The domino effect

Orica's OrePro 3D is used by geologists, post-blast, to determine the location of the ore and define waste boundaries

Automation, digitalisation, variable energy distribution, mechanisation; all these elements and more are making a difference for drill and blast engineers tasked with improving mining performance, Dan Gleeson reports

There is an exchange going on between the mining and mineral processing segments of the industry as their customers push for greater efficiencies in the face of falling ore grades, the need to decarbonise and heightened safety concerns.

Mineral processing companies, cognisant of the optimal conditions for the use of their equipment, are tracking drill and blast outcomes and, in some instances, advising on potential changes upstream of their part of the flowsheet to improve downstream recoveries. Those vendors involved in the drill and blast process are looking downstream, considering mineral processing when calculating drill patterns; emulsion/ANFO loading; initiation, detonation and timing practices; and more.

For the two segments to effectively meet in the middle, it will require an agnostic approach to hardware, software and networks where data can freely be transferred and analysed across platforms, regardless of the origin.

For their part, many in the drill and blast space are receptive to this concept.

The 'Connected Bench'

In its pursuit to improve mining outcomes for its customers, **Dyno Nobel** is open to collaborating with others in its field to create what it calls the 'Connected Bench'.

Leveraging its proprietary Nobel Fire digital platform, the company has linked together its unique design capabilities, bulk explosives products, explosives delivery and initiation systems to enable "end-to-end automation of the 'Connected Bench'".

Robert Rounsley, Chief Technology Officer of Incitec Pivot, Dyno Nobel's parent company, provided ***IM*** with a bit of background here.

"The whole purpose of the 'Connected Bench' is to get much better blasting design and much better execution of that design to create reproducible blasted ground outcomes that give you better downstream mining efficiencies," he said.

This concept is not new – the company outlined it several years ago – but Dyno Nobel has recently added new 'building blocks' on the way to making it a reality.

Wireless initiation and detonation will likely play a role here; an area the company has continued to make progress in.

Dyno Nobel's DigiShot® Plus.4G, equipped with Commander system, initiates blasting through a "wireless-through-the-air" connectivity function that results in fast deployment and programming, eliminating costly blast delays associated with misfires, the company says.

This initiating system comes with high-speed, two-way communication that offers a large data transfer to the DigiShot Plus.4G units, according to Rounsley.

"That is absolutely critical for allowing customers to know if the unit is 'good' or if they potentially have a misfire on their hands, before the blast has occurred, avoiding the potential disruption to the mining operation that comes with no prior knowledge of misfires," he said.

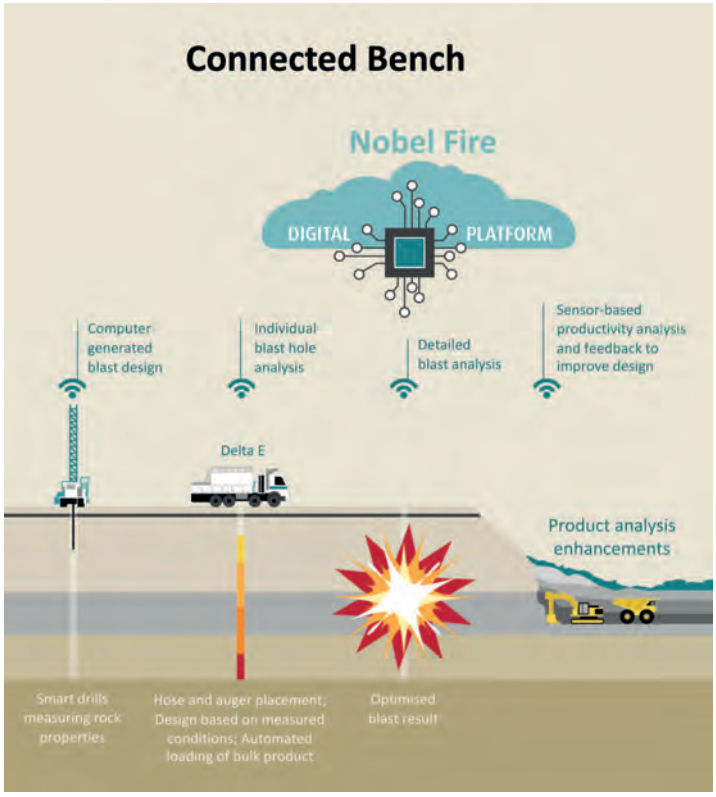
Then there is the company's CyberDet I® "wireless-through-the-ground" detonation solution.

Tailored to the underground mining setting, CyberDet I sees a signal transmitted to a unit while the detonator is in the ground, according to Rounsley.

It has no tether, harness or wire connection to the unit, he said.

The first ever underground wireless detonator blast in Western Australia was recently conducted using this system – at Westgold's Big Bell mine – with 34 CyberDet I detonators fired to produce "outstanding results", including a well fragmented muckpile, Incitec Pivot reported.

"It's a wonderful technology, but it has a fairly



The whole purpose of the 'Connected Bench' is to get much better blasting design and much better execution of that design to create reproducible blasted ground outcomes that give you better downstream mining efficiencies, Incitec Pivot's Robert Rounsley says

niche application in that it is focused on underground mining and, within that, particular types of underground mining," Rounsley said.

The two most notable benefits are the ability to allow operators to work in a safer environment during the blast loading process and the capacity to conduct shorter blast cycles, providing the potential to increase the number of tonnes mined. The latter benefit can provide significant value for customers, according to Dyno Nobel's case studies, with millions of dollars in productivity improvements observed.

In addition to the trial at Big Bell, the CyberDet I system has also been tested out in South Africa and Dyno Nobel has trial plans underway in North America.

"The drawback with that technology is that it only offers one-way communication," Rounsley said. "You have got to have a big energy source to transmit your signal and you cannot have that on a consumable unit that sits inside your blast hole. You can put one on your control equipment to send a message, but you cannot get one back."

This has led the company to develop a third wireless technology, this time for the open-pit mining space.

CyberDet II® is what the company describes as "wireless-from-the-collar" technology that provides both high speed data transfer and no surface "tie-in that you have to deal with other than an antenna that comes out of the top of a blast hole", Rounsley explained.

"We see that as a solution for automation in open-pit mining."

With an operational CyberDet II prototype already developed, the company hopes to be in the field testing the product towards the end of 2021 before a larger-scale rollout in 2022, Rounsley said.

All these wireless options are underwritten by the DigiShot Plus.4G detonator, which the company sees as being the "digital detonator standard".

In the underground setting using a centralised control system, BlastWeb, miners can choose between wireless electronics, wired, electronics, traditional non-electric systems or hybrid blasting techniques without any additional infrastructure.

"Whether I am using DigiShot Plus.4G, EZShot®, a standard LP (long period) Nonel® unit, CyberDet I, CyberDet II, or a DriftShot® unit, I can run it all from that one control system," Rounsley said.

This allows customers to choose what is the most economic or best matched – technically – blasting option for them in the specific application they are confronted with.

Dyno Nobel's offering flexibility goes beyond this, with a range of blasting consumables that can help miners achieve their production, sustainability and safety aims.

Use of its DIFFERENTIAL ENERGY® (ΔE) technology, a proprietary method for controlling the explosive energy profile in blast holes, in conjunction with the DigiShot Plus.4G detonators, is providing miners with enormous flexibility in blasting design, according to Rounsley.

The company has seen some notable improvements in fragmentation and productivity in Chile, for instance, where hard-rock miners are applying the two technologies.

"We gave blast designers a tool in terms of DIFFERENTIAL ENERGY and 4G detonation that allows them to change their design to solve particular problems," Rounsley said.

An example of this could be the need for a tighter fragmentation specification where the flexibility of the ΔE chemically-gassed emulsion product could be combined with the timing, accuracy and design flexibility the DigiShot Plus.4G detonator offers.

"You can use our ΔE bulk product to place energy very accurately in the blast hole, putting high energy explosives only where needed (eg in hard-rock bands) and lower energy explosives elsewhere (in softer-rock areas)," Rounsley said. "Velocity of detonation can also be dialled up to match rock types and strata, so there is an outcome that is much tighter in terms of the overall fragmentation."

DIFFERENTIAL ENERGY emulsion also comes with a lower average density than the industry standard emulsion, meaning less product can be

The first ever underground wireless detonator blast in Western Australia was recently conducted using Dyno Nobel's CyberDet I

applied in the blast holes to get the same result.

"If you can control your fragmentation to hit a target specification with much more accuracy, then the energy used in the mill is going to be less, creating efficiencies and reducing greenhouse gas emissions," Rounsley added.

The loading of blast holes with DIFFERENTIAL ENERGY emulsion and the ΔE jumbo truck was carried out manually via a control system that loads up a pre-planned blasting profile, but Dyno Nobel has released a second-generation system of semi-autonomous loading, and Rounsley sees a future where there is fully-autonomous loading that also connects back to the aforementioned Nobel Fire digital platform.

"With the generation one ΔE trucks, the loading of that tailor-made energy profile was carried out manually via the control system," Rounsley said. "Yet, there is a step after that saying: 'why do I want that particular blasting profile and what design is actually suitable here?'

"What you need to answer those questions is data from the ground. That could be measure-while-drilling data, the block model in a digital form, the geologists' input, etc."

ΔE generation two allows customers to use such data to calculate what the most advantageous energy profile will be for the ground to be blasted and the outcome required. This information is then directed to the truck's on-board control system to load the hole with that specific profile.

"This isn't automated driving of the trucks, it is automated pumping to a specific design," Rounsley stated. "It's doing a number of things – ingesting data, using that data to create a blast design and then directing the truck to load the hole to that design. Instead of only relying on the site's drill and blast experience to come up with the design, you are getting the benefit of all the skilled DynoConsult people that have put all of their intellectual knowledge into that ΔE algorithm to create the outcome you are looking for."

This solution is already available commercially, according to Rounsley.

The third generation ΔE platform is something to look forward to.

This is where the truck delivering the ΔE emulsion will come with automation capabilities, picking the required profile, lining up with the correct hole destination and loading the consumable in a "local remote method, a tele-op remote method, semi-autonomous or a fully-autonomous fashion", Rounsley said. He clarified on the latter: "That doesn't mean it will drive around the mine by itself with no-one there. Instead, it may be positioned to drive up and down the rows to load those holes by itself."

This generation of ΔE trucks, which will be able to "sense and identify humans, boosters and other products", is currently in the prototype phase, with two models developed and a third moving into an open-pit mining environment later this year.

This is where it comes back to the 'Connected Bench' concept and the Nobel Fire platform that started the discussion, where ingesting the correct data on the bench, carrying out the blast – through wireless or wired means – and reconciling that data, post-blast, can improve overall blasting outcomes.

"If you have that pathway from the truck with the data back to the cloud-based digital system, you also have the ability to send data the other way – with instructions going back to the truck," Rounsley said. "This brings you into the realm of ΔE Gen 3. The design information directed by modelling software like FDM (Fracture Density Model, Dyno Nobel's fragmentation simulation software) or GEM (Geologic Element Motion, Dyno's movement analysis software) will be sent to the truck which will run away and deliver it to plan, without direct human control.

"Then, of course, once the blast has concluded, you can measure the outcomes using whatever third-party system you like, we create the required APIs to bring it back into Nobel Fire and this information is then used to drive better decisions in the next blast design.

"It all comes back to the 'Connected Bench' concept."

Open to integration

Integrating and embedding its products and solutions into the wider mining process is also a key aim for **Orica**.

Through organic and acquisitive growth, the Australia-based company has become way more than a supplier of explosives and blasting equipment. Its solutions cover everything from bulk systems, packaged explosives, initiating systems and fragmentation tracking, to slope stability monitoring (with GroundProbe), ground support (through Minova) and gold leaching (through LeachIT™).

This wide-ranging expertise – underpinned by digital solutions that ensure companies can track all-important productivity, profitability and sustainability metrics – allows the company to look beyond blasting.

Even with such an expansive offering, Raj Mathiravedu, Vice President of Digital Solutions, acknowledges that the company cannot – and should not – take on the burden of improving mine site performance alone.

Instead, the company should facilitate such improvements through connecting its broad and connected offering with other systems present at mine sites.

"Our digital strategy is maturing beyond the range of technologies we offer as we continue to explore continuous integration of our individual digital blasting technologies and the systems at our customers' operating sites," Mathiravedu told ***IM***. "The multiple integration points for our suite of digital solutions ensures flexibility for our customers in leveraging the best combination of solutions that suit their operational needs."

Improved connectivity is proving key to enabling automation at multiple points and scales of a company's process, all aimed at supporting both upstream and downstream efficiency and productivity gains in mining, he said.

Orica's FRAGTrack™ is an example of this at the "micro level", Mathiravedu explained, with the fragmentation measurement tool using advanced machine vision technologies that interface with a site's crusher control to enable automated post-blast measurement and analysis.

Usually delivered as part of Orica's BlastIQ™ Digital Blast Optimisation Platform suite, FRAGTrack has previously allowed Boliden's Kevitsa mine to quantify the effect geology had on its blast performance, with the data used to make targeted design modifications to its drill and blast process.

Further upstream of this, the recent addition of Orica's Orebody Intelligence division and the Rhino™ measurement technology has allowed mine sites to infer more about their resources. Rhino comes as a set of drill string-mounted geophysical sensors that measure rock elastic moduli while drilling, streaming said data in real time to the cloud.

This platform, Mathiravedu says, creates a high-fidelity data stream that increases the level of insight and automation that can be delivered across Orica's platform.

Orica's OrePro™ 3D blast movement modelling solution goes even further, tracking rock mass, post-blast, for effective ore and waste distinction ahead of processing.

Some of these elements come together on a macro level within Orica's Design for Outcome software, which has helped improve performance at the Roy Hill iron ore mine in the Pilbara of Western Australia.

Design for Outcome applies machine learning to data integrated upstream and downstream of the blasting process, providing an automated workflow using algorithms to define the geological hardness and generate blast designs that accurately allocate the optimal energy to consistently achieve targeted mining outcomes, according to Orica.

These machine-learning algorithms domain the geology in each drill hole and match explosives energy to the said domain,

generating automated loading rules for blast charging, according to the company. This process has been supported using Orica's smart explosives delivery systems (MMU™ – Mobile Manufacturing Units), capable of retrieving automated loading rules from the cloud and facilitating accurate explosives charging in line with the loading rules generated by the algorithm; all with "minimal interaction by the MMU operator", Orica said.

Execution of these designs is, again, captured in the cloud, accompanied by excavation productivity from the resulting blast, providing a closed loop system to feed the machine-learning algorithms.

"Today, Roy Hill have successfully deployed Design for Outcome across their mining operations to improve mining profit by removing overcharging and redeploying energy to areas that were previously under blasted," Orica said.

The two firms are now working to expand Design for Outcome to increase mining productivity, optimise ore fragmentation and boost performance in the site's crushing and processing circuits.

All this mining knowledge and more is being introduced to the Integrated Extraction Simulator (IES), a cloud-based software platform that, Orica says, simulates and optimises every step in the mining value chain, from blasting through to final product.

Orica's new WebGen 200 suite of fully wireless initiating systems set to release in late 2021

Having, in late-2020, been named the commercialisation partner for IES, developed by the Cooperative Research Centre for Optimising Resource Extraction, Orica recently signed a software licence agreement with JKTech Pty Ltd that gives it access to models developed by the Julius Kruttschnitt Mineral Research Centre used in IES' comminution and flotation simulation.

"IES represents a generational advance in the technology of mining and mineral processing simulation," Orica said. "The system is the first simulator with the capability to model multiple ore and mineral types simultaneously, the first to incorporate blasting into the mineral processing flowsheet and the first to leverage cloud computing to access hundreds or even thousands of servers if they are required to solve complex non-linear optimisations."

Developed from the ground up as a multi-user system, any number of domain experts can collaborate simultaneously within IES to configure and run a flowsheet that represents the real-world mining and mineral processing value chain, according to Orica.

One notable area where IES is making a difference to mining operations is its ability to underpin the implementation of mine to mill initiatives, Mathiravedu said.

"Blast designs are optimised based on the geotechnical and geometallurgical characteristics of the blast to produce the maximum throughput and metal recovery without exceeding the functional capacity of the plant," he said. "IES is also making headway in the life-of-asset scenario planning space and provides the ability to simulate each block of an entire block model across multiple mining or flowsheet scenarios to select the best strategies for maximising net present value for the life of mine."

Orica sees much of this simulation capability showcasing the benefits of its new explosives and blasting technology.

In the wireless initiation space, Orica is building on thousands of hours of operational experience with its WebGen™ 100 underground

wireless blasting initiation solution to develop a new product with both underground and open-pit applications.

WebGen 200 harnesses digital technology to allow advanced reprogramming and digital inventory management, offering mine operations an integrated user interface with improved quality assurance, according to Adam Mooney, Vice President of Blasting Technology for Orica.

"Built with customers' needs and feedback built in, encoding capabilities and enhanced security, the reliability of each blast is further improved with the new generation WebGen 200 system," he told ***IM***, adding it has been designed to endure even greater shock resistance than WebGen 100.

Mooney said WebGen 200's development will support further "innovative and more complex mining operations", enabling the first stages of automating underground development charging. This is evidenced through the successful progression of Orica and Epiroc's fully mechanised development charging system, Avatel™. This system, currently undergoing factory acceptance testing in Sweden, could move to mine site trials in 2022.

"WebGen 200 will come in four product variants and will open new markets, applications and opportunities, including the large volume surface market; continuing our commitment to creating safer, more productive operations for our customers," Mooney said.

The development program for WebGen 200 is progressing to plan with further tests and field trials to be conducted across multiple market segments in Australia, Canada, Chile and Europe from July, according to Mooney.

"The commercially-ready solution, expected in late 2021, will include feedback on enhancements to the product and firing system from our extensive testing and consultations with our customers," he said.

Ahead of the upcoming wireless initiation launch, Orica has released its Fortis™ Protect bulk explosive system as part of an overall risk management approach. This will help customers operating in difficult conditions minimise the potential for nitrate leaching into ground water, the company said.

"The product uses a combination of advanced surface chemistry in combination with increased viscosity to significantly improve the robustness of the product," Mooney explained.

Orica has already registered significant interest in the technology from Canada-based miners, and a major customer has recently commenced demonstration and measurement of the technology benefits.

"Concerns around nitrates in ground water of operating mines is growing and the combination of best-in-class operational practices with Fortis Protect is helping customers to minimise this risk without compromising explosive energy," Mooney said.

Changing the density of the emulsion product in the hole, depending on where more or less energy is required, is not only optimising blasting effectiveness but also promoting sustainability and safety, according to BME's Joe Keenan

Sustainable blasting outcomes

South Africa's **BME** is also looking to use real-time data for optimal blasting and improved decision making across the mining process.

This is where its next-generation MMUs and XPLOLOG™ blast data management system can help the sector, according to BME Managing Director, Joe Keenan.

"Equipped with various monitoring technology and a connected device that provides the ability to transmit data in real time, BME's smart trucks now track and measure key performance indicators such as total tonnes pumped, breaking this captured data down into kilograms pumped per hole," he told ***IM***.

BME is working with a third-party technology provider to integrate the vendor's blast data management system into its XPLOLOG system. XPLOLOG gives customers a comprehensive summary of blast block progress online, including information on dipping, priming, charging, top up and stemming. This, the company says, gives managers the power to improve the quality of blast preparation – leading to better blasting results and more profitable mining.

The integration of the blast data management system into XPLOLOG will see data synchronised to a cloud-based database for real-time reporting and better decision making by mine management, according to Keenan.

"Our goal with our smart trucks is to help to do this by feeding back information through XPLOLOG," he said. "This allows the powder factor to be optimised alongside a reduction in explosives used, while better control over product volumes also improves safety."

Such integration also unlocks the ability to vary the energy distribution across the chosen blast hole.

Changing the density of the emulsion product in the hole, depending on where more or less energy is required, is not only optimising blasting effectiveness but also promoting sustainability and safety, according to Keenan.

"This can even be applied in underground applications where low-emulsion density can help reduce overbreak, helping optimise hanging wall and side wall strata control," he said.

Taking it one step further, BME's combination of software, digital tools and specialised products can also be leveraged to improve rock fragmentation and, as a result, reduce the energy mines consume in loading, hauling, crushing and milling of ore, according to Keenan.

As with all the company's individual projects, it will match the solution to the characteristics and densities of the rock for an optimal result.

BME has many solutions for such customisation with its AXXIS™ advanced electronic blast initiation system and BLASTMAP™ blast planning software (for surface and underground applications) usually gaining most of the attention – usually linked with record blasts on the African continent.

Yet, the company has taken sustainability to a whole new level with its use of used oil in emulsion explosives.

The Omnia group company has been incorporating used oil into the emulsion mix for over three decades, making blasting greener while reducing environmental risk.

Keenan said BME recently expanded its used oil technology beyond South Africa into

countries in the Southern African Development Community, West Africa and Indonesia.

To meet the company's stringent quality requirements, used oil is sampled at BME bulking points around South Africa, then collected and transported to its treatment plant near Delmas. Undesirable contaminants are removed before the oil is ready to be used as a fuel source in BME's range of emulsions.

In South Africa, BME is now the leading consumer of used oil in the explosives sector, using a considerable portion of South Africa's total available volume in its emulsion explosives, according to Keenan.

"Last year, we consumed about 15 million litres of used oil in the manufacture of our emulsion explosives, up from around 11 million four years ago," he said.

In other developments, the company is planning to launch its AXXIS TITANIUM™ system, the latest generation of BME's AXXIS electronic blast initiation platform, soon, while Phase 2 of BLASTMAP Underground – to include up-hole design capacity – is also in the works.

The company is also confronting the ammonium nitrate problem in blast-affected groundwater.

"From a sustainability and social licence point of view, we are looking at leveraging the benefits of calcium nitrate as a buffer against the potential hazards of post-blast ammonia release," Keenan said.

Bulk benefits

Spain-based **MAXAM** is another company intent on adjusting the explosive density of products to match the application at hand.

The benefits of its high energetic, robust and flexible density bulk product, RIOFLEX, have recently been proven in a study supported by independent external consultants and customer feedback.

RIOFLEX is part of the MAXAM X-Energy solution, a combination of rock characterisation and "unique and revolutionary" product applications to deliver the right energy for blasting, managed by advanced digital technologies, the company explained.

More than 14 historical studies and 30 specific trial blasts in a broad range of mining and quarrying applications across five continents were factored into the MAXAM RIOFLEX study

More than 14 historical studies and 30 specific trial blasts in a broad range of mining and

quarrying applications across five continents were factored into this study, together with theoretical analysis and laboratories tests run in USA and Spain, according to MAXAM.

The study compared the performance of RIOFLEX with that of standard bulk emulsion explosives documented by MAXAM and authors in peer-reviewed literature during the last 35 years. The studies carried out in mines and quarries in Africa, Australia, Europe and South America, and in laboratory scale evidence, repeated the advantages of RIOFLEX technology, the company said.

The theoretical characterisation of RIOFLEX and emulsion in different densities and non-ideal conditions – from its ideal thermodynamic characteristic to its non-ideal performance – demonstrated that RIOFLEX-based formulations have more energy to break and move rock than formulations based on emulsions, MAXAM said.

"The energy of non-ideal ammonium nitrate-based explosive depends on the water content of that explosive," it explained. "While RIOFLEX usually has less than 13% of water, some commercial emulsions can have up to 23% water. The amount of water negatively affects the total energy of the explosive."

Underwater energy tests and confined velocity of detonation (VOD) measurements carried out highlighted that, under identical conditions, 100% RIOFLEX has a higher VOD than 100% standard emulsion. On average, the VOD of RIOFLEX was found to be 15% higher than that of standard emulsions, MAXAM said.

More than 30 full-scale production blasts were carried out in three different mine operations to evaluate the outcomes of RIOFLEX versus different emulsion products regarding rock fragmentation, environmental effects and downstream impacts. All these blasts were carried out under similar rock and ground conditions, according to MAXAM.

The main results and conclusions obtained from the analysis were summarised as follows:

- Rock blasted with RIOFLEX had a smaller size than rock blasted with standard bulk emulsion as measured by the X80 fraction. The reduction ranged from 15-38%;
- Using RIOFLEX also allowed a powder factor reduction of 10-18%, depending on the baseline, without compromising rock fragmentation and digging rates;
- Better fragmentation facilitated 11-18% faster digging rates and lowered truck cycle times. One study found that truck cycle times dropped by 8%; and
- In ore milling, significant improvements of up to 13% in throughput rates and energy consumption were observed.

The study also demonstrated the theoretical models of the blasting results only predict a fraction of the actual observed benefits of RIOFLEX, MAXAM said.

"Real overperformance of RIOFLEX goes beyond the theoretical difference in energy," it said. "This unique feature relies on the different nature of RIOFLEX when compared to other products, due to the higher density of the matrix and mechanical sensitisation and cross-linking technology."

An autonomous future

Reviewing the past, present and future of blasting technologies at the *MassMin 2020* conference, Danko Morales, **Enaex** Manager of Underground Mining, covered a lot of ground – from the transition to mechanised charging using pumpable emulsions, to alternative pre-conditioning solutions for dynamic weakening with explosives, to the ongoing shift towards emulsions or other water-based explosives in the blasting process.

Morales stated: "In the near future…all operations will be mechanised, and explosives will become completely on-site manufactured. After the massive application of water-based explosives, the industry's next step will be the full automation of the rock blasting sequence, including priming, manufacturing, charging and initiation."

In 2019, simulation studies were carried out to evaluate the potential performance of an autonomous charging process in an important block caving mine in central Chile, Enaex said.

With the incorporation of autonomous equipment and emulsion, the exposure for personnel could be reduced from more than 25,000 hours to zero, with six additional effective hours potentially added to available daily working time, according to the company. Given the number of metres to develop, autonomous charging would allow preparation time to be reduced from 90 to 82 months (10% less), and, without interference, it could be achieved in just 41 months (55% less).

Beyond the use of autonomous activities and emulsions, further developments in robotics are projected in underground mines in the short term. These advances will transform many high-risk human activities into more secure, remote, autonomous and robotised tasks, Enaex said.

While this is yet to be realised underground, Enaex is closing in on this achievement in open-pit mining.

Robotic solutions, which include RoboMiner®, Mine-iTruck® and Stemming-iTruck®, can form a complete family of equipment for performing full remote blasting in open-pit mines, it claimed.

RoboMiner is a humanoid unit mounted on four wheels that can moor and prime the blastholes; Mine-iTruck is a "sophisticated" truck to transport raw materials, manufacture explosives on-site and load them; and the Stemming-iTruck can plug the blastholes with gravel.

"Mine-iTruck was first used in 2018 for the first tele-operated charging of ANFO in the world, carried out in a large Chilean open-pit mine," Morales said. "Mine-iTruck, together with Stemming-iTruck and RoboMiner, were used for the first full remote blasting in mining history. Today, this package that includes the full set of robotic solutions is the only one of its kind in the market, and it is being successfully implemented in an important operation in northern Chile."

He added: "From the point of view of open-pit mines, tele-operated, robotic and autonomous activities will increasingly define the future. Tele-operation and robotics are technologies already in use by Enaex and they have helped gain access to places that are difficult and/or dangerous to reach. Since 2019, Enaex has demonstrated that complete tele-operated and robotised blasting is possible in open-pit mines using RoboMiner, Mine-iTruck and Stemming-iTruck. The next step will be to automate all activities."

Today, Enaex units can drive autonomously thanks to Mobius® software, which is part of the partnership between Enaex and Automated Solutions Inc, but there are special tasks still requiring remote control.

As in underground mines, Enaex seeks to go further in open-pit mining to achieve fully automated blasting in the short term.

On the digitalisation front, Morales highlighted Enaex Bright® as one of the company's key projects. This digital platform can provide recommendations on blasting agent types, optimal mixtures and quantities based on data analysis, machine learning and artificial intelligence.

He explained: "Today, Enaex Bright is working on step one. It is collecting information from manufacturing trucks, saving design data like blasting geometry and rock type, and also saving operational parameters such as quantities of explosive and depth of the drill holes."

The digital network

Becker Mining Systems' newest product in its line of networking solutions, smartblast® LTE, is designed specifically to help a remote firing system work in conjunction with mine LTE communication systems.

Just one of the benefits that comes with applying smartblast LTE units in a drill and blast setting is the reduction in misfires due to the minimal infrastructure requirements and ease-of-use that come with applying smartblast LTE, the company claimed.

With the growing presence of LTE technology in the mining sector, Becker sought to develop a reliable LTE blasting device that wouldn't require extensive training, all while keeping safety a priority, Becker Varis' Albert Bower says of smartblast LTE

"With the growing presence of LTE technology in the mining sector, we sought to develop a reliable LTE blasting device that wouldn't require extensive training, all while keeping safety a priority," Albert Bower, CEO of Becker Varis, the Canadian division of Becker Mining Systems, said.

The 3GPP compliant system is comprised of two units: the Controller (RB1675-M) and the Remote (RB1675-R). The Controller features a historical log book and safe bi-directional communication with all installed Remotes, while being able to fire a total of 64 Remotes, according to Becker Varis.

Both units are designed to withstand harsh environments while the Remote includes sensors to detect seismic activity.

The benefits of the system have already been felt at Eldorado Gold's Lamaque underground gold mine in Quebec, Canada, where, Becker Varis, in partnership with Meglab (recently acquired by Epiroc), commissioned the first smartblast LTE remote firing system.

To ensure proper communication between the mine's LTE network and the smartblast LTE units, multiple tests were conducted and provided positive results as blasts were successfully initiated without misfires from multiple levels of the mine, Becker explained.

"We are very pleased with the results of the tests that were completed," Sylvain Frigon, Director of Technology Projects at Meglab, said. "With the emergence of LTE communications technology in Québec, we believe that we will be able to help our clients with a blasting system that fits their requirements."

In 2020, Eldorado Gold set up a private underground LTE network at Lamaque in collaboration with Meglab and Bell.

Split the difference

Hexagon has, once again, looked to improve fragmentation analysis within the drill and blast process by adding split colour features to its offering.

HxGN Split provides technologically advanced image-analysis techniques to help mines optimise fragmentation, saving significant costs while improving drill and blast processes, the company said.

New to Split's solution suite is HSL (Hue, Saturation and Luminance), a colour analysis feature that, Hexagon says, empowers mine operators with real-time ore type detection.

"Real-time tracking of product types allows for immediate decision making to optimise rock-size reduction and product-type treatments," Hexagon said. "The new feature further supports operational efforts to improve product throughput and ore recovery."

This is important when mining operations are continuing to maximise existing resources, using value-added technologies.

HSL's key benefits include:

- The ability to monitor product type blending for optimum processing;
- Reduce ore dilution by tracking product source mining;
- Maximise throughput with consistent product delivery to the plant; and
- Immediately adjust ore recovery treatments based upon product type.

"Hue, saturation and luminance values are measured during live plant production and provide a statistically relevant sample required to aid decision making," Hexagon said. "A colour wheel is applied to the images to provide calculated HSL values for every processed iteration. Evaluation of the Split HSL values are correlated to the mine geologic product types to find the unique image property signatures."

The HSL values are measured for the image samples to be trended on live operator screens. Step changes in the Split results provide immediate indicators for product type changes that signal the need for operational responses, Hexagon explained.

Timely decisions surrounding the operating conditions lead to improved plant throughput and product recovery, while additional detailed measurements for individual rock particles can be measured using the same Split HSL measurements to find the ratios of the product type blends.

The company concluded: "HxGN Split's image processing technology delivers high-quality information, ensuring the key step of fragmentation analysis is managed from drill to mill, thus improving mine profits."

A well-needed boost

Storage and transportation of explosives and its associated raw materials come with a fair amount of risk, with **AECI Mining Explosives** looking to address these issues with the development of a "ground-breaking" alternative booster technology manufactured from non-explosive raw materials.

The manufacture of boosters or primers from pentaerythritol tetranitrate (PETN), or cyclo-trimethylene trinitramine (RDX) and trinitrotoluene (TNT), has been unrivalled for decades in terms of performance and reliability. It remains the preferred method globally as an intermediary part of the detonation train due to its ease of initiation from a detonator and high VOD, according to the company. Yet PETN, RDX and TNT, due to their chemical make-up, require sophisticated plants and specialised raw material facilities for manufacturing.

The handling of energetic materials and explosive raw materials are, by their nature, hazardous and, therefore, highly regulated in the interest of public safety. This introduces some costly challenges, according to Hazel Bomba, Product Manager at AECI Mining Explosives.

As a result, the ability to position booster manufacturing sites in more geographically suitable areas to make the product more accessible is limited.

AECI Mining Explosives is developing an alternative booster technology wherein a high-powered explosive booster is manufactured from non-explosive raw materials. The alternative booster technology is currently being trialled in the field following lab testing. The company is confident its innovative PowerBoost product will be market-ready by the March quarter of 2022.

"This alternative technology opens up the opportunity for so much more," Bomba said. "AECI Mining Explosives has been trialling and optimising the booster design to the extent that its PowerBoost technology outperforms the equivalent PETN and TNT boosters. The use of non-explosive raw materials in booster technology simplifies logistics, has the potential to lower manufacturing costs and creates the ability to deploy simple mobile modular plants to strategically placed manufacturing hubs."