withdrawn. It can move due to subsidence of compacting material over time or through destabilisation due to external movement. Rills are unstable, which is why most mines ban their use as a work place due to their rough nature and the material can re mobilise at any stage. Where brow break back exists and where a basket does not afford enough work room, workers must work off the rill to recover initiation leads out of the blast hole. Some mines build up the floor of the drive to get workers closer to the collars of the hole and to protect the instability of the rill by buttressing it.

**INTRODUCTION**

Sub Level Cave Mining, by definition, is breaking ore bearing rock through blasting and drawing it out under the waste rock that is caving into the void created. Production blasting in a Sub Level Cave Mine, after initial slot establishment, is carried out in choked conditions, in that there is no open void to blast more than 1 or 2 rings without poor recovery and high dilution. Each ring has to be fired individually in a choked situation across a retreating front across the orebody. Drilling and charging can be done in advance of this retreating front of draw points, keeping personnel and equipment away from the brow and off the rill of broken rock at the draw points. The draw points have hazards such as fall of ground, break back, rills of unstable rock, unexpected rush of material to name a few and so the one operation that has the highest safety risk is in the blast hook up process. This hook-up process has to be carried out above or on a rill of broken material below the draw point brow, an area of high risk in the mine. Removing this process through the development of the wireless system is the game changing technology for SLC. With this system, the hook-up process is taken away from the underground mine and is moved to the office.

**ARTICLE**

**EVOLUTION OF SUB LEVEL CAVING – SAFETY IMPROVEMENT THROUGH TECHNOLOGY**

**WIRELESS ELECTRONIC BLASTING SYSTEM**

It is the brow area that has major hazards that are a safety risk to the operation. However hook-up of the initiation system must presently be carried out in this hazardous area just before firing. This also limits productivity of the draw points to be fired and adjacent draw points. If this hook up process could be eliminated, the risk profile of the SLC operation could be significantly reduced, while increasing the draw point availability and productivity.

A Wireless Electronic Blasting System which receives communications through the ground from a safe location is the answer. All data and power is with the initiator and it only requires the correct special signal to “wake up” and then the correct signal to fire. This system has no lead wires to connect and the sequence is “stored” during the charging of the ring.

This technology has now arrived with Orica having completed 20,000 lab tests, 1000 blast range tests and many full scale blasts in a long process to prove the concept and develop the system. The safety-critical elements of the wireless system have been designed and tested to IEC 61508 (SIL 3) (the highest level that can be practically be achieved for a commercial blasting product) and reviewed by an external authority. A SIL 3 component running continuously should have a safety-critical failure less than 1 in 1000 years.

This article discusses the system details and the impact this system can have on the Sub Level Cave Method that is used in many underground mines throughout the world.
The new Wireless Electronic Blasting System eliminates all these concerns by removing the need to carry out any hook-up of initiation system. The selection of correct data to “load” into the firing system is carried out on the surface with all personnel out of the mine. This elevates the need for best practice data integrity systems to ensure that the correct rings are fired.

The brow of a draw point is an intersection between ground support systems and blasted ground. The draw of material in the extraction process can destabilise rock or ground support mechanisms close to the brow thereby making it more prevalent to unexpected rock falls. Any system or process which removes personnel from this area will reduce the exposure to these falls of ground.

Wear to the brow is common and in some cases, the collars of the next ring are consumed by the retreating brow. In this case if the collars are not able to be accessed, these holes or even the whole ring could be lost. This could mean that there is significant burden left to be blasted on that ring, but as the collar cannot be accessed, the hole or ring has to be abandoned. This causes significant dilution and recovery issues. There may be an instance where the remaining holes or the next ring does not have the energy to recover the extra ground. This can result in bridging which will require extra drilling, even re slotting.

Wireless systems remove this issue. All parts of holes that have a primer in contact with good explosives will be initiated to carry out rock breakage work and stopping isolated live boosters in the muck pile.

There are a number of deep mining SLC mines which have experienced rushes of material out of draw points that have filled the extraction drift by up to 20 m from the brow. These events can bury mining equipment and result in injuries or fatalities. These events are an enormous exposure for personnel. Operations with this exposure have looked at alternative drilling and blasting processes and have installed large bunds to avoid this exposure. The simplest solution is, now, to use the wireless system of initiation along with pre-charging.

SLC mines blast intensively as they blast against a rill of broken material in a choked manner. This causes extra damage back to the next firing ring (slept ring) which is not fired in this blast. This damage can be in the form of hole dislocation and in damage to the initiation systems. With conventional systems it is believed that this one major reason for the misfire rate in present initiation systems. The wireless system will solve the dislocation issues as there will be no wires to be cut. But the biggest exposure to the new system will be dynamic shock and initial trialling of the system in this application will highlight how much of a problem this will be.

The hazards outlined above have caused mines to resort to many controls to mitigate them. This results in extra cost and time to perform them. Bunds, shotcrete, and extra ground support all take time and introduce complexity to the process that reduces draw-point availability and therefore productivity. A solution to this problem is to eliminate the high risk process of “hook up” occurring underground by moving the hook up process to the office with a data integrity system.

**WIRELESS COMMUNICATION THROUGH ROCK (MALLETT, 2015)**

Low frequency electromagnetic waves have been used for communication through liquid and/or solid media for decades. The frequency ranges are variously called Very Low or Ultra Low or Extremely Low Frequency, hence VLF, ULF and ELF. Military navies use ELF for submarine communication. VLF communications are widely used in underground mining for PED (personal emergency device) systems. Such communication is one-way from a large surface transmitter to receivers carried (usually in a belt pack) by each miner underground.

Low frequency communication for mining applications requires a range from the transmitter to the in-hole receivers in the order of hundreds to thousands of meters. The transmitting antenna required to achieve this range is a loop of one or more copper wires of tens to hundreds of square meters in area and carrying several hundred amps of current. There is a trade-off between current and area. The system has to be highly reliable.
Alternating currents generate oscillating fields which can be made to carry data by modulating the frequency or amplitude. Lower frequencies carry less data but are able to penetrate through larger objects. The choice of frequency is thus a trade-off between the desired range and the amount and rate of data transmission to safely initiate a blast. The system described has a frequency of less than 5000 Hz.

Electromagnetic signals generated in this way are transmitted primarily by their magnetic component. As a result, communication in the VLF or ULF range is called magneto-inductive or magneto-resistive. In our magneto-inductive system the receiving antenna is a coil of copper wire with thousands of turns. Such coils can detect tiny changes in their ambient magnetic field and reflect such changes in sophisticated electronic circuitry that amplifies and interprets the incoming signals.

The physical embodiment of these principles is shown in Figure 3 where it can be seen that data originally generated in the controller is conveyed via an oscillating magnetic field to the in-hole receiver.

The critical attribute of the signal detected in the borehole is its signal to noise ratio. Magnetic noise in a mining environment is generated mainly by electric motors and AC power lines. When power lines convey power at 50 or 60 Hz, magnetic fields are created at harmonics of these frequencies. Very sensitive magneto detectors can easily detect such harmonics of 60 Hz (i.e. 120, 180, 240 Hz etc.). The exact communication frequency for blasting must therefore be chosen carefully and controlled precisely to avoid likely noise sources.

**DESIGNS FOR A SAFE SYSTEM (MALLETTE, 2015)**

In a fully wireless blast there is no connection from the in-hole device to the controller. This brings two new and potentially hazardous situations into play. Firstly, the in-hole device of necessity contains its own power source. Secondly, with wired initiation systems, only initiators actually connected to the wire could possibly respond to a fire command. That is not the case here as any wireless initiator that is energized and within range of the transmitter will “hear” the fire command. These new circumstances required many hazard studies and the invention or adoption of new hardware, software and procedures to ensure the safety of the system.

An early decision for the wireless electronic blasting system was to base its safety and reliability on the excellent platform that has been established with electronic detonators. These specific detonators are inherently safe. Inherent safety means that the programming device to establish timing has neither sufficient voltage nor sufficient current to initiate the detonator. Further, this can be tested during manufacture such that any detonator components, especially the fusehead and capacitor that fall outside the inherent safety limits are culled during a simulated test-fire procedure.

Since this detonator has an excellent track record in the field, it was incorporated into the wireless system with only minimal changes. Despite our confidence in being able to design and build safe electronic initiation systems for blasting, we decided this wireless system should also comply with the guidelines of an external standard, IEC61508 was chosen as the standard to meet the rigorous safety requirements needed for the blasting and mining industries. "IEC 61508 is an international standard for electrical, electronic and programmable electronic safety related systems. It sets out the requirements for ensuring that systems are designed, implemented, operated and maintained to provide the required safety integrity level" (SIL). Level 3 is the highest level that can practically be achieved for a commercial blasting product. A SIL 3 component running continuously, for example in a chemical plant, should have a safety-critical failure less than one in 1000 years. The safety-critical elements of the wireless system have been designed and certified to IEC 61508 (SIL3).

The DRX is a sophisticated communications device that also controls the safety-critical generation of the firing voltage and fire command to initiate countdown in the attached detonator. During programming or encoding on the blast pattern, the DRX communicates with the detonator only at programming voltage. Communications between the encoder and DRX include the passing to the DRX of the delay time for its detonator, and its group identity number (GID). This group number allows pre-selected groups of primers to be fired as a subset of all the primers within communication range of the transmitter. As an example (explained in more detail below) pre-loaded rings of holes in a sub-level cave blast could be selectively fired in groups of one or two rings at a time. Ensuring that all selected DRXs, and only those selected, respond at firing time is also a safety-critical function.

After deployment of the wireless primer into the borehole, the primer actively listens to the ambient magnetic field. If the wake-up signal (from the transmitter) is detected...
the DRX enters the active state and listens for further commands. The next command tells the DRX which GIDs have been selected for that firing event. When a DRX receives a code that matches its stored GID it enters the armed state. All other DRXs revert after a timeout to the listening state. Great care has been taken in the system design to ensure that this DRX selection and arming step is reliable. 

During all of these actions the DRX is operating at or below the inherently safe voltage of the detonator. Only at the last moment before sending the fire command to the detonator does each armed DRX generate the firing voltage. Control of this step is safety critical, and failure of any single component is the entire system will not compromise this control. The well-established safety practice of requiring at least two independent faults for failure of a safety-critical function is used within the DRX for control of the detonator firing voltage. 

As was mentioned above, ambient magnetic noise is a concern for reliable magneto-inductive communications. The set of digital commands and data used in this wireless system has been carefully chosen to minimize the chances of any command or GID number being mistaken for any other command or number, even in a noisy environment.

In summary, the safety design is based on:
- thorough hazard studies and the management of each identified hazard,
- use of the detonator with its inherently safe communications mode,
- control of the generation of the firing voltage by the DRX via established dual-fault methodology, and
- careful selection of a command and data set to minimize the chance of misinterpretation. 

As a result, the system was designed and qualified to meet IEC61508 (SIL3) for field trials.

**CONCLUSION**

The Wireless Electronic Blasting System has been designed to be safe, reliable and specifically designed for underground mining. The system is IEC61508 qualified (SIL3 rating) and aimed at six sigma reliability. The system is a revolutionary, game-changing technology.

This system of initiation has no wires and so there is no need for a hook up process in a SLC ring blasting application (or any other) – thereby removing a high safety risk operation from these mines. The initiation system is programmed at charging and with unique codes that limit initiation to that mine only. These initiators are rendered remote firing inert if they are taken offsite and safety systems render them inert if they are not placed in a hole within 30 minutes. 

With no wires to damage, there are less problems that could cause misfires, there are no problems with lack of access to the holes, there is no bogging down time for a hook up stage and there are no safety risks with hook up. Wireless initiation makes most sense to SLC Mines where multiple small blasts can be controlled better with less safety risk and greater productivity. Access to holes is the main reason SLC mines move away from advanced drilling and pre-charging, the wireless system eliminates this access issue enabling advance drilling and charging significantly reducing cost and time in standing up rills, rework and redrilling.

Safety is every company’s first priority and when safety risks can be eliminated with an engineering solution there is a need to test the value of it. Initial trials will test this wireless system in SLC Mines and determine if it can serve the customer need in a most challenging environment. 

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**References**
