

A complete system for surface and underground rail ore transport has been developed by Schalke, Bombardier Transportation and Nordic Minesteel Technologies (NMT) and is used by Codelco and LKAB, with a third major installation soon to start up at Grasberg

Future mining – underground

Paul Moore looks at some of the innovative projects and methods aimed at furthering underground mining efficiency that are being presented at the upcoming MassMin 2016 conference in Sydney, May 9-11, as well as some other new technologies

Future mining underground encompasses everything from haulage to mine planning to networks, and is an area where all the major mining companies and many of the smaller ones are focussing, both to maximise production efficiency and increase safety.

In his keynote at MassMin 2016, Fidel Baez Nunez, Head of Technology and Innovation at Codelco will speak on *Smart Mining Technologies – The Way Forward*. The paper is a good example of how a multi-operation company is approaching technology. Codelco says its innovation strategy “involves transferring and adapting existing technologies and developing new ones to address the challenges confronting each of the company’s eight mining and processing operations,” namely Andina, Chuquicamata, Teniente, Gabriela Mistral, Ministro Hales, Radomiro Tomic, Salvador and Ventanas.

In recent years Codelco has been focusing on developing smart mining technologies for use at every stage of the production process, from extraction at the minesite to the production of cathodes used in a wide variety of electrical and electronic goods and systems.

“These technologies are helping us to improve productivity and operational efficiency and to make significant cost savings. Tele-robotic mining, for example, using remote controlled robotic machinery to extract minerals

is reducing the risks for miners. We are using robots at our Gabriela Mistral mine in Antofagasta to inspect equipment to improve the efficiency of our maintenance services. The haul trucks used there are also completely autonomous. New digital technologies are also allowing us to achieve higher levels of integration and automation of processing operations and to manage them remotely.”

Tongkuangyu phase 2

The Tongkuangyu copper mine is currently the only mine in China employing block caving and a presentation on its progress to date will be given at MassMin 2016. It comprises two large orebodies known as the No 4 orebody and the No 5 orebody. They are approximately 50° in dip angle, 80 to 240 m in width and 800-1,000 m in strike length. The two orebodies are separated by a distance of 110-130 m. Production with block caving originally (Phase 1 project) started at Tongkuangyu from the first undercut at a depth of 200-300 m below the surface and was designated as Lift 810 m in late 1989 and caving has continued to the present. During the last 25 years, Tongkuangyu has mined three lifts – Lift 810 m, 690 m, and 530 m. The previous two lifts utilised slusher processes with an annual designed production rate of 4 Mt. In context, the Lift name represents the elevation of track haul level.

The Tongkuangyu Phase 2 project serves two lifts (Lift 530m and 410m) at an elevation of 690 m and the annual designed production rate is 6 Mt. Since the orebody is approximately 50° in dip angle, it was originally designed that production at Lift 530m would be comprised of one main extraction level and two auxiliary extraction levels in the footwall, with undercutting started from one end of the extraction footprint forward to the another end, which is from the northeast to the southwest.

Production at Lift 530m started in March 2011 and reached 6.39 Mt in 2013 and 6.9 Mt in 2014. Additionally, Tongkuangyu improved its block caving processes and used more modern mining equipment than was used in the previous two lifts. Blastholes for undercutting and drawbell-preparation are now drilled using jumbos. The blasted ore is transferred to the underground crushing station via 10 t electric LHDs and then delivered to surface via a belt conveyor 3,200 m long.

Due to increasing ground pressure, a consequence of increasing mining depth, stress abutment and inadequate support, significant damage occurred at the Tongkuangyu copper mine with the production at Lift 530m. This resulted in significant production delays and rehabilitation costs. A series of improvements have since been implemented including an advanced undercut sequence and increased ground support. All of these improvements have allowed Tongkuangyu to alleviate ground control issues, reduce operating costs and ensure safe production.

The development of caving projects in deeper areas provides a greater challenge in establishing the mine designs that can sustain

the increase of the in-situ stresses in the rock mass, thereby ensuring safety of the mine personnel, and achieving the development and continuity of the project.

Optimised undercuts at El Teniente

Codelco El Teniente has tried and transitioned between different mining methods and undercut geometries, some of the used and tested designs ranging from pre-undercutting with a narrow undercut geometry, and testing a combined crinkle-cut geometry with flat and inclined holes, as well as commonly using post-undercutting with a conventional fan drilling design.

At MassMin 2016, El Teniente will report that it is currently designing an optimised post-undercut conventional design, with an increased distance between the production (PL) and undercut levels (UCL), a higher drawbell, and greater spacing between the drifts and crosscuts, creating an overall larger volume of rock between the PL and the UCL, to support the higher stress environment they will be in.

A second design being developed is a pre-undercut variant using a modified crinkle-cut geometry, with three main levels (Production, Undercut and an undercut validation level named Apex). This method also considers a high drawbell and the same production layout than the first model, aiming to generate the stress support than the previous model.

An optimisation of the initial fragmentation of the rock column is also being designed, in order to reduce the number of possible hang-ups and secondary reduction for the projects.

Rail haulage and GBC

Schalke Eisenhütte und Maschinenfabrik GmbH (SCHALKE), Nordic Minesteel Technologies (NMT) and Bombardier Transportation (BT) have been collaborating on future underground haulage for years and says they can now offer “a complete turnkey system which is unique in the industry.” The consortium states: “We have integrated each of our unique areas of expertise resulting in the most economical rail haulage system in the world encompassing SCHALKE’s mining locomotive technology, NMT’s continuous loading and unloading technology and BT’s INTERFLO 150 signalling and automation technology. We have developed an evaluation tool which considers the main cost drivers of the rail, truck and conveyor haulage systems on the market today. In almost every circumstance, the advantages of our haulage solution are far better than any other haulage system available.”

The operators of several large mines already put their trust into this complete system. Beginning with Codelco using SCHALKE’s

locomotives in conjunction with BT’s automation and signalling system, to LKAB’s Kiruna mine using the complete system and equipment provided by SCHALKE, NMT and BT, soon Freeport’s Grasberg mine will be the latest mining operation “to see the advantages of utilising the complete haulage solution.” The solution and the Grasberg example are the subject of several papers at MassMin 2016.

In detail, The Grasberg Block Cave (GBC) mine is one of the future underground mines of PT Freeport Indonesia (PTFI). Located in the remote highlands of Papua, Indonesia, the GBC mine is scheduled to start production in 2017 reaching its peak production capacity of 160 000 t/d in 2023.

The design entails 28 km of rail and 119 ore chutes which will be brought online over the course of ten years. The train haulage system will be driverless and fully automated. Sequentially, the system includes remote controlled rock breakers at the top of the chutes grizzlies, followed by remote controlled chute loading of the trains, then autonomous train haulage, and autonomous unloading. An overhead catenary system (OCS) will power the locomotives which are additionally equipped with on-board batteries to drive through the loading and unloading sections. Service locomotives with drivers move material-laden freight cars in and out of the service shaft, destined for workshops and the magazine and batch plants. Service locomotives are also used for haulage level maintenance. Highly reliable and redundant control and communications systems are required to manage more than 12 trains in simultaneous operation.

Crushing is accomplished by way of three gyratory crushers each with a capacity of 3,300 t/h. Nine conveyors operating in two parallel systems, each system over 3 km in length, will move the ore from the crushers to the stockpiles. These systems require a network of larger tunnels and mass excavations to accommodate the planned production facilities. A combination of lateral and vertical development methodologies and equipment, including drill jumbos, mechanised raise climbers and specialised ground support equipment, have proven successful in the development of a quality ore handling system.

Gravity caving in Kazakhstan

Located in the northwest of Kazakhstan is a world class podiform chromite deposit. The Eurasian Resources Group (ERG) operates two underground mines in this area, one of which is the “10th Anniversary of Kazakhstan Independence” (DNK) mine. The mine currently applies the gravity caving mining method, producing 1.8 Mt/y ROM utilising a slusher

layout and rail transport to the hoisting shafts. The deeper zones form the largest mineral resources at the DNK mine and are planned to be developed in the next several years. At this depth, the generally poor ground conditions, combined with the high in-situ stress state will potentially lead to extremely challenging mining conditions.

A MassMin 2016 paper will describe the technical study undertaken by SRK to determine the possibility of increasing the maximum production rate from 6 to 7.2 Mt/y and to reduce the time to steady state production.

Based on a newly created 3D model, the inclined caving method was proposed for the largest orebodies. This method, currently not implemented at any operating mine, although planned for two other projects, was deemed very suitable to deal with the weak rock mass characteristics, and the plunging morphology of the mineralisation.

Dassault Systems Geovia’s Footprint Finder software was used to determine the caving zones and production schedules, as the geotechnical data available was limited. The total mine design was completed in Deswik software, and resulting schedules combined in Excel.

Several other suggestions were made to increase the productivity of the mine, such as the application of a conveyor belt system transporting multiple material types, tele-remote technologies, and the application of thin sprayed liners to reduce the swelling of the rock mass.

Cave flow modelling

Once the draw process has begun in a block cave, it is very difficult to identify which regions of the cave have successfully propagated and where the caved material is flowing from. The uncertainty around cave flow increases as the cave matures and is further compounded by poor draw control practices. All of these uncertainties make it difficult to plan effective draw strategies to control dilution and shed the vertical load from the cave column, as flow model predictions tend to gradually diverge from the actual state of the cave. The ultimate consequence of cave flow uncertainty is manifest as poor ore recoveries.

In order to measure the real-time flow of caved material within an active block cave CRC Mining and Elexon have developed a cave flow monitoring system (Cave Tracker), which is being trialled at Argyle Diamond Mine (ADM) in Western Australia and is the subject of a MassMin 2016 paper. The Cave Tracker System at ADM comprises of electronic beacons that have been installed down long HQ diameter holes located above the extraction level. As the

cave propagates and fragments due to draw, the beacons are released into the muckpile and flow along with the caved material down to the drawpoints below. At Argyle, the beacons are configured to emit a signal every three days, and these signals are picked up by detectors installed on the extraction and undercut levels. The signals from the beacons are used to locate their exact position in the caved muckpile, and this information is related directly to the production draw.

By examining the caved material flow rate in different regions of the cave, the cave flow mechanisms can be better defined and draw control can be proactively tailored to manage the flow of cave material in real-time. Thus previously undetectable situations such as excessive rilling, rapid cave propagation, cave stall, air-gaps and dilution entry can be identified early and continuously as the cave progresses. "The draw strategy can thus be amended 'on the fly' and changes in cave flow behaviour managed more effectively. The Cave Tracker System is the tool in the cave management system that finally enables mining engineers to truly manage their caves in real-time for the first time in caving mining history."

Chuqui underground and Resolution

The definition of the ore handling system, and its consequent layout design, is of crucial importance in cave mining projects. It not only represents the main driver in the production capacity and reliability of the mining system, but also a fundamental variable in the footprint's development time and cost.

During the last few decades, LHD tramming distance optimisation, through arrangements that involved the allocation of several ore passes inside the footprint area, has been the most common practice in ore handling system layouts' definition at Codelco's operations. Today, the improvement of existing technology such as higher capacity LHDs and jaw-gyratory crushers, together with intensive preconditioning techniques to improve fragmentation proven at large scale, allows the conceptualisation of simple and highly productive ore handling system layouts for wide caving areas that avoid the complexity and high cost of developing numerous ore passes inside the footprint.

The initial Macro Blocks of the Chuquicamata Underground Mine Project (PMCHS) consider an ore handling system layout in which LHDs dump into ore passes located inside the footprint area, transferring the ore into crusher chambers located below the production level, where ore is crushed and then conveyed to surface.

"Aiming to capture the opportunities in development time and cost reduction, a new ore handling system layout for the PMCHS



experimental Macro Blocks was engineered considering the implementation of improved technologies and techniques in a simpler mining system." The paper is to present the analysis and main results of the new ore handling system layout for the project's experimental Macro Blocks, which eliminates ore passes, from a comparative perspective with the traditional LHD-ore pass layout in terms of production capacity and reliability, and development time and cost.

Resolution Copper Mining (RCM), in Arizona, USA, is a joint venture between Rio Tinto and BHP Billiton. It is one of the largest undeveloped copper porphyry deposits in the world, with an orebody at depths of more than 2,100 m and virgin rock temperatures exceeding 80°C. RCM began a pre-feasibility study in 2007 with a vision to develop a large scale, low operating cost mine. As the study has progressed, techniques for increasing ventilation flow and maintaining working temperature have been considered and are being presented at MassMin 2016. The planned use of hard ice plants and air reconditioning will allow for improvements in production rates without having to increase the required number of shafts. The base production of 120,000 t/d, and a number of other alternative smaller entry level cases are being considered with plans to phase up to that ultimate production rate. The smaller starter cases have ruled out the large scale rail haulage systems in the base case, allowing for truck haulage using road trains to reduce the kW/t required compared to standard mine trucks.

Preconditioning with explosives

Currently, underground mining of deeper massive deposits with lower grades, harder rock conditions in high strength environments, entails

One option for Macro Blocks in the Chuquicamata Underground Mine Project (PMCHS), here showing a development heading, considers a new, simpler ore handling system

difficulties in caving, fragmentation and seismicity of the orebody. In a MassMin 2016 paper by Orica Chile and Codelco, the companies will report that so far, the use of Pre-Conditioning (PC) with Hydraulic Fracturing (HF) has shown positive results in terms of seismic response and caving ability, while preconditioning combined with explosives aims to weaken the rock mass, causing an additional effect on fragmentation.

In particular, mines commonly referred as "Super Caves", operated by caving methods, have the need to integrate mine to plant processes. Then rock fragmentation appears as a key tool. "In fact, it implies making mining and comminution processes more efficient to the plant and for mines mined by caving, justifies the innovation in drilling and blasting techniques to precondition the rock mass. Thus, this paper aims to show the feasibility of numerical blast modeling to weaken the rock mass using explosives, mainly through sensitivity analysis applied to designs to minimise bias and uncertainty in results. It is shown how the presence of structures, their geometry and in situ stresses determine or interfere with the preconditioning method to be used."

From this work, it has been concluded that better knowledge on the application of explosives weakening allows specialists to strengthen numerical models associated with every design and therefore previously validate their applicability, helping to understand complex phenomena such as the propagation of mechanical waves in non-elastic heterogeneous

The five Herrenknecht BBMs are successfully operating in mines in Australia and South America with production rates of up to 20 m per day and up to 3 m per hour

media. In this sense, it is understood that while there are studies showing that the transfer of energy in the rock mass could be even greater in a confined environment, the more competent rock mass and higher in situ stresses interfere mostly on the effectiveness of the explosive technique.

Box hole boring

The Herrenknecht Boxhole Boring Machine (BBM) enables fast and safe construction of vertical and inclined slot holes in hard rock. The design focuses on high productivity, optimum machine mobility and minimum space requirements as well as improved occupational safety through a remote-controlled machine.

The Herrenknecht BBM models that have been introduced to the market are the BBM1100 and the BBM1500. They are capable of drilling diameters of 1.1 and 1.5 m, respectively, slot hole lengths of up to 60 m and an inclination of up to $\pm 30^\circ$ from vertical.

Today, five BBMs are successfully operating in mines in Australia and South America with production rates of up to 20 m per day and up to 3 m per hour. Altogether, more than 200 slot holes with a total length of 4,500 m have been



excavated. Due to industry demand, Herrenknecht told *IM* that it is currently developing more BBM types.

The concept of the Boxhole Boring Machine is based on the proven pipe jacking technology that has been adapted for upward vertical and inclined excavation: from a jacking frame, a boring unit at the head of a pipe string is pressed upwards by hydraulic jacking cylinders. More thrust pipes are successively installed and

pushed forward to increase the length of the drive accordingly.

The thrust pipes transmit the thrust forces of the jacking frame to the boring unit and handle the controlled removal of the excavated material. The thrust pipes were developed by Herrenknecht specifically for BBM jacking and are included in the scope of delivery.

For its relocation, the remote-controlled crawler unit makes the BBM independent from

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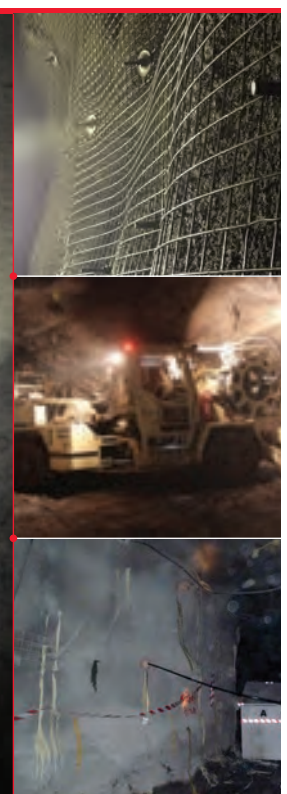
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HERRENKNECHT BBM	BBM1100	BBM1500
Drilling diameter	1,100 mm	1,500 mm
Hole length	30 m	70 m
Angle (to vertical)	±30°	±30°
Max. torque rate	50 kNm	115 kNm
Thrust / pulling force	2,000 kN/200 kN	3,000 kN/1000 kN
Power	160 kW	200 kW
Dimensions, L x W x H	7.5 m x 2.5 m x 3.3 m	7.0m x 2.8 m x 3.5 m

other operations in the mine. It only takes two to three hours to set up or de-rig the BBM. The BBM requires no concrete slabs or special preparatory work before excavation begins.

In view of improving safety regulations in mining worldwide, the Herrenknecht BBM is a future-oriented technology. "During excavation the system is operated by remote control without any personnel in the danger zone. Setup, alignment and de-rigging are also done by remote control or automated by the machine's own hydraulics and using the crawler unit. For more stringent safety regulations Herrenknecht also offers the BBM with a modern safety control and monitoring system which allows more automated functions."

The company concludes: "Together with clients, further developments and adaptations to individual project requirements or country-specific standards are being implemented. Through a worldwide network of subsidiaries, Herrenknecht provides close on-site support if required. A next generation BBM1500 was developed and manufactured by the end of 2015. It incorporates technical improvements to further optimise excavation activities. The drilling capacity was raised to drill holes up to 70 m. Furthermore, the machine's dimensions were reduced to increase its mobility and flexibility." The new BBM1500 will be officially presented to the public in April at Bauma 2016 in Munich.

PYBAR Mining Services has been awarded its first international contract for the provision of rapid underground development and raise boring services at OceanaGold's Didipio high-grade gold-copper mine in the Philippines.

The contract will utilise PYBAR's newly acquired Herrenknecht RBR600-VF raise bore rig, the second largest in Australia, which is currently mobilising and was due on site by end March 2016. PYBAR's rapid development team commenced at the project in late February. Currently an open pit operation, OceanaGold plans to begin developing underground exploration drifts by the second half of 2016 to allow for drilling of the Didipio deposit at depth.

PYBAR will develop three ventilation shafts of 5.5 m in diameter with depths of 135 m, 150 m and 220 m as part of the infrastructure required prior to the commencement of underground production. PYBAR CEO Paul Rouse said: "Our team at Didipio has a strong depth of

international experience gained from a number of overseas raise bore projects. Combined with our track record in delivering safe, rapid underground development, we look forward to accelerating production of the underground expansion." The contract duration is 11 months with the potential

for extension. Didipio is located approximately 270 km north of Manila on the island of Luzon.

Caterpillar to update on Rock Flow

At the last MassMin conference in Sudbury, Caterpillar's vision of a continuous mining concept for block caving operations was presented on the background of global raw material demand and its continuous increase. By analysing the structure of mining processes in block caving, the paper highlighted the main bottlenecks in the process chain and identified conceptual solutions by help of a case study. The main focus was the paradigm shift from discontinuous batch type operation to a



The Rock Flow System is now running at Codelco Andina



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continuous mining process in full production of the blocks.

Today, in 2016, Caterpillar says “the vision is a big step ahead and remote continuous operation became reality.” Caterpillar’s continuous operation system – the Rock Flow System – started operation in Codelco’s Andina mine in Chile in the beginning this year. Based on continuous product developments, this year’s MassMin paper sets the focus to two main aspects of continuous mining. “First field experiences of the Rock Flow System will be shared, highlighting the Andina project course from system installation process to commissioning and successful system start. The second aspect concentrates on the system and mine layout as discussed in the case study scenario from the MassMin conference in 2012. Based on Caterpillar’s continuous product development, the Rock Flow System setup and panel design were modified for a general roadway design and draw point layout. The new design allows an optimised use in block preparation phase (spreading) and full production phase (reaping), operating a fleet of LHDs and Rock Flow Systems. The combined use of the two technologies optimises the mining process in every stage of block life and significantly increases the performance of the continuous block caving operation in the production panel to pave the road for next generation Super Caves.”

Boart Longyear DCi allows upgrading to automation

Drilling contractors looking to gain the advantages of automation in underground drilling don’t necessarily need to wait until they can justify investing in a new drilling rig. They may be able to upgrade their current rigs for only a modest capital investment.

Boart Longyear’s says one solution is its Drill

Control Interface (DCi), a fully electronic interface that allows one operator to control both the rig and the rod handler while providing real-time feedback on drilling conditions.

The DCi comes as an optional feature on new rigs in Boart Longyear’s LM™ series. For many contractors, however, an advantage is the fact that the DCi can be retrofitted to LM™55, LM™75, LM™90 and LM™110 rigs already in their fleet.

LM rigs were introduced by Boart Longyear more than 30 years ago, and the company says they are “known throughout the industry for their reliability and performance. With the additional benefits the DCi brings, they are even more versatile than ever. The DCi helps increase efficiency, productivity and safety by moving the driller away from moving parts and hydraulic hoses and through its range of automated features, including unattended drilling and semiautomated rod feed and pull functions.” With the DCi facilitating unattended drilling, the rigs can complete a 3 m rod run while drillers complete a shift change, rest or catch up on other tasks. In one field test, that advantage contributed to a 19% increase in six-month average metres drilled and a monthly productivity increase of 13.5%.

The DCi also features one-touch rod feed and pull functionality, allowing the operator to efficiently trip rods. A wireline drum counter allows semiautomatic descent and retrieval of the wireline.

The rigs also offer a rod breakout device to further mechanise the drill, negating the need to manually break rod joints by hand. With drill components sized for moving in tight spaces, the mix-and-match philosophy of the LM rigs allows users to change power packs, feed frames, rotation units, water pumps and wireline hoists to suit different applications without having several complete drills in their fleet.

“Moreover, the DCi provides real-time key performance data, which is recorded, stored and easily downloaded onto a USB stick for quick analysis. This current information allows a driller to make adjustments to the drill rig, increasing productivity on the go. Rotation unit sensors, for example, measure RPM and detect the location of the drill rod within the rotation unit – providing critical information that previously had to be determined visually or by manual means. The water pump sensors, wireline counters and other hydraulic pressure sensors, meanwhile, collect and convert data into a digital readout of depth, water pump flow, penetration rate and weight on bit, again facilitating information that once had to be interpreted through hydraulic pressures gauges and other indirect methods.”

The DCi also provides significant instrumentation data, allowing a system diagnostic to be run to determine rig and operator performance, and provide early detection of operational errors and faults and even equipment failure.

RCT offers independent guidance

As demand for technology increases, RCT says it is responding to the growing interest in mining automation, and releasing the latest Automation solution - the ControlMaster® Independent Guidance (Point-2-Point) system.

“The ControlMaster Independent Guidance is the ultimate underground automation mining solution in the market today. The only input required from the operator is the press of a button to activate the system. The operator can then leave the machine to navigate by itself to the destination. The ease of use is apparent; steering, braking, and speed are automatically controlled by the system, together with laser technology which is utilised to keep the machine on the centre path of the drive avoiding walls and other major obstacles.”

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The RCT ControlMaster® Independent Guidance is described as the ultimate underground automation mining solution in the market today. The only input required from the operator is the press of a button to activate the system

technology takes the stress out of operating machines on narrow and difficult to navigate underground drives, resulting in less fatigue, less machine downtime, and significant gains in productivity.

RCT says that the ControlMaster Independent Guidance improves the bottom line of underground production with greater speeds, consistent high production and less damage ensuring KPI targets are met every time. It can be installed on all types of underground loaders and trucks.

“RCT’s proven global experience in Automation and Control paved the way for the development of this next generation, state-of-the-art system. We aim to set benchmarks for productivity and safety, and this new Independent Guidance system will reflect that,” said Dave Holman, ControlMaster Product Manager. Independent Guidance has been deployed on several mine sites for trials, and has now become a permanent solution for these operations, after evident gains in productivity.

Underground networks in Brazil

New wireless network technologies are helping to facilitate the challenging venture of underground mining by opening up communications in places that until recently were dead zones. When an underground gold mining site in central Brazil was struggling to successfully deploy a wireless network, it asked a partner to conduct a site engineering study to help create a future plan for an end-to-end wireless communications network throughout the mine.

The study’s goal was to find an end-to-end wireless communications network that supplied reliable, high-throughput application connectivity throughout the mine. The network would need to have the scalability to add future applications such as autonomous mining, as well as the connectivity to support dispatch and onboard machine health systems, access to business systems, asset tracking, wireless and wired VoIP systems and, where appropriate, IP cameras.

The mining company and its partner in the study, 3D-P, examined several possible wireless solutions and narrowed the list to two options: a Kinetic Mesh network and an 802.11n outdoor meshing wireless solution.

The mine comprises 160 km of underground tunnels. Multiple levels are connected by tight spiraling ramps, limiting the distance wireless communications can travel. At each level, an Ethernet switch is fed by fibre from one of the vertical shafts. Systems on each mine level are able to connect to the core network through these switches, but not wirelessly.

Two-way voice radio systems provide communications across the majority of the site. However, there is no way to direct communications out of the tunnels.

While connectivity and throughput demands are high in the active stope area, no wired infrastructure exists there. Throughout the various mine levels, there are limited, if any, power sources, as well as a lack of Ethernet except in the shaft.

After running four tests on the two options, 3D-P recommended Rajant Corporation’s Kinetic Mesh network. 3D-P’s design involved placing multiple

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nodes at each level, connecting them to the existing Ethernet switch, and allowing them to mesh between each other on each level. At each spiralling ramp, coaxial radiating cable would connect radios at the top and bottom of the ramp, establishing a single mesh network between the two levels of the mine, with the added benefit that clients on the ramp would maintain 100% coverage.

The radios on each level would allow several layers of redundancy between all nodes. Should one node fail, the mesh can bypass that unit and establish a connection with the next radio along the tunnel. The second level of redundancy would be the connection between the levels through the spiralling ramp, allowing traffic access to the level through this second path.

The multi-radio meshing functionality of the Kinetic Mesh, along with the network's own software algorithm, would prevent throughput loss across multiple hops of a mesh, with testing out to 10 hops having been conducted without loss of throughput. This would allow both the high redundancy and high throughput capability the mine requires for its communications.

Heavy duty interfaces

The interface between operator and advanced machine is a key part of any future mining system. maximatecc specialises in operator-machine interface solutions for critical environments and has supplied solutions for Sandvik, Atlas Copco and other key underground OEMs. The company recently launched CCpilot XM2, a display computer offering state-of-the-art computing performance for severe duty applications. In addition to display computers and interfaces, maximatecc provides underground mining OEMs with industrial I/O controllers, powerful main controllers and cable harnesses. With these components, OEMs can design modular systems, easily configured for the



maximatecc specialises in operator-machine interface solutions for critical environments, such as underground mining operations and works with key OEMs and system suppliers

automation needs of different equipment types.

In response to the demand for more advanced automation solutions, maximatecc first launched the CCpilot XM display computer platform back in 2011. It has since been adopted in several heavy mining applications. Recently the company launched CCpilot XM2 – an upgrade of the platform offering considerably higher computing power and graphics performance.

With an Intel® Atom E3826, dual core 1.46 GHz main CPU, the XM2 “has greatly improved computing power compared to its predecessor” – and according to the company, in many benchmark tests it has proven to be 2-3 times faster. Graphics performance has been radically improved through the Intel HD Graphics Gen 7 Graphics Processing Unit with native support in Linux, supporting hardware accelerated rendering of 2D, 3D vector graphics.

This computing performance together with the LinX Software Suite, an open software applications platform based on Qt, makes it possible to create advanced user interface systems and premium graphics with limited software engineering effort. The product is supplied either with a Win7 or Linux operating

system as standard but can also run Android.

Through an industrial grade CPU, CCpilot XM2 has a temperature range of -25 to +70°C and users can run at full CPU load over the entire range. Many on-board PCs and rugged tablets in the market are based on ATOM dual cores, such as the D2550, but are not industrial grade.

Compared to its predecessor it has also minor improvements, like CFAST storage for faster and safer writing to hard drive. The sturdy enclosure as well as connectors and external interfaces are kept identical to the old CCpilot XM, enabling easy upgrade from the predecessor. “CCpilot XM is supplied to leading equipment OEMs and system suppliers, serving in mission critical applications in severe environments.” This calls for the highest quality level and the company says it has achieved a less than 300 ppm fault ratio.

In conclusion, “CCpilot XM2 is an on-board PC that delivers dependable and state-of-the-art performance in demanding applications, offering OEMs and System Suppliers a resourceful platform for advanced automations systems in the rough.”

Hard-Line Teleop evolves further

Hard-Line is a global leader in design, manufacturing, and installation of radio remotes and tele-remote control systems for heavy mining machinery. The company describes itself as a technology company that is diverse and flexible; with systems customised to suit any customer needs. “Through these creative advancements in technology, Hard-Line is able to raise efficiency, enhance safety, and increase the profits of mines all over the world.”

Hard-Line's core product is Teleop, a tele-operational control system which allows the operation of heavy machinery from a distant location, such as on surface. Teleop provides a safer and more productive environment for the operator. “The system allows for continued

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Teleop AutoX will allow for an operator to run multiple machines automatically that can be programmed for multiple destinations

operation during shift changes and more efficient allocation of modified duty work force, resulting in increased productivity. Teleop can be installed and customised for any machine, any make, any model, any year, and anywhere. Teleop can be used on a variety of heavy machinery – LHDs, rockbreakers, excavators, dozers, and drills are just a few examples of the unlimited possible applications.” It works through connecting to the existing mine network or through the Hard-Line stand-alone Wi-Fi system which can be expanded as mining progresses, and has the capability of interconnecting mine-wide for surface control. “The benefits of Teleop are immediately reaped through increased productivity and reduced costs.”

Hard-Line told *IM* it has been working to further its Teleop control system’s autonomous capabilities. Hard-Line says it is in the testing phase for its latest product, Teleop Auto. Teleop Auto allows one operator to run a machine automatically and can be programmed for multiple destinations. This upgrade will allow the operator to manually scoop a full load, then through automated steering, speed, and braking functions, the machine will automatically drive to the designated dumping location, dump the load, and return. Teleop Auto is an add-on to Teleop, it can be configured to any LHD or truck, and any Hard-Line Teleop LHD or truck can be upgraded to Teleop Auto upon release.

“Another advancement to the Teleop control system is Teleop AutoX. Teleop AutoX will allow for an operator to run multiple machines automatically that can be programmed for multiple destinations. AutoX will allow for an even greater increase in productivity as the operator will be able to continuously move ore. The operator is able to obtain a full load and then select for the machine to automatically haul it to the sensor specified location and return to the stope. While a machine is automatically driving to dump and return, the operator can begin the process again on another machine. Teleop Auto and AutoX minimises equipment damage, increases vehicle speeds, reduces operator errors, all while increasing productivity.” AutoX is in the design phase and will be available for upgrade on any Teleop or Teleop Auto system, and can be configured to any LHD or truck upon release. All of these systems “allow for the continued movement of ore during shift changes and the more efficient allocation of modified duty work force. Hours of lost operation time can be saved every day.”

Underground proximity detection

The Matrix IntelliZone® proximity detection system from Indiana, US-based Matrix allows users to create customised Caution, Shutdown and Operator Zones around mobile equipment. IntelliZone technology detects workers in low visibility or obscured line-of-sight locations while allowing the operator to work in a safe location. “Matrix IntelliZone is durable, simple to operate and easy to maintain.” Personal locators worn by support workers are compact and cell-phone sized, lightweight, robust, simple to use and easy to maintain. The IntelliZone Locator uses audible and visual alerts to warn

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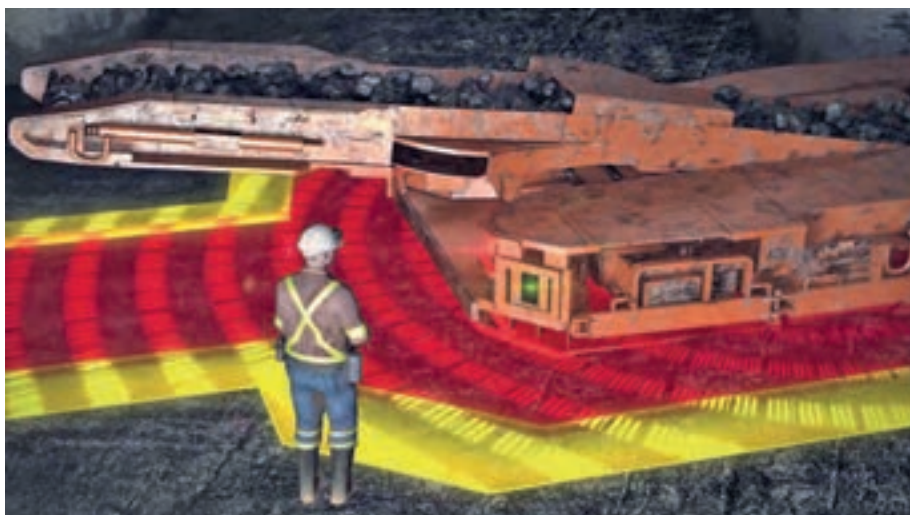


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personnel of potential danger and is powered by a rechargeable battery. All IntelliZone Locators for underground coal mines are Intrinsically Safe (IS).

The Matrix IntelliZone® proximity detection system helps train personnel to stay clear of danger zones present around mobile equipment. The system is designed for use on all brands of continuous miners, shuttle cars and other mobile underground equipment. It is MSHA approved and has been proven in US coal mines but is also applicable in hard rock mines. First introduced in 2009, there are more than 350 Matrix proximity detection systems operating in US operations, mainly with CM and shuttle car operations.

Dynamic SharpZone™ technology in the Matrix IntelliZone system minimises false alarms and allows long-range, through-curtain detection

The systems are described as robust and compact locators offering accurate worker location and dynamic zones. Dynamic SharpZone™ technology minimises false alarms and allows long-range, through-curtain detection. The Operator Zone allows continuous miner operators, for example, to work in a safe location without triggering alert zones. Non-bubble zones allow precise location of support workers. Machine-integrated “drivers” are compact and

robust for maximum uptime, and manufactured for harsh operating conditions. All Matrix IntelliZone systems are backed by Matrix’s field service technicians and distribution network.

Mobile haulage awareness zones vary based on speed and direction of travel. Higher speed means longer forward zones to allow for higher stoppage time. Mobile haulage awareness zones can “see” through curtains to warn of worker collisions. Zones around the CM tail automatically shrink in cutting mode and expand while tramping. In addition, unlike other proximity products, Matrix IntelliZone can create straight-line and angled zones which automatically change depending on the operational status of the equipment. As shuttle car speed increases, the zones increase in length to accommodate the longer required stopping time. The zones can “see” through barrier curtains which helps protect workers.

In the future, the IntelliZone Locator will be an optional accessory for the MX3 voice handset. IntelliZone systems will be able to send safety data through the MX3 network to the surface.

Another Matrix product is the MineOwl Camera System which “delivers superior in-cab video quality in low-light environments. By providing equipment operators with better vision, MineOwl could make the difference between a serious accident and a near miss. MineOwl delivers the best combination of durability, high-resolution and low-light performance available in an XP camera system.” **IM**

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