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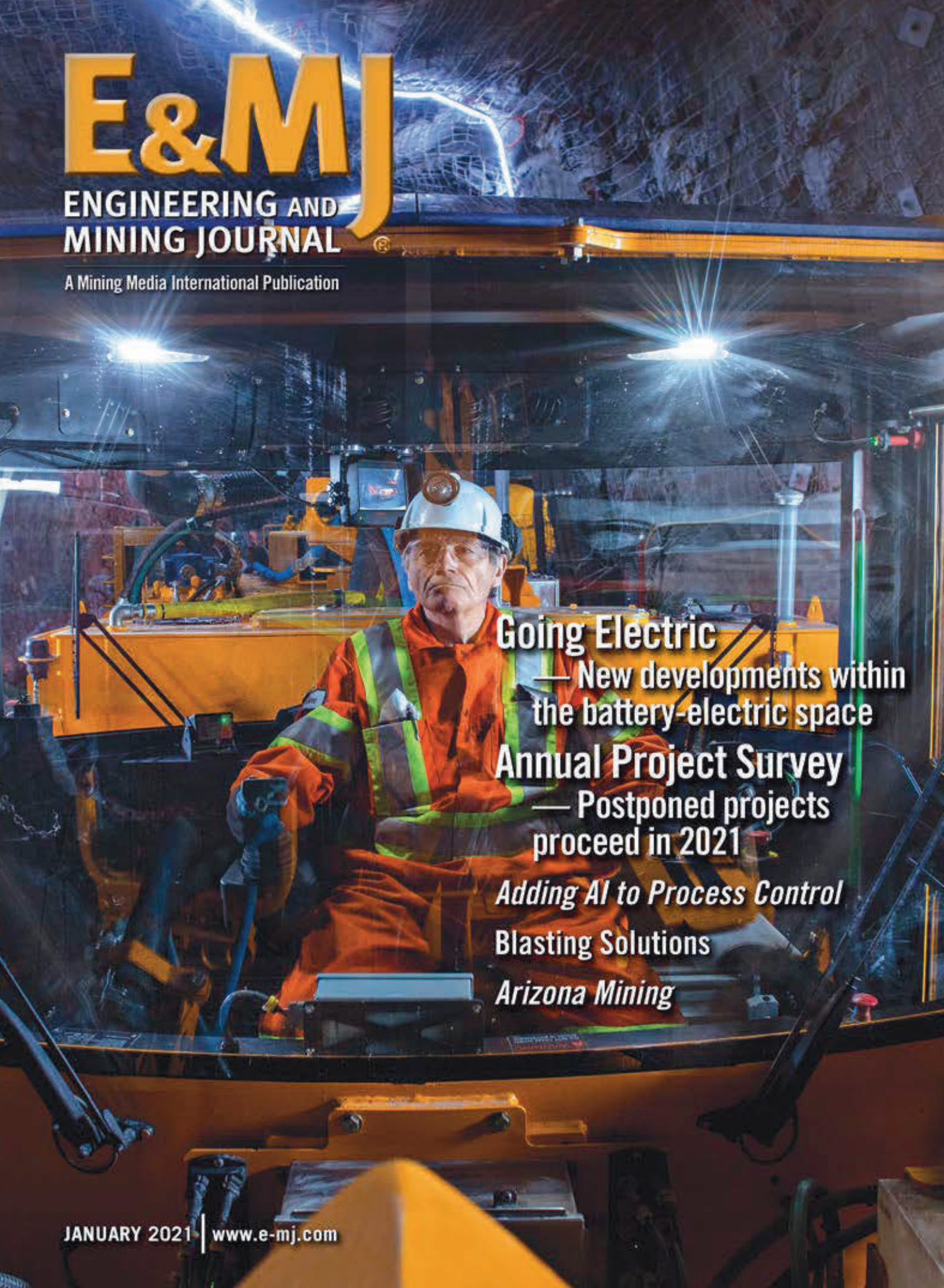

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E&MJ ENGINEERING AND MINING JOURNAL

FEATURES

LEADING DEVELOPMENTS

AROUND THE WORLD

In addition to the annual Project Survey, E&MJ *reviews the latest in the battery electric vehicle (BEV) space. On the cover, MacLean operator trainer, Dave Drake, sits behind the controls of an SS5 BEV shotcrete sprayer. (Photo: MacLean Engineering/Mining Industrial Photographer)*

DEPARTMENTS


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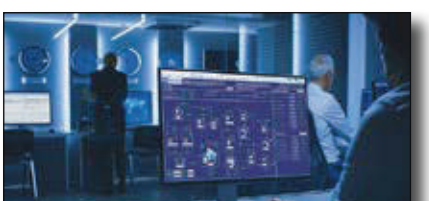
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Steve Fiscor
Publisher & Editor-in-Chief

Looking Forward to a Better Year

Last year was a difficult year for everyone and, for those of you who lost family, friends and coworkers to the pandemic, you have our sympathy. This time last year, the mining sector was on a roll. Metal prices were healthy and many operations were considering expansion plans. The coronavirus (COVID-19) entered the *E&MJ* lexicon for the first time on February 5 and by the end of March, most of the world was coming to grips with the pandemic. It disrupted our day-to-day lives and businesses. At the same time, prices for energy minerals and copper and other non-ferrous base metals lost steam. It looked bleak and mining companies began to table their expansion plans and conserve discretionary spending.

Fortunately for our small slice of the world, mining was deemed an essential industry and allowed to continue to operate in most areas. It could be done safely and required flexibility almost beyond comprehension. Working remote became a familiar concept for many people, not just the travelers. Suppliers had to rethink logistics and video conferencing took the place of in-person training and sales.

As the year wore on, metal prices firmed and more operations were brought back online. Gold prices eventually climbed above $2,000/oz before settling around $1,900/oz, and by the end of the year, copper and iron ore were trading at seven-year highs. Those that stayed the course and found a way to make it work even as a second wave of infections began to spread, reaped the rewards.

Annually, *E&MJ* publishes its Project Survey in the January edition. It has always been a popular piece as the projects that are noted in it today will be the mines of tomorrow. Globally, there are an estimated 13,000 active projects that represent $1.18 trillion in potential capital spending, according to Industrial Info, the group that performs the research for the survey. Most of that money will be invested in U.S. and Canada ($268 billion), Latin American ($199 billion), Africa ($114 billion), and Australia and Oceania ($108 billion).

Of that massive mix, *E&MJ* tracks the major metal mining projects ($25 million and greater). Copper represents the largest area of investment ($115 billion), followed by gold ($66 billion) and iron ore ($59 billion). Those three commodities represent 85% of the total tracked investment of $288 billion. It's easy to see where mining companies are making the bulk of their investment these days.

The good news in all of this is that the survey indicated that the plans that were postponed last year will likely proceed again in 2021. While some commodities suffered and still do today, especially in the energy sector, the mining business in general is doing OK and the prospects for the mining sector in 2021 look good.

Hopefully this year will better for the rest of the world as they turn the page on 2020 and COVID-19. Partisan politics have driven a stake of bitterness through the heart of America. A second wave of infections has forced parts of Canada and Latin America to impose curfews. Several European countries are locking down, again. Unemployment is still high, and many people are struggling to make ends meet. A little bit of patience and empathy could go a long way in today's world. Enjoy this edition of *E&MJ*. Take care and be safe.

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Equinox Acquires Premier, i-80 Gold Spins Out

i-80 Gold will own the South Arturo property (above) and McCoy-Cove property. (Photo: Premier)

Equinox Gold Corp. will acquire all of the outstanding shares of Premier Gold Mines Ltd. and at the same time, Premier will spin out i-80 Gold Corp., a newly created U.S.-focused gold production and development company. i-80 Gold will own the South Arturo and McCoy-Cove properties and complete Premier's previously announced acquisition of the Getchell Project, all of which are located in Nevada along U.S. Interstate 80. Equinox Gold will retain Premier's interest in the Hardrock Project in Ontario, the Mercedes mine in Mexico, and the Hasaga and Rahill-Bonanza properties in Red Lake, Ontario. Orion Mine Finance Group will purchase Centerra Gold Inc.'s 50% interest in Hardrock, making it joint venture partners with Equinox on the project.

Premier shareholders will receive 0.1967 of an Equinox Gold share for each Premier share held and 0.4 of a share of i-80 Gold for each Premier share held. On closing of the transaction, existing Equinox Gold and Premier shareholders will own approximately 84% and 16%, respectively, of Equinox Gold. Equinox Gold and existing shareholders of Premier will own 30% and 70%, respectively, of i-80 Gold.

Equinox Gold will have seven operating gold mines with construction under way at an eighth site, a healthy project pipeline and the financial capacity to fund development of Hardrock, which has 5.54 million ounces (oz) of proven and probable mineral reserves grading 1.27 grams per metric ton (g/mt) gold, the company said. It is expected to produce an average 414,000 oz/y of gold with average head grade of 1.45 g/mt gold for the first five years and 358,000 oz/y of gold over the initial 14-year mine life.

The Mercedes mine in Sonora, Mexico, adds approximately 50,000 oz/y of gold (with expansion potential to 80,000 oz/y to 90,000 oz/y) to the estimated 700,000 oz/y gold production expected in 2021 from Equinox Gold.

"This transaction is exactly the kind of accretive Americas-focused growth we promised shareholders when we started Equinox Gold at the beginning of 2018," Equinox Gold Chairman Ross Beaty said. "The addition of a top-tier, low-risk mining jurisdiction in Ontario, Canada, creates a lower risk profile, with greater asset and country diversification."

Beaty said Hardrock will be an excellent, low-cost, long-life gold mine with significant exploration upside and the Mercedes mine will bring an immediate increase to production and cash flow.

"Combining a 50% interest in the permitted, development-ready Hardrock Project with our strong balance sheet and operating cash flow provides a clear path to production for Hardrock that I believe will unlock substantial value for both Equinox Gold and Premier Gold shareholders," Equinox Gold CEO Christian Milau said. "We look forward to developing Hardrock with Orion as our partner, integrating the Mercedes mine into our portfolio of producing gold mines, and being a substantial and supportive shareholder of i-80 Gold."

i-80 Gold will be led by Premier CEO Ewan Downie. i-80 Gold intends to conduct a financing of up to $75 million. Equinox Gold has committed to subscribe for 30% of the aggregate amount of the financing up to a maximum subscription amount of $22.5 million. Pursuant to the transaction, it is expected that i-80 Gold's initial working capital will include approximately $15 million in cash, pre-financing.

In connection with the transaction, Equinox Gold plans to complete a C$75 million equity financing, fully underwritten by Beaty, at a price per share to be set in the context of the transaction and the market after at least five clear trading days.

The directors of Equinox Gold and the directors of Premier have unanimously approved the transaction and the Board of Directors of Premier have recommended that Premier shareholders vote in favor of the transaction. The transaction is also subject to court approval.

Orion will purchase Centerra Gold Inc.'s 50% interest in the Greenstone Gold Mines Partnership (GGM) for $225 million plus certain contingent payment obligations of approximately $75 million (assuming a $1,500/oz gold price). Premier currently owns the other 50% of GGM, whose principal asset is the Hardrock Mine project located on the Trans-Canada Highway near Geraldton, Ontario, Canada, and represents one of the most significant large-scale, permitted, mine development opportunities in North America, according to the company.

Agnico Eagle Will Acquire TMAC Resources

Canadian gold mining company, Agnico Eagle Mines Ltd. has entered into an agreement to purchase TMAC Resources Inc. at a price of C$2.20 per share in cash. The total equity value under the transaction is approximately C$286.6 million. TMAC Resources owns the Hope Bay property located in Nunavut, Canada.

This is 26% higher than the C$1.75 per share price offered by Shandong Gold Mining back in May and a premium of approximately 66% to TMAC's 20-day volume-weighted average price as of January 4.

The offer from Shandong was rejected back in late December by the Governor in Council, which issued an order under the Investment Canada Act (Canada) directing Shandong Gold Mining Co. Ltd. and its affiliate not to proceed with the transaction.

"We are very pleased to have the opportunity to bring our extensive northern operational and community experience to the Hope Bay Mine and the Kitikmeot Region of Nunavut," Agnico Eagle Vice Chairman and Chief Executive Officer Sean Boyd said. "Together with the TMAC team and our Nunavut partners, we look forward to advancing exploration and expansion initiatives to realize the full potential of the mine and its large unexplored land package."

Resource Capital Funds (RCF), Newmont Corp. (Newmont), Shandong and all directors and officers of TMAC, collectively holding approximately 62.3% of the current outstanding TMAC common shares, have agreed to not interfere with the transaction.

TMAC President and Chief Executive Officer Jason Neal expressed excitement regarding the transaction. "The acquisition being completed by Agnico Eagle is a great outcome for all stakeholders," he said. "Agnico Eagle is one of the strongest gold producers internationally, a Canadian champion and has been operating in Nunavut for more than a decade with a great track record with communities, employees and the environment."

The board of directors of TMAC has unanimously approved the transaction and it is expected to close on or before February 8, 2021.

TMAC began producing gold in early 2017 from Doris, its first mine at Hope Bay, and processed gold at the Doris processing plant, which originally had nameplate capacity of 1,000 tons per day (t/d) and expanded to 2,000 t/d midway through 2018. TMAC is now permitted to produce from both Madrid and Boston.

Rio Tinto: Oyu Tolgoi Underground Will Reach Production by October 2022

Rio Tinto has unveiled a pathway for the ongoing development of the underground project at Oyu Tolgoi in Mongolia, one of the largest known copper and gold deposits in the world. The company estimated that Oyu Tolgoi underground will achieve sustainable production for panel zero by October 2022 with development capital of $6.75 billion.

Agnico Eagle will acquire the Doris gold mining operations (above) in Hope Bay, Nunavut, Canada,

"We now have a pathway to bring the underground project into production, which will unlock the most valuable part of Oyu Tolgoi," Chief Executive of Copper and Diamonds Arnaud Soirat said. "We will continue to work together with the government of Mongolia and TRQ (Turquoise Hill) to progress the project, including finalizing all necessary approvals and agreeing a solution on power and funding."

This will ensure the project can commence caving operations in 2021, the company said.

At peak production, Oyu Tolgoi is expected to operate in the first quartile of the copper cash cost curve and by 2030 is expected to be the fourth largest copper mine in the world.

Oyu Tolgoi is expected to produce 480,000 metric tons (mt) of copper per

PDAC Convention Goes Virtual

Following the lead of so many large trade shows, the annual Prospectors & Developers Association of Canada convention will take place virtually. The event, which brings together mine developers, prospectors and potential investors, will take place March 8-11, and the association is offering a C$200 discount for its all-access pass to those who register before February 12.

PDAC said its virtual event will offer more than 100 hours of content across the four-day period and registrants will be able to access the content for as long as 90 days after the event. Attendees will have live virtual access to short courses, the opening and closing sessions, a keynote program, the corporate presentation forum, a series of master classes and much more. Delegates will also be able to experience the trade show, the core shack, the investor's exchange and prospector's tent online as well as the awards gala.

The keynote program includes four presentations: Doug Silver from Orio Resource Partners will present "The Fate of Gold Deposits;" Jumana Saleheen from CRU will present "The Economy After COVID-19;" Laura Tyler from BHP Billiton will present "Technology in Mining;" and John Lewins from K92 Mining with present, "Kora North Deposit, Kainantu Mine, Papua New Guinea." Lewins will also accept the Thayer Lindsley Award for the Kora Noth Discovery at the Gala Event. At the event, the PDAC will also recognize Phillip Walford and Sherry Dunsworth with the Bill Dennis Award; Dennis Jones with the Distinguished Service Award; Naliane Morin with the Skookum Jim Award; Mark O'Dea with the Viola R. MacMillan Award; and B2Gold's Fekola Mine with the Sustainability Award.

The PDAC also said they would offer a series of entertainment breaks and networking opportunities, including a backstage tour of the Royal Ontario Museum and Peruvian cocktail party.

For more information, visit www.pdac.ca/convention.

Oyu Tolgoi produces more than 1 million mt of copper since it opened in 2013.

year on average from 2028 to 2036 from the open pit and underground, compared with 146,300 mt in 2019 from the open pit. The underground Ore Reserve has an average copper grade of 1.52%, which is more than three times higher than the open pit ore reserve, and contains 0.31 grams per mt of gold, according to Rio Tinto. The size and quality of this asset provides additional expansion options, which could see production sustained for many decades, it added.

Oyu Tolgoi is jointly owned by the government of Mongolia, 34%, and Turquoise Hill Resources, 66% of which Rio Tinto owns a controlling interest of 50.8%. Rio Tinto has been the manager of the Oyu Tolgoi project since 2010.

The open-pit mine was completed in less than 24 months and production started in 2013. Since then, more than 240 million mt of ore have been milled, with more than 1 million mt of copper in concentrate sold.

This announcement comes after a strongly worded letter from Pentwater Capital Management LP, the largest minority shareholder of Turquoise Hill Resources Ltd., to the Rio Tinto plc Board of Directors, describing Rio Tinto's "oppressive" actions taken against minority shareholders. It also threatened to file an action for oppression against Rio Tinto if its behavior is not corrected. Pentwater wasn't the only one with concerns. On November 25, the government of Mongolia asked Oyu Tolgoi LLC to seek an independent review into delays and costs overruns in the underground expansion of the Oyu Tolgoi mine. The board of directors of Oyu Tolgoi LLC approved a resolution establishing the special board committee to conduct the independent review.

4 Mining Companies Adopt Mining LPRM

Mining Shared Value (MSV), a non-profit initiative of Engineers Without Borders, has announced that four mining companies have now adopted the Mining Local Procurement Reporting Mechanism (LPRM). The LPRM is a publicly available information sharing framework that was created by MSV in partnership with the German development agency GIZ, to increase and standardize information on mine site level local procurement processes and results.

"With hundreds of millions spent each year by a typical mine site, local procurement of goods and services has huge potential to not only create economic and social benefits for host communities and countries, it is also an incredibly effective way of strengthening a mine's social licence to operate," MSV Managing Director Jeff Geipel said. "We created the Mining LPRM as a public good because there was no information-sharing framework for this ESG issue that has such immense potential impact in host countries."

Ivanhoe Mines became the first company to use the international transparency standard in 2019, and Lundin Gold, Golden Star Resources and Teranga Gold have now come out with their sustainability reports using the framework.

The LPRM hopes to strengthen the local economy surrounding a mining operation.

"We believe that it is imperative to build local capacity across the supplier value chain," Jasmine Abrahams, Ivanhoe Mines group manager, sustainability, said. "The Mining LPRM allows us to communicate to stakeholders, including investors and ESG ratings agencies, that we have systems in place to understand and prevent risks associated with procurement."

Abrahams said when comparing the company's year-on-year jurisdictional procurement spend, procurement in the DRC increased by 133%, while procurement in South Africa increased by 72%.

According to MSV, whether companies buy from local suppliers in a significant way is becoming a high-profile issue for the sector, and governments in the last few years have implemented regulations requiring local sourcing in countries including Ghana, Tanzania, Saudi Arabia and the Argentine province of Salta. Indigenous communities in both Canada and Australia have also been able to secure local procurement commitments as part of binding community development agreements (CDAs). Stakeholders are wanting to see concrete results that mining sector activity is contributing to host country economic benefits.

Golden Star Resources, who released its first sustainability report using the LPRM in September, operates in Ghana where the government is currently in the process of increasing regulations on the mining sector regarding local procurement. Philipa Varris, Golden Star executive vice president, head of sustainability, said, "Our objective is to move beyond social licence to operate, to creation of lasting value — in 2019 almost 84% of our procurement spend was with Ghanaian companies, up from 73% in the previous year. Local procurement provides the framework for genuinely interdependent relationships — where miners and host communities succeed together. The Mining LPRM provides a standardised method for ensuring transparency and in practical terms has guided our efforts and performance improvement."

The Mining LPRM is structured like the Global Reporting Initiative, providing a set of disclosures for companies to provide information on key elements, such as local procurement policies, how much is spent in host countries, and supplier development programs. It will also provide the information for other reporting programs.

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WE DISCOVER POTENTIAL

Coeur Plans Rochester Expansion

The Rochester mine (above) produces 3.7 million oz of silver and 35,400 oz of gold in 2019. Construction on the POA 11 expansion should be completed in late 2022.

Coeur Mining Inc. plans to expand its Rochester silver-gold mine in Nevada. Significantly higher reserves and a large-scale expansion is expected to reposition Rochester as the company's cornerstone asset.

"The expansion of Rochester represents the company's single-largest organic growth opportunity," Coeur President and CEO Mitchell J. Krebs said. "The combination of significant reserve growth, the scope of the expansion project to leverage economies of scale, and the benefit of higher and faster silver recoveries from HPGR technology is expected to generate an internal rate of return of more than 30%."

"Importantly, the project is supported by a technically sound foundation with robust economics that helps drive an anticipated step-change in Coeur's cash flow profile, which we believe will fundamentally reposition the company and unlock meaningful long-term value for our stockholders."

Rochester's planned expansion under plan of operations amendment (POA 11) includes the construction of a new leach pad, a crushing facility equipped with two HPGR units, a Merrill-Crowe process plant, and related infrastructure to support the extension of Rochester's mine life. The company plans to fund the project with a combination of cash on hand, internally generated cash flow from its four operating mines and existing debt capacity.

Coeur commenced early-stage earthworks and began establishing infrastructure for POA 11 in early August 2020. Major construction is expected to begin in 2021 and be largely completed by late 2022.

Seabridge Gold Will Use Proceeds From Financing to Buy Snowfield Property

Seabridge Gold Inc. has successfully closed its previously announced bought deal financing consisting of 6,710,000 common shares at a price of US$17.25 per share for gross proceeds of US$115.7 million inclusive of the exercise of the entire over-allotment option held by the Underwriters. Proceeds will be used to fund the purchase the Snowfield Property from Pretivm Resources Inc., which was announced on December 4. Proceeds from the financing will pay the entire US$100 million up-front cash payment payable in respect of the acquisition of the Snowfield Property, the expenses related to the acquisition, with the remainder used for general working capital.

The closing of the Snowfield acquisition is expected on or before December 16. Seabridge holds a 100% interest in several North American gold projects. The company's principal assets are the KSM and Iskut projects located near Stewart, British Columbia, Canada, and the Courageous Lake gold project located in Canada's Northwest Territories.

Cantor Fitzgerald Canada Corp. acted as lead underwriter and sole bookrunner on behalf of itself and a syndicate of underwriters including B. Riley Securities Inc., Canaccord Genuity Corp., Roth Capital Partners LLC and Red Cloud Securities Inc.

Cypress Studies Chloride Leaching for Clayton Valley Lithium Project

Cypress Development Corp. has completed the first stage in the scoping level study into the extraction of lithium using chloride-based leaching. Continental Metallurgical Services Inc. (CMS) prepared a large sample from the company's Clayton Valley lithium project and conducted the acid leaching test. Samples of the leach solution and the initial and final solids were shipped for assay. The remaining steps of testing will focus on the treatment of the leach solutions and are expected to be completed by the end of the year.

Upon addition of acid, CMS observed vigorous frothing. The filtered leachate was yellow versus the lime green seen with the sulfuric acid leach. Notable in test was that the slurry separated into solid and liquids portion in the span of several hours, to the extent leach solution was decanted from the mixing tank with no filtration, which could be an advantage over sulfuric acid leach. Leach slurry samples were shipped to Pocock in Salt Lake for testing on solid-liquid separation. These results will be important in determining if changes in the filtration and tailings handling portions of the plant design will be warranted.

If the chloride leaching is successful and is indicated to be economically jus-

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tified, steps within the lithium concentration and recovery process will require additional equipment in the pilot program to evaluate.

Clayton Valley is a world-class resource of lithium-bearing claystone located adjacent to the Albemarle's Silver Peak mine, North America's only lithium brine operation.

PureGold Mine Pours First Gold

Pure Gold Mining Inc.'s high-grade PureGold mine in Red Lake, Ontario, had its first gold pour on December 29, following the introduction of ore to the mill on December 15.

"Today, the PureGold mine has come to life," PureGold President and CEO Darin Labrenz said. "With our first gold pour, we have transitioned to producer, and delivered on our promise to build Canada's newest gold mine in the heart of Red Lake Ontario, on budget and on schedule."

The company is now focused on ramping up the operation to steady state production as it continues to build a long-life growth company in Red Lake. Commercial production is expected by the end of the first quarter of 2021.

"PureGold will also continue to pursue its aggressive growth strategy in 2021, with ongoing exploration drilling from both surface and underground, an update of mineral resources to include drilling completed over the last two years, and incorporation of significant improvements in mine design and mine plan," Labrenz said.

Wyloo Metals Will Purchase Cornerstone Position in Noront

Australia's Wyloo Metals Pty Ltd. has entered into a definitive agreement to become a cornerstone investor in Noront Resources Ltd. by acquiring the interests controlled by Resource Capital Fund and its affiliates (RCF). The deal is Wyloo Metals' second Canadian investment, and follows several similar strategic investments aimed at supporting the discovery and development of critical commodities.

Noront is a Canadian listed mining company with several assets, including the high-grade Eagle's Nest nickel project in the Ring of Fire, an emerging multi-metals region located in the James Bay Lowlands of northern Ontario. Eagle's Nest is the largest high-grade nickel discovery in Canada since Voisey's Bay and is anticipated to have an initial mine life of 11 years, with the potential for an additional nine years. This excludes the development of the adjacent chromite resources, which presents a further development opportunity. Once developed, the Ring of Fire has the potential to generate significant business and employment benefits for Ontario's northwestern region.

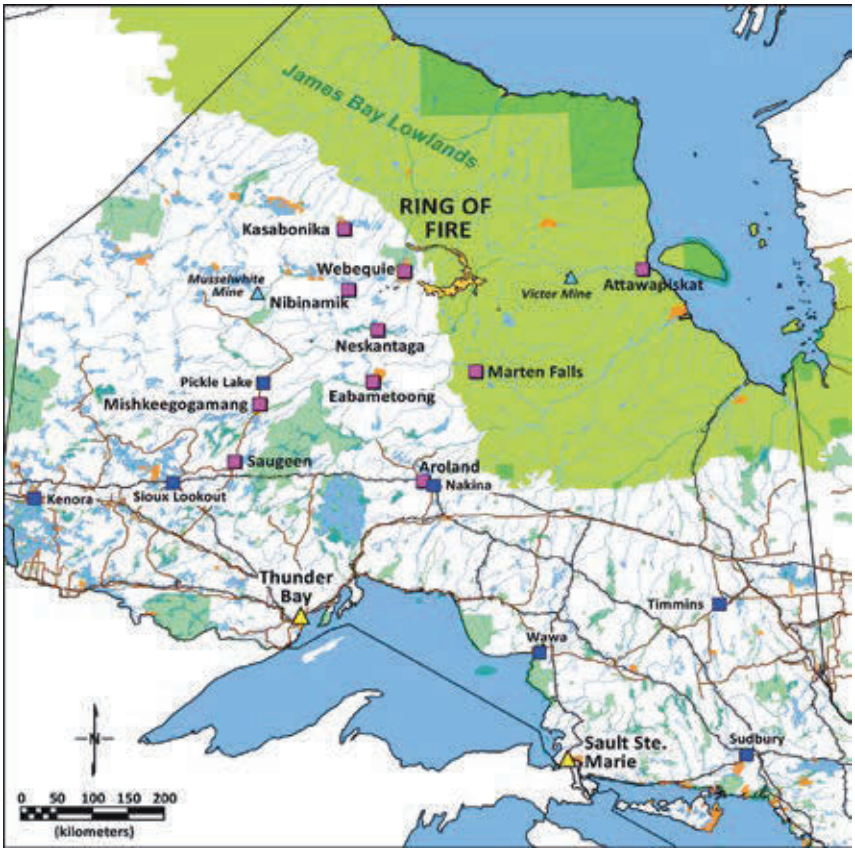
Under the terms of its agreements with RCF, Wyloo Metals will purchase the more than 95.5 million Noront common shares for $11.5 million and it will also purchase a convertible loan for $15 million. The Noront common shares to be acquired represent approximately 22.65% of the more than 417.5 million currently outstanding Noront common shares. Based on the current conversion price of the loan, Wyloo Metals would acquire 96.6 million Noront common shares upon full conversion of the loan and would, if the warrants it is to acquire were also exercised, result in Wyloo Metals holding nearly 193 million Noront common shares, representing approximately 37.4% of the Noront common shares on a partially diluted basis.

Closing of the transactions is subject to customary closing conditions.

Head of Wyloo Metals Luca Giacovazzi said the partnership with Noront presents a unique opportunity to join forces with a proven management team in the development of the Eagle's Nest deposit and the continued exploration of the world-class Ring of Fire region.

"This investment reflects a long-term and collaborative strategy to support the discovery and development of the next generation of mines required to meet the growing demand of critical materials needed to power the decarbonization of the global economy," Giacovazzi said.

Noront President and CEO Alan Coutts said, "They are known for making long-term, strategic investments in companies that mine responsibly, and that is a philosophy that aligns very well with the approach we are taking as we develop the Ring of Fire in an environmentally responsible manner in collaboration with our First Nation partners."



Noront owns several assets in Ontario's Ring of Fire district.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Jakob Stausholm

Rio Tinto has appointed **Jakob Stausholm** as CEO January 1. He joined Rio Tinto as an executive director and CFO in 2018. Prior to joining Rio Tinto, he was group CFO and strategy and transformation officer of A.P. Moeller-Maersk A/S.


Raul Benavides

Compañia de Minas Buenaventura announced that **Raul Benavides** will retire as vice president of business development following 40 years of service at the company. Benavides has held the position since 2011. Prior to this role, he served as the manager of business development since 1997.


Alex Morrison


Allen Palmiere

Gold Resource Corp. announced new leadership in conjunction with the spin-off of its Nevada Mining Unit as Fortitude Gold Corp. Gold Resource Corporation Chairman **Bill Conrad** has stepped down as chairman and will continue to serve as an independent director on the board. Current Gold Resource Director **Alex Morrison** has been appointed to serve as chairman. Outgoing Gold Resource CEO, President and Director Jason Reid has stepped down from all company positions to lead Fortitude Gold. **Allen Palmiere** has been appointed CEO and a director of Gold Resource Corp. **Lila A. Manassa Murphy** and **Joseph Driscoll** have been appointed as independent directors to Gold Resource's Board.


Lila A. Manassa Murphy


Joseph Driscoll


Gary Haywood

Fission Uranium Corp. appointed uranium mining expert, **Gary Haywood** as vice president of project development. Haywood served seven years with Cameco as general manager at the McArthur River and senior mine engineer at the Eagle Point uranium mining operations.


Brendan Creaney

Trevali Mining Corp. appointed **Brendan Creaney** as CFO. Creaney joined the company in August 2019 as vice president, investor relations, and has served as interim CFO since September 2020. Before joining Trevali, he held several finance roles with Goldcorp from 2012 to 2019 in such functions as corporate development, business planning. studies and projects, capital allocation, and strategy.


Chris Haubrich

Pure Gold Mining Inc. appointed **Chris Haubrich** as vice president, business development. Prior to joining PureGold, he served as vice president, investment banking with National Bank Financial where he covered the mining sector and advised clients on a wide range of M&A and financing transactions.

Pretium Resources Inc. announced the resignation of **Robin Bienenstock** from the Board of Directors. Bienenstock joined the board in 2018 and was a key member of the Compensation Committee, acting as its chair since February 2019, as well as the Corporate Governance and Nominating Committee.

The *Indonesian Ministry of Energy and Mineral Resources* (*MoEMR*) has approved **Fatchil Amal** as Kepala Teknik Tambang (mine technical manager) for Baru Gold's Sangihe gold project.

SouthGobi Resources Ltd. announced that Sir **Kwok Siu Man KR** tendered his resignation as joint company secretary of the company in Hong Kong. **So Shuk Wan** has been appointed as the Hong Kong company secretary and the authorized representatives with retrospective effect from January 1, 2021.

E3 Metals Corp. appointed **John Pantazopoulos** as CFO. He will replace **Greg Florence,** who resigned as CFO to pursue another opportunity. Most recently, Pantazopoulos held the position of interim CEO and CFO of a green hydrogen technology company.

Noront Resources Ltd. announced that **Gregory Honig,** director of origination, Canada, Resource Capital Funds, has resigned from the board of directors. Honig's resignation follows the recently announced agreement that will result in the sale of Resource Capital Fund's beneficial equity and debt interests in Noront Resources to Wyloo Metals Pty Ltd.


Anthea Bath


Makko DeFilippo

Ero Copper Corp. announced two promotions of executive officers: **Anthea Bath,** previously vice president, technical services, has been promoted to COO; and **Makko DeFilippo,** previously vice president, corporate development, has been promoted to president and will retain overall responsibility for corporate development and investor relations.

Prosper Gold Corp. appointed **Rory Ritchie** to vice president of exploration to replace **Dirk Tempelman-Kluit** who will remain on the board as a director and as a part of the technical team.


Timothy Heenan

Mirasol Resources Ltd. promoted **Timothy Heenan** to the position of vice president of exploration. Heenan has served as Mirasol's regional manager for South America for more than 15 years. He was directly involved in several discoveries, including the famous Cerro Negro Mining District in the Province of Santa Cruz, Argentina, and several other high-profile projects throughout the region.


Leif Nilsson

Surge Copper Corp. appointed **Leif Nilsson** as CEO. **Dr. Shane Ebert** will continue as president and vice president of exploration. Most recently, Nilsson was senior vice president at an Australian multinational investment bank.

The *Indonesia Energy and Mineral Resources Ministry* has appointed **Ridwan Djamaluddin** as the ministry's new mining director general.

Jervois Mining appointed **James May** as CFO and executive general manager of finance, as it advances the financing and construction of its Idaho Cobalt Operations (ICO) in the U.S. and the restart of the São Miguel Paulista (SMP) refinery in São Paulo, Brazil.


Mikko Keto

Mikko Keto has officially taken up his position as mining president and member of Group Executive Management at *FLSmidth.* The appointment, first announced in 2019, follows Manfred Schaffer's decision to retire after more than six years as mining president. Keto joins FLSmidth from Metso, where he was president, minerals services and pumps.


Sam Palombo

Derrick Corp. appointed **Sam Palombo** as vice president, mining and industrial division. Palombo brings 20 years of industry experience in major leadership roles to Derrick. For the past eight years, Palombo has been with Weir Minerals, most recently serving as general manager, comminution, North America.


George Apostolopoulos

George Apostolopoulos was appointed vice president of global sales for *Robit.* With more than 20 years of managerial experience in the heavy equipment and mining industries across Europe, West Africa, and Central Asia, George comes with an impressive track record of sales success.


Peter Spora

Golden Star Resources Ltd. reported the untimely passing of **Peter Spora,** executive vice president of growth and discovery, on December 9, 2020. Spora joined the company in November 2019 having had a highly successful career in exploration, technical and corporate development roles at Homestake Gold, Barrick Gold Corp., Acacia Mining and La Mancha.

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Lundin Will Expand Fruta del Norte Mine

Lundin expects to produce 380,000 oz to 420,000 oz of gold from the Fruta del Norte mine (above) in 2021.

Lundin Gold will invest $18.6 million to expand its Fruta del Norte gold mine in Ecuador. The expansion is projected to be completed in 2021. It will result in a 20% increase in the mine's production and the mill throughput will increase from 3,500 to 4,200 metric tons per day (mt), according to Lundin.

Lundin Gold estimated the mine's gold production in 2021 will be between 380,000 and 420,000 ounces (oz) based on an average of 10.4 grams/mt (g/mt) and an average recovery of 90% gold. Probable mineral reserves will increase 8% to 5.41 million oz at 8.1 g/mt, as a result of a change in the mining method.

The company plans to begin construction in the first quarter of 2021, mine production will increase to 4,200 mt/d in the third quarter and the mill in the fourth quarter of 2021. It is anticipated that the expansion can be completed with minimal disruption to the operations and financed with the cash flow of operations.

In 2021, Lundin will also undertake a $11 million, 9,000-meter drilling program on two high-priority exploration targets in its concession portfolio, Barbasco and Puente-Princesa, which are located along the Pull-Apart Basin de Suárez, about seven kilometers from Fruta del Norte.

Codelco Approves $1.38B Investment for New Pit at Salvador Division

Chile state copper producer Codelco has approved a $1.38 billion project at its Salvador Division in the northern Atacama region. This new project, the Inca Pit (Rajo Inca), will increase production from 60,000 metric tons (mt) to 90,000 mt of fine copper from the first half of 2023. The project requires a 22-month pre-stripping period and a seven-month ramp up of the concentrator plant. Commissioning is expected to begin in the second half of 2022, to reach an overall production of 90,000 mt in the first half of 2023.

The investment is 33% lower than previously contemplated by Codelco in 2014, thanks to the maximization and optimization of the existing infrastructure, especially in the mine and tailings deposit areas, and the overhaul of the processes of concentrator and hydrometallurgical plants, according to the company. Savings were also achieved through the reuse of mining equipment. Once in operation, Rajo Inca will require between 25 and 30 300-mt capacity trucks, hydraulic shovels and large-capacity wheel loaders. Most of the equipment will be coming from other Codelco divisions.

Vale Invests in Renewable Energy

Vale plans to begin the Sol do Cerrado project, a solar power generation project in Jaíba, Minas Gerais, Brazil. The project involves the construction of a photovoltaic plant, including 17 sub-parks that add an installed capacity of 766 peak megawatts (MWp), with an estimated investment of $500 million, which will be eligible for sustainable financing lines.

"The investment is a strategic alternative that, in addition to helping to achieve the goals of sustainability and competitiveness, will provide a reduction of approximately $70 million per year in electricity costs," the company said, highlighting that it is part of Vale's $2 billion investment strategy to reduce carbon emissions.

The project, which is scheduled to begin operations in the fourth quarter of 2022, will produce approximately 193 average megawatts (MWm) of energy for Vale's operations annually, corresponding to 13% of the mining company's estimated demand in 2025.

Wheaton Acquires Stream From Cozamin Mine

Wheaton Precious Metals Corp. has entered into a streaming agreement with Capstone Mining Corp. regarding the Cozamin mine located in Zacatecas, Mexico. Wheaton will pay Capstone upfront cash consideration of $150 million upon closing for 50% of the silver production until 10 million ounces (oz) have been delivered, thereafter dropping to 33% of silver production for the life of the mine. In addition, Wheaton will make ongoing payments for silver ounces delivered equal to 10% of the spot silver price.

The streaming agreement became effective December 1.

For the five years starting in 2021, attributable silver production is forecast to average approximately 820,000 oz per year.

Wheaton is also in advanced discussions with Capstone regarding a potential gold stream on their Santo Domingo project, which would provide additional near-term growth for the company.

Rio Tinto Mends Relationship With PKKP

Rio Tinto and the Puutu Kunti Kurrama and Pinikura people (PKKP) have taken initial steps in rebuilding their relationship following the destruction of historic sites at Juukan Gorge in May 2020.

PKKP in cooperation with Rio Tinto have been involved in remedial works at Juukan Gorge. And Rio Tinto said these works will continue.

Rio Tinto said, "While there has been some important progress made in the relationship so far, we are not underestimating the time it will take to genuinely work together and achieve the mutual objectives of this partnership."

PKKP said it is encouraged by the steps to date, but they are the first of many that will be needed to ensure the avoidable and unnecessary destruction of cultural heritage sites, like Juukan Gorge, will never be repeated.

Kurrama Elder Burchell Hayes said, "While we have made some initial positive steps in rebuilding our relationship there is so much more we need to do in order to shape a shared future for our next generations of PKKP people working with Rio Tinto."

Acting chief executive of Rio Tinto Iron Ore, Ivan Vella, said, "We know we have a lot of work to do in order to rebuild trust and confidence in our business. I look forward to continuing the work with PKKP Traditional Owners to re-chart our partnership and build a shared future."

A mining moratorium has been extended around the Juukan Gorge and a purpose-built facility is being established to store artifacts discovered during heritage preservation works.

Rio Tinto has also introduced changes to ensure heritage sites of exceptional significance, like the Juukan Gorge rock shelters, are protected and preserved. These include:

- Reassessing any activities that have the potential to impact heritage sites, with an immediate focus on locations that could be impacted over the next 18 to 24 months. Monitoring of operational impacts has also been increased.
- Executive accountability for impacts to heritage sites where avoidance is not possible.
- A commitment to modernize agreements with traditional owners.
- Creation of a new standalone Communities and Social Performance Area of Expertise, which is aligned with the existing Health, Safety, Environment (HSE) functions.
- A $50 million investment to increase employment opportunities for Indigenous Australians through business and enhance Indigenous leadership in our Australian operations.
- The creation of a new role, appointing a senior Indigenous leader as chief advisor, Indigenous Affairs, who has a direct reporting line to the chief executive.
- Ongoing consultation with traditional owners about a proposal to establish an indigenous advisory group to help the company better incorporate traditional owners' views and concerns into its operations.

Red 5 Receives Final Permit for Processing Plant

Red 5 Ltd. has taken another significant step toward the development of its 2.4-million-ounce 16-year life-of-mine King of the Hills (KOTH) gold project in Western Australia, after receiving approval for the Mining Proposal from the Western Australian Department of Mines.

All approvals for the commencement of construction of the processing facility are now in place and the engineering, procurement and construction (EPC) contractor, MACA Interquip, has mobilized to the site and commenced earthworks in the process plant area.

The EPC contract — encompassing the KOTH processing facility, equipping of the bore fields, high voltage power distribution, workshop, warehouse and bulk earthworks — is being undertaken as a fixed-price contract. The detailed design of the processing facility is well advanced, as many aspects of the circuit are being leveraged off previous similar plant designs and the platework for the CIL tanks has been ordered.

A 15-megawatt SAG mill, shell and motors have been shipped from Houston to Johannesburg to undergo refurbishment and upgrade.

"With final approval for the commencement of construction of the processing plant now in place, we have a hive of activity under way at King of the Hills, with bulk earthworks progressing and installation of the village well under way," Red 5 Managing Director Mark Williams said. "Major components of the mill are being manufactured or undergoing refurbishment and upgrade, putting all of our workstreams on-track for the achievement of first gold production from the 4 million-metric-ton-per-year KOTH bulk mining operation in the June quarter of 2022."

Red 5 selectively mines high-grade gold veins underground at KOTH and trucks the ore to Red 5's nearby Darlot processing plant. A new mill will allow the mine to process ore on-site.

Resolute Sells Interest in Bibiani Gold Mine

Bibiani is placed on care and maintenance after Resolute acquired it in 2014.

Resolute Mining has agreed to sell its interest in the Bibiani gold mine (Bibiani) in Ghana, through the sale of shares in Mensin Bibiani Pty Ltd., to Chijin International (HK) Ltd., a subsidiary of Chifeng Jilong Gold Mining Co. Ltd, for total cash consideration of $105 million. Resolute would receive a $5 million deposit when the agreement is signed and the remaining $100 million on completion of the transaction, which is expected in March 2021.

"Resolute is proud of its contribution to Ghana and pleased that our investments at Bibiani in exploration, feasibility studies, and community support will provide a strong base for future success and value creation," Resolute Interim CEO Stuart Gale said.

Chifeng said it is committed to injecting the necessary capital immediately to achieve the rapid restart of Bibiani in the shortest possible timeframe.

"We are delighted to have secured such a significant gold mining asset in the current market," Chifeng Executive Chairman Wang Jianhua said. "Resolute has defined an exciting future for Bibiani as a high margin, long life underground gold mining operation."

Transaction completion is conditional upon approval by Ghana Minister of Lands and Natural Resources, Australia's Foreign Investment Review Board, and various Chinese governmental approvals.

Resolute is required to notify Chifeng if any superior proposal is received for Bibiani, following which Chifeng has 20 business days to match the offer. If Chifeng does not match the offer, either Chifeng or Resolute may terminate the agreement, upon which a break fee of $10 million will be payable by Resolute. The break fee is also payable by Resolute if Chifeng terminates the agreement due to a breach by the company of its obligations under the agreement.

Freeport Sells Interest in Undeveloped DRC Project

Freeport-McMoRan Inc. has completed the sale of its interests in the Kisanfu undeveloped project in the Democratic Republic of the Congo to a wholly owned subsidiary of China Molybdenum Co. Ltd. (CMOC) for $550 million.

The Kisanfu project is a large, undeveloped cobalt and copper resource discovered by Freeport's exploration team. Following Freeport's sale of its interest in the adjacent Tenke Fungurume mine in 2016, the company said the Kisanfu project was no longer strategic to its long-term strategy.

As of December 31, 2019, Freeport had no proven and probable reserves associated with the Kisanfu project. FCX expects to record an after-tax gain of approximately $350 million in the fourth quarter of 2020 associated with this sale.

Botswana Extends Karowe's Mining License to 2046

Lucara Diamond Corp.'s application for the renewal of the mining license for its Karowe mine has been approved by Botswana's minister of Mineral Resources, Green Technology and Energy Security. The renewal was effective January 4 for a period of 25 years, securing Lucara's mining rights to 2046 and marks a critical step in the formal sanction of the Karowe underground expansion project.

"The receipt of our mining licence renewal and extension to 2046 is an important milestone for the Karowe underground expansion project, paving the way for the completion of a supplemental debt financing and full project sanction later this year," President and CEO Eira Thomas said. "Lucara is grateful for the confidence and support demonstrated by the government of Botswana as we work to expand our operations at Karowe underground, for the benefit of the government and the people of Botswana together with Lucara's shareholders. We look forward to continued cooperation and a mutually rewarding partnership with the government of Botswana."

The Karowe underground expansion project, which continued to advance in 2020 under a revised $22 million budget in response to COVID, focused on time critical-path items, detailed engineering and design, and limited earth works and geotechnical studies. The company continues to explore debt financing options for the underground expansion and anticipates financing to be in place by the second half of this year. The underground expansion program has an estimated capital cost of $514 million and a five-year period of development, with first ore anticipated from underground in 2026.

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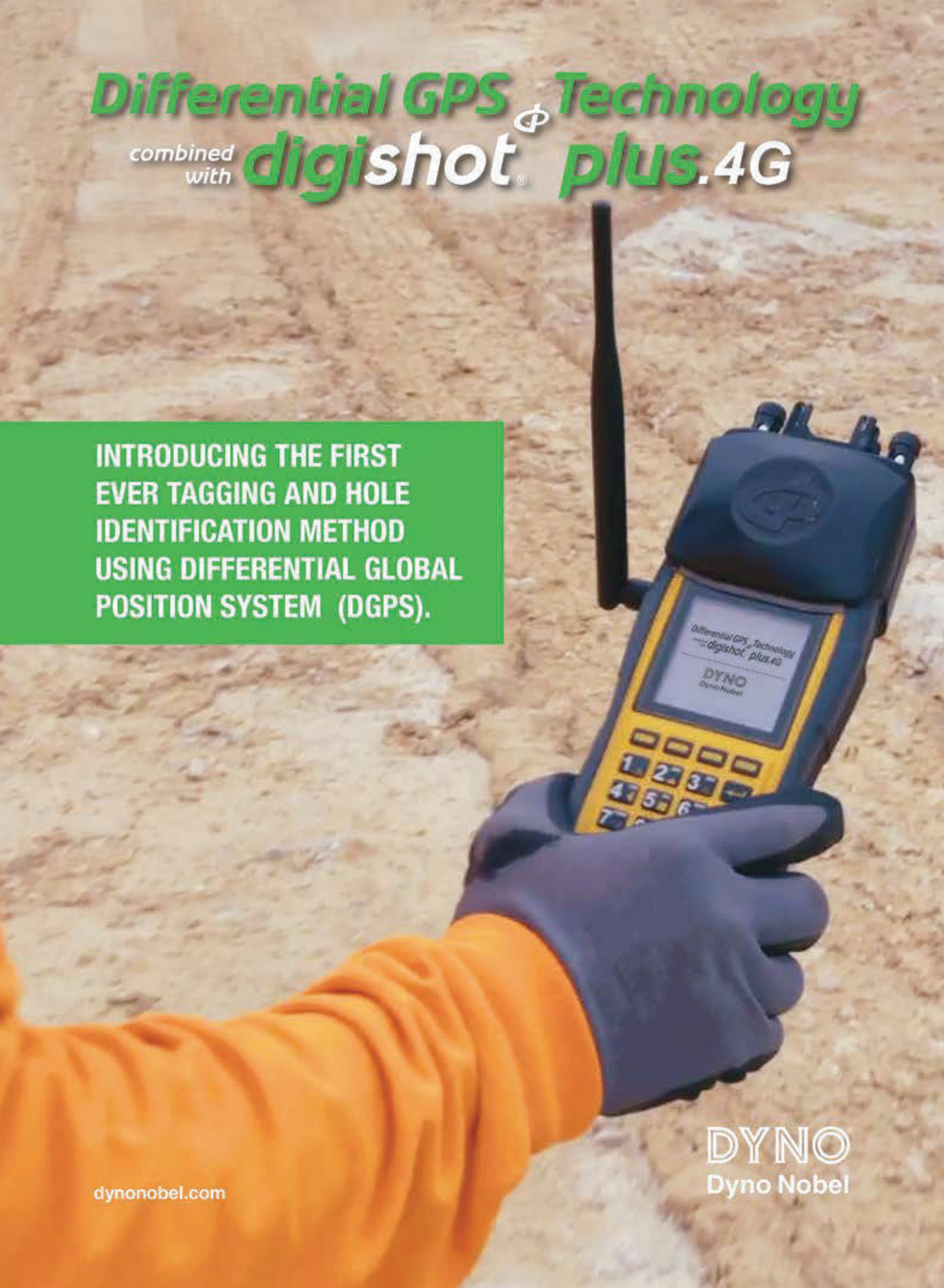

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Allegiance Plans to Restart New Elk Mine

Much of the infrastructure for the New Elk mine is intact and prime for a restart.

Allegiance Coal Ltd. announced that, depending on funding, it plans to commission the New Elk coking coal mine in southeastern Colorado by the end of Q2 2021. The company has embarked upon an ambitious plan to create a new source for metallurgical coal. They have also refined their sales strategy to include blending New Elk's low-sulfur, high-vol B (HVB) coal with high-sulfur, high-vol A (HVA) coals from Alabama to produce a premium product, which would be exported from New Orleans, Louisiana. The blending scheme allows Allegiance to achieve its goal of 1.4 million metric tons per year (mt/y) more quickly and allows the company to delay the investments it would have had to make to achieve those goals on its own.

Using this approach, Allegiance announced a revised mine plan for New Elk mine plan during April. The new mine plan keeps things simple and focuses on becoming efficient and profitable in the early years of production. It reduces the startup capital requirement and the amount of money the company would have to raise to commence production. It also reduces the sustaining capital requirement in the early years of production to invest retained earnings into debt reduction rather than capital expenditure.

Allegiance Coal closed the New Elk acquisition during October acquiring all the shares in New Elk Coal Co. LLC, which owned the New Elk mine. "Timing for completion of the acquisition of New Elk could not have been better with the current strong recovery in coking coal prices toward pre-COVID levels, as previously forecast by analysts," Allegiance Chairman and Managing Director Mark Gray said.

Cline Mining Corp. acquired the property, formerly known as the Allen mine, in 2008 for C$17 million. In 2010, the mine was reopened as the New Elk mine. Cline upgraded the mine's infrastructure, including the wash-plant and supporting infrastructure, developed a second underground portal entry, and recommenced production at an estimated capital cost of some C$150 million. Production recommenced in 2011 and the mine operated for several months, but was forced to close in July 2012 when world hard-coking coal prices plummeted. Cline filed for bankruptcy protection, which resulted in all liabilities being extinguished, and the senior secured creditor ultimately taking ownership of Cline and its subsidiary New Elk Coal Co. It has remained on care and maintenance since.

In addition to assuming the remaining Cline debt of approximately $31.6 million, Allegiance will issue $4 million in debt repayment shares. Another $3 million cash payment will be made to Cline once the $5.2 million cash reclamation bond is released to New Elk Coal Co. after Allegiance posts the new bond.

Based in Vancouver, Allegiance is focused on developing and mining metallurgical coal projects in the U.S. and western Canada. The company is also developing the Tenas metallurgical coal project, located in northwest British Columbia, in partnership with Itochu Corp.

Malabar Receives Approval for Maxwell Underground

Malabar Resources said the New South Wales (NSW) Independent Planning Commission (IPC) approved the Maxwell Underground Project, located near Muswellbrook in the Upper Hunter Valley. The determination follows the project's comprehensive and technical review by independent experts and rigorous assessment by the NSW Department of Planning, Industry and Environment.

Malabar Chairman Wayne Seabrook said Malabar is eager to begin the necessary next steps to begin construction in 2021. The 30-year Maxwell Underground Project will produce mostly metallurgical-grade coal and provide about 250 construction jobs and 350 jobs during operation, generating $55 million in annual wages once the project is up and running.

Altius Will Appeal Alberta Court Decision

The Alberta Court of Queen's Bench recently dismissed a claim Altius Minerals Corp. brought against both the governments of Canada and Alberta (the defendants) in relation to regulatory changes that will force the discontinuation of coal-fired electrical generation from the Genesee and other Alberta power plants by 2030. The lawsuit sought compensation for actions that Altius believed were tantamount to expropriation of its Genesee royalty asset.

The defendants filed for dismissal of the Altius claim. On January 4, a master of the court granted the application to dismiss the statement of claim on a summary basis and without a trial. Altius said it believes this decision is in error and incorrectly applies the law on taking and constructive expropriation. It said it is entitled to a full hearing before a justice of the court and intends to appeal the decision promptly.

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MARCH 14-17, 2021

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Tucson Hosts Haulage & Loading 2021

Join us for the three most productive days in open-pit mining. Held every two years, Haulage & Loading is the conference for surface mining professionals. The event, which brings mine operators and suppliers together in an informal Arizona resort setting, focuses on improving surface mining operations in general and truck-shovel loading in particular. The technical program offers continuing education for mining engineers and mine managers and the exhibit allows suppliers to interact with customers.

In 2019, nearly 150 mining professionals attended the event, including personnel from Agnico Eagle Mines, Asarco, Barrick Gold, Cleveland Cliffs, Colowyo Coal, Detour Gold, Freeport-McMoRan, Hudbay Resources, Kinross Gold, Peabody Energy, Syncrude Canada, Suncor Energy, Teck Resources and Usibelli Coal.

The venue, the Hilton El Conquistador Resort in Tucson, Arizona, and Mining Media International (MMI) are working to provide a clean and safe format to meet and conduct business. Adhering to CDC protocols for COVID-19, the ballroom and outdoor settings offer ample space for the proper social distancing of a group this size. Face masks and sanitary stations will be established throughout the venue. MMI is designing a touchless registration program to minimize the risk of the possible transmission of the virus. The Hilton El Conquistador Resort's COVID-19 policy is available at the bottom of the accommodations tab on the Haulage and Loading website.

We hope to see you at the El Conquistador for Haulage & Loading 2021.

Steve Fiscor, Publisher & Editor
Mining Media International

Registration Rates & Deadlines

	Advanced 10/16/20 - 12/31/20	Regular 1/1/21 - 3/14/21	Onsite Begins 3/15/21
Full Conference Delegate Includes engineers and management personnel from mining companies.	$599	$699	$699
Non-exhibiting Suppliers Includes companies who wish to conduct business without purchasing a sponsorship.	$3,200	$3,400	$3,400

Tentative 2021 H&L Technical Program

Monday, March 15, 2021

Session 1: Operating Approaches

Nevada Gold Mining Operational Efficiencies in the Wake of COVID-19
By Terry Morris, P.Eng., mine manager, Nevada Gold Mines

Using Technology to Assess a Potential Fleet Improvement Strategy
By Brian M. Wright, Fort Knox MEM senior reliability engineer, Kinross Gold

Optimum Economic Assignment of Trucks
By Benton T. Kelly, mining consultant (former mining engineer for Drummond Co.)

Session 2: Emerging Technology

Considerations for a Transition to Autonomous Mining
By Drew Larsen, director of business development, ASI Mining

A Golden Opportunity: Gamification in Open-pit Management
By Phillip Hotzen, technical account manager, MineWare

Full-scale Numerical Simulations to Optimize Rope Shovel Loading Performance
By Andreas Svanberg, industrial doctorate candidate, Boliden

Change in the Advent of New Technology Innovation
By Andrew Scott, executive chairman, Queensland Robotics

Tuesday, March 16, 2021

Session 3: Safety & Training

Potential New MSHA Regulations for Surface Mobile Equipment and Powered Haulage Equipment
By Mark E. Heath, Spilman, Thomas & Battle PLLC, (co-chair firm MSHA and OSHA Practice Groups)

GMG & ISO Coming Soon Surface Mining Operational Safety Focused Standards
By Glenn Johnson, senior mining engineer-technology, Teck Metals

Personnel Safety Around Fixed Equipment
By Mike Walling, general manager of safety electronics, Strata Worldwide

Innovation in Mine Training Achieves Supervisor Proficiency at Faster Rates
By Richard Beesley, professional services manager, Immersive Technologies

Session 4: Optimization Strategies

An Integrated Approach to ROM Fragmentation, FMS and Impact of Primary Crusher Feed
By Tom BoBo, director of business development, Split Engineering, Hexagon

Benefits of Using On-Board Scales on Underground and Above Ground Mining Vehicles
By Bill Zimmerman, R&D design engineer, VPG On-board Weighing, Vulcan On-board Scales

Emerging Technology in Non-traditional Surface Mining Loaders
By Erik Zimmerman, product manager-mining, Wirtgen GmbH

Optimizing Payload Management
By Modular Mining

Wednesday, March 17, 2021

Session 7: Workshop (Virtual): Haulers & Haul Road Design

By Roger Thompson, principal, Mineravia Consulting; and Tim Joseph, principal, JPI Canada and professor emeritus, University of Alberta

*Preliminary, January 6, 2021 (subject to change)

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2021 HAULAGE & LOADING EXHIBITION AND CONFERENCE

MARCH 14-17, 2021

Safety Protocols

Now and going forward, your health and safety are paramount to this event, and we are making sure there is a comprehensive health and cleanliness program in place to ensure the safety and health of our attendees, while adhering to the CDC protocols for COVID-19.

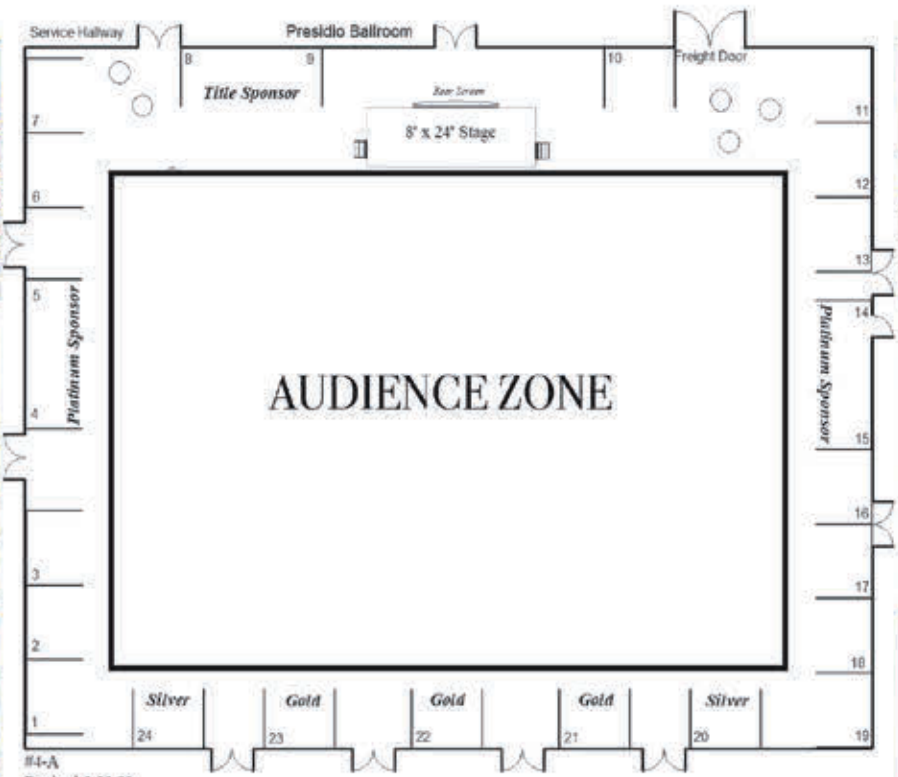
The following are some of the safety protocols that MMI and the Hilton El Conquistador have put into place. If you have any questions or concerns as it relates to safety protocols, reach out to Kristin Thompson at kthompson@mining-media.com.

MMI Safety Protocols

- Contactless on-site registration process
- Self-serve print stations at registration
- Physical barriers between registration staff and attendees
- Disposable face masks provided upon request
- Socially distanced general session & meal seating
- Visual indicators such as floor graphics & signage for one-way exit/entry
- Integration of boundaries and safety barriers as appropriate
- Safety greeter at entrance of space to ensure everyone is wearing masks and following guidelines
- Flexibility in registration and cancellation policies

Hilton El Conquistador Safety Protocols

- Employee temperature checks upon arrival at work
- Proper cleaning and disinfecting of the public areas where people have direct and constant contact
- Staff fully trained in sanitization and food handling procedures
- Hand sanitizing stations throughout the venue, show floor and session space
- Seated dining
- Individually packaged meals
- Buffet served by hotel staff with personal protection equipment – not self serve
- Screens present at all food displays
- Signage suggesting limited number of passengers in elevators
- Plexiglass barriers at front desk



RUSAL Extends ASI Certification

Five of RUSAL's aluminum smelters have achieved Aluminum Stewardship Initiative (ASI) certification. Boguchansky aluminum smelter (BoAZ), Bratsk aluminum smelter (BrAZ), Krasnoyarsk aluminum smelter (KrAZ), KUBAL (Kubikenborg aluminum AB) and Sayanogorsk aluminum smelter (SAZ) have successfully passed the certification audit for compliance with ASI Performance and ASI Chain of Custody Standards and have been included in RUSAL's current ASI certificates. The independent third-party audits of the operations were carried out by DNV GL.

With the extension, nine of RUSAL's facilities have already confirmed that their activities meet the requirements of the ASI. In 2019, RUSAL's headquarters and three production sites — Boksit Timana (bauxite mining), Urals aluminum smelter (alumina refining) and Irkutsk aluminum smelter (aluminum smelting, casthouse and alloys production) — were successfully certified against the ASI Standards. The company said it plans to continue certification of its facilities.

"The expansion of the ASI certification serves as additional confirmation of our success in implementing best ESG practices," RUSAL's CEO Evgenii Nikitin said. "Despite the volatility of the global market, RUSAL always follows sustainable principles and strives to actively participate in the new, low-carbon reality, meeting the demand for products with minimal impact on the environment."

'Green' aluminum ingots made in Russia sit on pallets at the Boguchansky smelter.

The ASI Performance Standard has been developed in collaboration with the industry, downstream users and nongovernmental organizations and is recognized as the only sustainability supply-chain standard applicable across the entire aluminum value chain. The ASI Performance Standard requirements cover 11 groups of criteria ranging from business ethics and governance, environmental performance, human rights and social practices.

In related news, Rusal's parent, En+ Group, the largest private sector generator of hydropower, is upgrading the Irkutsk hydroelectric power plant (HPP) in eastern Siberia by installing a second hydraulic turbine. En+ Group's HPP assets allow it and Rusal to produce and sell "green" aluminum.

"Having already launched the first new hydraulic unit at the Irkutsk HPP, we are continuing to progress with the HPP's equipment modernization project," Mikhail Hardikov, head of En+ Group's energy sector, said. "This will increase overall performance and the HPP's capacity by another 23 megawatts. It will also allow us to reduce the repair works' cost, improve units' operating characteristics and improve occupational safety."

The Irkutsk HPP renovation program is part of En+ Group's large-scale modernization project called New Energy, implemented at the Angara-Yenisei cascade HPPs (Ust-Ilimsk, Bratsk, Irkutsk and Krasnoyarsk HPPs), which is worth 21 billion roubles ($269 million). It was launched in 2007 at the suggestion of the company's founder Oleg Deripaska.

NEWS - CALENDAR OF EVENTS

MARCH 1-5, 2021: **SME Annual Conference & EXPO, (Virtual).** Contact: Web: www.smeannualconference.com.

MARCH 7-10, 2021: The annual meeting of the **Prospectors & Developers Association of Canada, (Virtual).** Contact: Web: www.pdac.ca/convention/attendee-info/pdac-2021-convention-goes-virtual.

MARCH 14-17, 2021: **Haulage & Loading 2021, Hilton El Conquistador Resort, Tucson, Arizona, USA.** Contact: Web: www.haulageandloading.com.

APRIL 19-23, 2021: **Expomin, Espacio Riesco, Santiago, Chile.** Contact: Web: www.expomin.cl.

MAY 4-6, 2021: **Canadian Institute for Mining (CIM), Montreal, Quebec, Canada.** Contact: Web: convention.cim.org.

MAY 4-6, 2021: **US Coal Show/Longwall Edition, Pittsburgh, Pennsylvania, USA.** Contact: Web: www.longwallusa.com.

MAY 11-13, 2021: **14th International Gold, Silver and Copper Symposium, Lima, Peru.** Contact: Web: simposium-del-oro.pe.

JUNE 1-3, 2021: **Euro Mine Expo (Virtual), Kraft Center, Skelleftea, Sweden.** Contact: Web: www.eurominexpo.com.

JUNE 7-11, 2021: **Elko Mining, Elko, Nevada, USA.** Contact: Web: www.ExploreElko.com.

SEPTEMBER 13-15, 2021: **MINExpo INTERNATIONAL, Las Vegas, Nevada, USA.** Contact: Web: www.minexpo.com.

2021 Global Mining Investment Outlook

Many of the projects postponed during the pandemic will proceed this year

By Joseph F. Govreau

Last year was a challenging year to say the least, but also one that presented opportunities for 2021 and beyond. A year ago, the mining sector was ramping up with regard to capital expenditures, with plans for about a 12% increase in capital spending for the year, continuing a trend of increased capital spending, which started at the bottom of the cycle in 2017 (metal prices had hit lows in late 2016). All of that changed when the COVID-19 pandemic threw a wrench into the global economy in March 2020. Mining firms have been recalibrating business plans since.

Companies learned, very quickly, how to operate safely in the pandemic environment. This includes working at a social distance or remotely. New technological advancements in the form of process or equipment modifications have been accelerated in this environment, which is giving way to opportunities for companies offering automation, digitalization, remote access or related services.

To conserve cash, most mining firms deferred capital expenditures and halted or slowed project activity in 2020. GDP growth, an important leading indicator for capital spending in the mining industry, is estimated by the International Monetary Fund (IMF) to have declined by about 4.9% in 2020.

As of the end of 2020, the number of metals and mining industry projects impacted by the pandemic exceeded 1,600, representing $212 billion, according to surveys conducted by Industrial Info. About 66% of that is for mining projects, with the remainder being for downstream processing and smelting sectors. The good news is that most of these projects are merely being delayed as opposed to canceled. Most delays range from three to 18 months, with a lot of project development being pushed into 2021-2022 timeframe.

Overall capital spending in 2020 ended down about 3% when compared to 2019. Now, that doesn't seem so bad, all things considered. And indeed, the mining industry is faring much better than other sectors, such as oil and gas, during this downturn.

Improving Leading Indicators in 2021

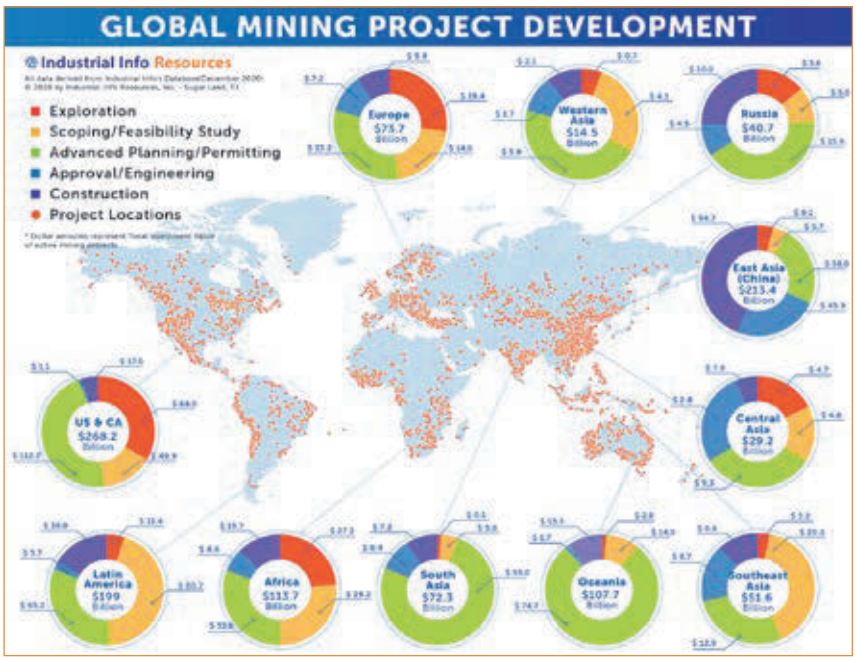
Government financial stimulus and an early and strong recovery in China have lessened the impact and paved the way for what should be a much-improved 2021. Metals prices have improved significantly from early 2020 lows. The IMF is forecasting GDP growth for 2021 to be in the 5.4% range. This bodes well for amplified capital expenditures in 2021 and Industrial Info is expecting at least a 10% to 15% increase based on what we are hearing from mining firms.

As a safe haven investment, gold reached a historic high price in 2020, exceeding $2,000 per ounce (oz) for the first time. The price of gold has essentially doubled since hitting the bottom of the market at the end of 2016. This is incentivizing investment in gold mining projects and operating gold mines to increase production where possible to take advantage of the favorable price environment. Industrial Info is tracking more than 2,000 gold mining projects totaling $170 billion worldwide.

Prices for other metals improved as well. Copper and iron ore prices reached seven-year highs as 2020 concluded. Miners worldwide welcomed these higher prices, which will provide the impetus to invest.

There are several reasons to be optimistic about capital spending in 2021 and beyond. The long-term drivers of spending, such as population growth, urbanization, and electrification, remain intact, and will continue to drive demand for metals and minerals. And while COVID cases continue to rise, the number of vaccines being released and distributed is bringing hope that there is light at the end of the tunnel.

Globally, there are more than 13,000 active capital projects in the mining industry, representing $1.18 trillion in total investment value, according to Industrial Info's Business Intelligence. These are projects that run from the early exploration stages, through planning, engineering and construction. Researchers have noted increased activity in projects reaching the feasibility stage, as well as projects reaching the approval/engineering stages and even those going to construction.



Last year marked the lowest number of new mines coming online since Industrial Info has been tracking these stats. Roughly 240 mines came online in 2020 compared with 520 during 2014. There are many reasons for the decline. Easy-to-access resources are dwindling. New mines tend to be more remote, expensive and difficult to permit. Where possible, mining firms are looking to life extension projects and new satellite open-pit or underground mines at existing assets rather than building new mines. There also was a significant capital outlay for new mines built during the mining boom peaking in 2014 and companies have been concentrating on optimizing production from those assets. For 2021, new mine construction, including grassroot mine and brownfields, account for 20% of current projects, while in-plant expansions, additions, retrofits, modernizations, automation and maintenance projects account for 80% of the projects in 2021.

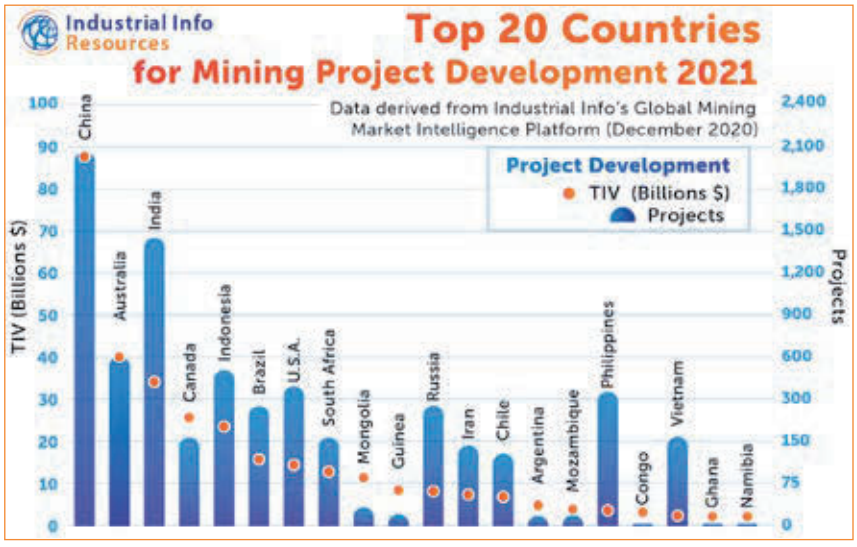
Decarbonization Fever

The pandemic blues of 2020 will be replaced by decarbonization fever in 2021. The transition toward electric powered vehicles will continue to accelerate. General Motors, for example, plans to spend $2.5 billion retrofitting its plant in Tennessee for electric vehicle production. In the long term, projects like this will require more batteries, fuel cells and other technology and will increase demand for energy transition metals including lithium, cobalt, graphite, nickel, aluminum and others. Electric vehicles are projected to require at least four times as much copper content as conventional automobiles.

Despite the rosy long-term outlook for electric vehicle demand and thus battery raw material prices, the lithium market has been on a downtrend for the past two years. Prices for lithium surged over 2016 and 2017, but additional capacity expansions outstripped demand growth between 2018 and 2019, triggering a slump in prices.

The COVID-19 pandemic added further bearish pressure to lithium prices in 2020. The result has been some capacity idling and planned expansions deferred until the market returns. Nevertheless, there's a large number of lithium mining and processing projects planned from the exploration stage through to advanced planning.

Mining companies are increasingly installing captive power plants or outsourcing to build/own/operate companies to supply power. More and more, these plants are fueled by renewables, mainly solar and wind, along with hybrid installations with battery storage, and are getting away from diesel fuel. Industrial Info is tracking about 870 projects totaling $36 billion in power generation projects pertaining to mines.



Accounting for 27% share of global electricity production and an important steelmaking ingredient, coal represents the largest sector for investment in the mining industry accounting for 24% of the project spending. After coal, copper, precious metals, iron ore and potash/phosphate round out the largest markets for capital spending.

Demand for iron ore is recovering nicely, especially in China, where infrastructure stimulus is keeping steel mills busy. Steelmakers in China are in the midst of a massive relocation and replacement program, where complete steel mills are being built anew in coastal areas with new technology that improve emissions reduction and capacity at the same time. Chinese steelmakers are planning $153 billion worth of projects, accounting for about 45% of the value of the world's steel projects.

Many countries are implementing programs to encourage domestic development of critical minerals such as rare earth metals. The Russian government recently announced plans to spend $1.5 billion to build out 11 projects for rare earth production. Industrial Info is tracking more than $13 billion rare earth mining and processing projects worldwide. There are currently 29 projects in the U.S. and Canada for rare earth mining and production.

Mining Investment Destinations

Looking at the top 20 countries for mining project development in 2021, China leads the way, followed by Australia, India and Canada. In addition to Canada, the Americas are represented by Brazil, the U.S., Chile and Argentina. Surprisingly absent from the top 20 list this year is Peru and Mexico, both of which have been severely impacted by the pandemic and other social issues causing mining firms to delay some projects beyond 2021. Africa continues to be a continent of growing mining exploration and development activity by many countries, including China and India, looking to secure long-term resource supply. African countries including South Africa, Guinea, Mozambique, Congo, Ghana and Namibia will lead the continent in spending for 2021.

Lengthy permitting and regulatory processes continue to constrain new mine project development in the U.S. In recent years, increased attention has been given to reducing the regulatory load on critical minerals projects on federal lands; however, it is expected the government stance on this may change with the new administration.

Potash, phosphate and fertilizer projects account for more than 25% of project activity in the U.S. and Canada, where there are 35 potash and phosphate projects.

The pandemic, along with economic, geopolitical and social issues, continue to constrain development in many countries in Latin America. In Brazil, Vale recently approved a $1.5 billion expansion of the Serre Sul mine, which aims at increasing

iron ore capacity from 90 million tons per year (t/y) to 120 million t/y.

In Chile, Codelco has restarted copper projects and mines that were shuttered due to the pandemic. The company is in the middle of a $40 billion, 10-year upgrade and will resume work at El Teniente and Chuquicamata.

Companies like Glencore have announced coal production cutbacks in Australia. BHP Billiton recently announced plans to sell its coal assets. As a result, Industrial Info expects Australia's coal miners to reduce capital expenditure reductions and delay projects until the market improves. Still, Bravus is moving ahead with the Carmichael coal megaproject in Queensland and other major coal projects continue.

In contrast, Australia's iron ore miners are continuing to expand to meet growing demand from Asia (China). Major Australian iron ore miners — BHP, Rio Tinto and Fortescue — are benefiting from surging iron ore prices and supply holdups in Brazil. China currently imports almost 70% of its iron ore from Australia.

In conclusion, there are good reasons for miners and those who invest in mining to be optimistic going into 2021 as most leading indicators point to a rebound, and long-term drivers for capital spending remain intact. Mining companies continue to reinvent themselves and reinvest in mining assets to keep up with the world's changing commodity appetite, as well as decarbonization and sustainability targets. This will drive innovation in new processing technologies, automation and emissions reduction.

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Major Mining Projects, Year-end 2020*

Project Name	Location	Status	Type	Products	Owner	Project Cost (US$M)**
BASE METALS:						
Copper						
Baimskaya	Russia	Feasibility, delayed	OP	Cu, Au	KAZ Minerals	8,000
Resolution	USA	Prefeasibility	UG	Cu, Mo	Rio Tinto, BHP	6,000
Tampakan	Philippines	Feasibility	OP	Cu, Au	Sagittarius	5,900
Quellaveco	Peru	Construction	OP	Cu, Mo	Anglo American, Mitsubishi	5,300
Quebrada Blanca Phase 2	Chile	Construction	OP, Conc.	Cu	Teck, Sumitomo	4,800
Pebble	USA	Prefeasibility	OP	Cu, Au	Northern Dynasty	4,500
El Teniente	Chile	Construction, expansion	UG	Cu, Mo	Codelco	3,900
Oyu Tolgoi	Mongolia	Construction, expansion	UG	Cu, Au	Rio Tinto, Gov't. of Mongolia	3,600
Frieda River	PNG	Feasibility	OP	Cu, Au	PanAust, Highlands Pacific	3,600
NuevaUnion	Chile	Feasibility	OP	Cu, Au	Newmont, Teck	3,500
Schaft Creek	Canada	PEA	OP	Cu, Au	Teck, Copper Fox	3,256
El Pachón	Argentina	Feasibility	OP	Cu, Mo	Glencore	3,000
El Arco	Mexico	Prefeasbility	OP, Conc., SX-EW	Cu	Southern Copper	2,900
Los Chancas	Chile	Feasibility	Conc., SX-EW	Cu	Southern Copper	2,800
CuMo	USA	Prefeasibility	OP	Cu, Mo	American CuMo	2,800
Alpala	Ecuador	Prefeasbility	OP	Cu, Au, Ag	SolGold	2,800
Centinela Phase 2	Chile	Feasibility, delayed	OP	Cu	Antofagasta Minerals	2,700
Collahuasi	Chile	Expansion, conceptual	Plant, Bioleach	Cu, Mo	Anglo American, Glencore	2,600
Michiquillay	Peru	Feasibility/Planning	OP	Cu, Mo	Southern Copper	2,500
Agua Rica-Alumbrera	Argentina	Prefeasbility	OP	Cu	Yamana, Glencore, Newmont	2,400
Los Azules	Argentina	PEA	OP	Cu, Au	McEwen	2,363
Casino	Canada	Feasibility	OP	Cu, Au	Casino Mining	2,150
Santo Domingo	Chile	Feasibility	OP	Cu, Fe, Co	Capstone, KORES	2,100
Rosemont	USA	Feasibility, delayed	OP	Cu	Hudbay	1,920
Vizcachitas	Chile	PEA	OP	Cu, Mo	Los Andes Copper	1,900
Weda Bay	Indonesia	Feasibility	Smelter	Cu	Tsingshan Steel	1,800
La Granja	Peru	Prefeasibility	OP	Cu	Rio Tinto	1,650
Kennecott LOM	USA	Construction	OP	Cu	Rio Tinto	1,500
Tia Maria	Peru	Construction, delayed	OP	Cu	Southern Copper	1,400
Kamoa-Kakola	Dem. Rep. Congo	PEA	UG, Complex	Cu	Ivanhoe, Zijin, Gov't. DR Congo	1,360
Ann Mason	USA	PEA	OP	Cu, Mo	Hudbay Minerals	1,350
Udokan	Russia	Construction	OP	Cu, Ag	Baikal Mining	1,350

Project Name	Location	Status	Type	Products	Owner	Project Cost (US$M)**
Los Pelambres	Chile	Expansion, suspended	OP	Cu	Antofagasta Minerals	1,300
West Mustgrave	Australia	Prefeasibility	UG	Cu, Ni	OZ Minerals	1,100
NorthMet Phase 1	USA	Permitting	OP/Complex	Cu, Ni, PGM, Co	Polymet	945
Arctic	USA	Feasibility	OP	Cu, Zn, Pb	Trilogy Metals	905
Filo del Sol	Chile	Prefeasibility	OP	Cu, Au	Filo Mining	792
Coroccohuayco	Peru	Feasibility	OP	Cu	Antapaccay Mining	590
White Pine North	USA	PEA	UG	Cu, Ag	Highland Copper	512
Mt. Isa/Townsville	Australia	Construction, expansion	Smelter, refinery	Cu	Glencore	378
Eva	Australia	Feasibility	OP	Cu	Copper Mountain Mining	350
El Pilar	Mexico	Construction	OP	Cu	Southern Copper	310
Prieska	South Africa	Feasibility	UG	Cu, Zn	Orion Minerals	284
Black Butte	USA	Feasibility	OP	Cu	Sandfire Resources	275
T3 Motheo	Botswana	Feasibility	OP	Cu, Ag	Sandfire Resources	259
Copperwood	USA	Feasibility	UG	Cu	Highland Copper	245
Kutcho	Canada	Feasibility	UG	Cu, Zn	Kutcho Copper	221
E26 Lift 1 North	Australia	Construction	UG	Cu	China Molybdenum, Sumitomo	200
Zaldivar CuproChlor	Chile	Construction	HP L	Cu	Barrick	189
El Domo	Ecuador	PEA	OP/UG	Cu, Au	Adventus	168
Gediktepe	Turkey	Prefeasibility	OP	Cu, Zn, Au, Ag	LIDYA	164
Cadia Stage 2	Australia	Construction, expansion	Plant	Cu, Au	Newcrest Mining	132
Copper Mountain	Canada	Prefeasibility, expansion	Plant	Cu, Au, Ag	Copper Mountain Mining	123
Hog Ranch/Bells	USA	Scoping	HP L	Cu	Rex Minerals	58
Nickel						
Wingellina	Australia	Feasibility	OP	Ni, Co	Metals X	2,500
Decar	Canada	Prefeasibility	OP	Ni, Co, Fe	FPX Nickel	1,670
Sunrise	Australia	Feasibility	OP, Conc.	Ni, Co, Sc	Clean TeQ	1,330
Rönnbäcken	Sweden	Prefeasibility, suspended	OP	Ni, Co	Nickel Mountain Resources	1,260
Dumont	Canada	Feasibility	OP	Ni, Co	Waterton	1,000
Araguaia Stage 1 & 2	Brazil	Feasibility	OP	Ni	Horizonte Minerals	692
Vermelho	Brazil	Prefeasbility	OP	Ni	Horizonte Minerals	652
South Cluster Phase 1 & 2	Russia	Construction, expansion	OP/UG, Conc.	Ni, PGM	Nornickel	616
Eagle's Nest	Canada	Feasibility	UG	Ni, Cu, PGE	Noront	609
Talnakh Phase 3	Russia	Construction, expansion	Smelter	Ni	Nornickel	544
Santa Rita	Brazil	PEA	OP/UG	Ni, Cu, Co	Atlantic Nickel, Appian	355
Samapleu	Côte d'Ivoire	PEA	OP, Complex	Ni	Sama Resources	282
Mt. Thirsty	Australia	Prefeasibility	OP	Ni, Co	Barra Resources, Conico	280
Kambalda	Australia	Construction	UG	Ni, Cu, PGE	Mincor Resources	179
Zinc/Lead						
Izok Corridor	Canada	Feasibility	OP	Zn, Cu	MMG Ltd.	2,500
Admiral Bay	Australia	Prefeasibility	UG	Zn, Pb	Metalicity	837
Hilarion	Peru	Prefeasibility	UG	Zn, Pb	Nexa Resources	585
Pine Point	Canada	PEA	OP/UG	Zn, Pb	Osisko Metals	555
Citronen	Greenland	Feasibility	UG	Zn, Pb	Ironbark, Nyrstar	514
Tala Hamza	Algeria	Feasibility	UG	Zn, Pb	Terramin, ENOF	413
Macmillan Pass	Canada	PEA	OP	Zn, Pb	Fireweed Zinc	404
Back Forty	USA	Permitting	OP	Zn, Au, Cu, Pb	Aquila Resources	294
Palmer	USA	PEA	UG	Zn, Cu, Au, Ag	Constantine, Dowa Metals	278
Prieska	South Africa	Feasibility	UG	Zn, Cu	Orion	267
Ayawilca	Peru	PEA	UG	Zn, Ag, Pb	Tinka Resources	262
McIlvenna Bay	Canada	Prefeasbility	UG	Zn, Cu, Au, Ag	Foran	261
Prairie Creek	Canada	Permitting	UG	Zn, Pb, Ag	NorZinc	253
Rosh Pinah	Namibia	Expansion, delayed	UG	Zn, Pb	Trevali	80
IRON ORE						
Simandou 1 and 2	Guinea	Feasibility	OP	Fe	SMB-Winning	16,000
Simandou North	Guinea	Feasibility	OP	Fe	Rio Tinto, Baowu, Gov't.	10,000
Jack Hills	Australia	Expansion, suspended	OP	Fe	Sinosteel	6,860
Mbalam-Nabeba	Cameroon/D. R. Congo	Expansion, suspended	OP	Fe	Sundance Resources	4,686
Balmoral South	Australia	Feasibility	OP	Fe	Mineralogy	3,968
Southdown	Australia	Feasibility, delayed	OP	Fe	Grange Resources, SRT	2,936
Koodaideri	Australia	Construction	OP	Fe	Rio Tinto	2,600
Iron Bridge Magnetite Phase 2	Australia	Construction	OP/Complex	Fe	FMG Magnetite, Formosa Steel	2,600
Zanaga Phase 1	Republic of Congo	Feasibility	OP	Fe	Glencore, Zanaga Iron	2,200
Serra Sul 120	Brazil	Construction, expansion	OP, Plant	Fe	Vale	1,500
Hawsons	Australia	Prefeasibility	OP	Fe	Carpentaria, Pure Metals	1,400
Razorback	Australia	Scoping	OP	Fe	Magnetite Mines	1,200
WTS2	Australia	Construction	OP	Fe	Rio Tinto	749
Carlin	USA	PEA	OP	V	First Vanadium	535
Kapstevel South	South Africa	Construction	OP	Fe	Kumba Iron	470
Mont Sorcier	Canada	PEA	OP	Fe, V	Vanadium One	457

Project Name	Location	Status	Type	Products	Owner	Project Cost (US$M)**
Shymanivske	Ukraine	Prefeasibility	OP	Fe	Black Iron	436
Queens Valley	Australia	Construction	OP	Fe	Fortescue	287
PRECIOUS METALS & DIAMONDS:						
Gold						
Donlin	USA	Feasibility	OP	Au	Barrick, NovaGold Resources	6,700
Norte Abierto	Chile	Prefeasibility	OP	Au, Ag	Barrick, Newmont	6,000
Galore Creek	Canada	Prefeasibility	OP	Au, Ag	Newmont, Teck	5,208
KSM	Canada	Prefeasibility	OP/UG	Au, Cu	Seabridge Gold	5,200
Sukhoi Log	Russia	Prefeasibility	OP	Au	Polyus	3,300
Wafi-Golpu	Papua New Guinea	Prefeasibility	UG	Au, Cu, Ag	Newcrest, Harmony	2,800
Detour Lake LOM	Canada	Construction	OP	Au	Kirkland Lake	2,500
Yanacocha Sulphides	Peru	Construction	UG	Au	Newmont, Buenaventura, Sumitomo	2,000
Rosia Montana	Romania	Permitting	OP	Au, Ag	Gabriel Resources, Gov't.	1,970
Metates	Mexico	Prefeasibility	OP	Au, Ag	Chesapeake Gold	1,910
Livengood	USA	Prefeasibility	OP	Au	International Tower Hill	1,840
Courageous Lake	Canada	Prefeasibility	OP	Au	Seabridge	1,520
Pueblo Viejo	Dominican Republic	Feasibility, expansion	Plant	Au	Barrick, Newmont	1,300
Côté	Canada	Construction	OP	Au	Iamgold	1,147
Goldrush	USA	Construction	UG	Au	Nevada Gold Mines JV	1,000
Cangrejos	Ecuador	Prefeasibility	OP	Au	Lumina Gold	1,000
Stibnite	USA	Prefeasibility	OP	Au	Midas Gold	970
Gramalote Ridge	Colombia	PEA	OP	Au	B2Gold	901
Mansourah - Massarah	Saudi Arabia	Construction	OP	Au	Saudi Arabian Mining	880
Salares Norte	Chile	Construction	OP	Au	Gold Fields	834
Mount Todd	Australia	Prefeasibility	OP	Au	Vista Gold	826
Springpole	Canada	PEA	OP	Au, Ag	First Mining Gold	809
Horne 5	Canada	Feasibility	UG	Au	Falco Resources	802
Tanami 2	Australia	Expansion	UG	Au	Newmont	800
Hope Bay	Canada	Feasibility	UG, Plant	Au	Shandong Gold	683
Blagodatnoye Mill-5	Russia	Feasibility, expansion	OP, Plant	Au	Polyus	600
Obuasi Phase 2	Ghana	Construction	UG	Au	AngloGold Ashanti	545
Island Gold	Canada	Feasibility	UG	Au	Alamos Gold	514
Chulbatkan	Russia	Prefeasibility	OP	Au	Kinross Gold	500
Media Luna	Mexico	Prefeasibility	OP	Au	Torex Gold	482
Wasamac	Canada	Feasibility	UG	Au	Monarques Gold	464
Cariboo	Canada	Feasibility	UG	Au	Barkerville Gold	458
Martha/Gladstone/WKP	New Zealand	PEA	OP/UG	Au	OceanaGold	447
Amursk POX-2	Russia	Feasibility	Plant	Au	Polymetal Intl.	431
San Gabriel	Peru	Feasibility	Plant	Au	Buenaventura	430
Massawa	Senegal	Feasibility	OP	Au	Teranga Gold, Barrick	412
Lac Windfall	Canada	Prefeasibility	UG	Au	Osisko	397
Magino	Canada	Construction	OP	Au	Argonaut Gold	380
Montagne d'Or	French Guiana	Permitting	OP, Complex	Au	Nordgold, Columbus Gold	361
Nezhda	Russia	Construction	OP/UG	Au	Polymetal Intl.	330
Turquoise Ridge	USA	Construction, expansion	UG	Au	Nevada Gold Mines JV	325
Block 14	Sudan	Feasibility	OP	Au	Orca Gold, Gov't.	321
Macassa	Canada	Construction, expansion	UG	Au	Kirkland Lake	320
Moose River	Canada	Prefeasibility	OP	Au	St. Barbara	319
Coffee	Canada	Prefeasibility	OP	Au	Newmont	317
Loma Larga	Ecuador	Feasibility	UG	Au, Cu, Ag	INV Metals	316
Volta Grande	Brazil	Feasibility	OP	Au	Belo Sun	298
Spanish Mountain	Canada	PEA	OP	Au, Ag	Spanish Mountain	273
Valentine Lake	Canada	Prefeasibility	OP	Au	Marathon Gold	272
Hod Maden	Turkey	Prefeasibility	UG	Au, Cu	Sandstorm Gold	272
Boto	Senegal	Feasibility	OP	Au	Iamgold	271
Klaza	Canada	PEA	OP/UG	Au	Rockhaven Resources	244
Eskay Creek	Canada	PEA	OP	Au, Ag	Skeena Resources	233
Bombore	Burkina Faso	Feasibility	OP	Au	Orezone Gold	216
Cerro Blanco	Guatemala	Feasibility	UG	Au, Ag	Bluestone Resources	196
Tulu Kapi	Ethiopia	Feasibility	OP	Au	Kefi Minerals	180
Ixtaca	Mexico	Feasibility	OP, Complex	Au, Ag	Almaden	174
DeLamar	USA	PEA	OP	Au, Ag	Integra Resources	161
West Kenya	Kenya	Scoping	OP/UG	Au	Shanta Gold	161
Tasiast 24K	Mauritania	Expansion	OP	Au	Kinross Gold	150
Premier/Red Mountain	Canada	Feasibility	UG	Au	Ascot Resources	147
Cerro de Gallo	Mexico	Prefeasibility	HP L	Au	Argonaut Gold	134
South Railroad	USA	Prefeasbility	OP	Au	Gold Standard	132
Camino Rojo	Mexico	Construction	OP	Au	Orla Mining	123
Essakane	Burkina Faso	Feasibility	HP L	Au	Iamgold	115
Bibiani	Ghana	Restart, feasibility	UG	Au	Chifeng Jilong Mining	115

Project Name	Location	Status	Type	Products	Owner	Project Cost (US$M)**
CK Gold	USA	Prefeasibility	OP	Au, Cu	US Gold	114
Santa Luz	Mexico	Construction	OP	Au	Equinox Gold	103
Tabakoroni	Mali	Prefeasibility	UG	Au	Resolute Mining	86
Kutyn	Russia	Construction	OP	Au	Polymetal Intl.	80
Aurizona	Brazil	PEA	UG	Au	Equinox Gold	70
Egoli	South Africa	Feasibility	UG	Au	Pan African Resources	66
Jacobina	Brazil	Feasibility, expansion	UG, Plant	Au	Yamana Gold	57
La Fortuna	Mexico	PEA	OP	Au	Minera Alamosa	27
Silver						
Pitarrilla	Mexico	Feasibility	OP, UG	Ag	SSR Mining	741
Corani	Peru	Feasibility	OP	Ag, Pb	Bear Creek Mining	579
Hermosa	USA	Prefeasibility	UG	Ag	South32	519
Rochester	USA	Construction, expansion	HP L, Plant	Ag	Coeur	397
Bawdwin	Myanmar	Prefeasibility	OP/UG	Ag, Pb, Zn	Myanmar Metals	267
Prognoz	Russia	Prefeasibility	OP/UG	Au	Polymetal Intl.	250
Cusi	Mexico	PEA, Expansion	UG	Ag	Sierra Metals	91
PGMs						
Darwendale	Zimbabwe	Feasibility	UG	Pl (4E)	Great Dyke Investments	2,000
Platreef	South Africa	Feasibility	UG	PGM (4E)	Ivanplats (Ivanhoe Mines)	1,400
Waterberg	South Africa	Feasibility	UG	PGM (4E)	Platinum Group Metals	874
Garatau	South Africa	Feasibility	UG	Pt, Pd	Nkwe Platinum	659
South Cluster Phase 1 & 2	Russia	Construction, expansion	OP/UG/Conc.	Ni, PGM	Nornickel	616
Marathon	Canada	Feasibility	OP	Pd	Generation Mining	413
Diamonds						
Venetia	South Africa	Construction, expansion	UG	Dia	De Beers	2,100
Jwaneng Cut-9	Botswana	Construction	OP	Dia	Debswana	2,000
Star-Orion	Canada	PEA	OP	Dia	Star Diamond	1,410
Ekati Fox Deep	Canada	Planning, expansion	UG	Dia	Dominion Diamond	628
Karowe	Botswana	Feasibility	UG	Dia	Lucara	514
Chidliak	Canada	PEA	OP	Dia	De Beers	435
ENERGY & BATTERY METALS:						
Uranium						
Patterson Lake South	Canada	Prefeasibility	OP/UG	U	Fission Uranium	1,459
Arrow	Canada	Prefeasibility	UG	U	NexGen	1,200
Norasa	Namibia	Feasibility	OP	U	Forsys Metals	433
Wheeler River	Canada	Prefeasibility, suspended	UG	U	Denison, JCU	322
Mulga Rock	Australia	Feasibility	OP	U	Vimy Resources	255
Etango-8	Namibia	Prefeasibility	OP	U	Bannerman Resources	254
Wiluna	Australia	Prefeasibility	OP	U	Toro Energy	220
Salamanca	Spain	Feasibility	OP	U	Berkeley Energia	96
Langer Heinrich	Namibia	Prefeasibility, restart	OP	U	Paladin	81
Kayelekera	Malawi	Scoping, restart	Complex	U	Lotus Resources	50
Lithium & Rare Earth Elements						
Thacker Pass	USA	Prefeasibility	OP	Li	Lithium Americas	1,300
Sonora Stage 1 & 2	Mexico	Feasibility	OP, Plant	Li	Sonora Lithium	800
Rhyolite Ridge	USA	Feasibility	OP	Li	Ioneer	785
Clearwater	Canada	PEA	Brine extraction	Li	E3 Metals	602
Caucharí-Olaroz	Argentina	Construction	OP	Li	Lithium Americas	565
Kings Mountain	USA	Feasibility	OP, Conc.	Li	Piedmont Lithium Ltd.	545
Kvanefjeld	Greenland	Feasibility	OP	REE	Greenland Minerals & Energy	505
Clayton Valley	USA	Prefeasibility	OP	Li	Cypress Development	493
Cinovec	Czech Republic	Feasibility	UG	Li	CEZ	483
Kalgoorlie	Australia	Construction	Plant	REE	Lynas	425
Tres Quebradas (3Q)	Argentina	Prefeasibility	Brine extraction	Li	Neo Lithium	319
Kwinana Stage 2	Australia	Construction, delayed	Plant	Li	Tianqi	300
San Jose	Spain	Prefeasibility	OP	Li	Infinity Lithium	268
Pilgangoora Stage 2	Australia	Construction	OP	Li	Pilbara Minerals	231
Jadar	Serbia	Feasibility (Funding)	UG, Complex	Li	Rio Tinto	200
Zinnwald	Germany	Feasibility	UG, plant	Li	Zinnwald	195
Goulamina	Mali	Prefeasibility	OP	Li	Mali Lithium	166
REE Processing Facility	Canada	Construction	Plant	REE	Saskatchewan Res. Council	31

** Information listed above has been compiled from available public sources, including corporate reports and presentations, press releases and regulatory filings. E&MJ and its publisher, Mining Media International, assume no responsibility for errors, omissions or suitability for purpose.*
*** Original capital cost estimate is shown in most cases; mature projects may show updated late-stage capital estimate.*

Solutions to Boost Efficiency, Remote Work

Going digital, streamlining processes and facilitating remote work are among the benefits offered by the most recently released or updated blasting solutions

By Jesse Morton, Technical Writer

Lockdowns, travel restrictions and social distancing have inadvertently brought to the fore some powerful digital solutions for blasting. There has perhaps never been a better market for solutions that reduce the required number of people on site to plan and execute a blast.

The opportunity is not lost on the major suppliers. Even before news of a novel virus in Wuhan went global, their flagship offerings were being trumpeted as game changing at improving efficiency.

Recent headlines from the space reveal that, since then, case studies, miner testimony, record-shattering blasts and accolades all but prove they can help miners best conform to the emergent brave new world.

Case Studies of Big Efficiency Gains

Dyno Nobel released a white paper showing how Dyno42 and SignaShot were used to generate big cost savings for a customer.

The customer, a U.S. coal operator, had previously determined it would deck casting blasts to prevent vibrations from exceeding the max allowed for nearby pipeline and risers. The miner used Dyno Nobel's Dyno42 and SignaShot to vet that decision and draw up a better plan.

Dyno42 analyzed data captured from seismographs on an exemplary single-hole blast, referred to as a signature hole blast. The software provided a range of possible timing schemes in Excel that could then be sorted and ranked. SignaShot analyzed the range and provided statistical confidence for each possible scheme.

The software solutions proved the miner's previous plans were too conservative. They helped the miner arrive at the optimal timing scheme to mitigate vibration. Blasting could then continue largely as normal, undecked.

Multiple direct cost savings were identified. The ability to blast normally gave the miner a subtle advantage in subsequent negotiations with the pipeline owner over plans to move the pipeline and risers.

An Indiana mine uses Dyno42 and SignaShot to reverse a costly decision to deck blasts. The software systems mandate use of electronic detonators, which provide the required timing accuracy. (Photo: Dyno Nobel)

DynoConsult, a division of Dyno Nobel, said the case study revealed how the calculations typically used at mine sites to forecast vibrations tend to err on the side of conservatism, sometimes to the detriment of the miner. "The scale distance equations typically used to determine pounds per delay are usually conservative and their peak particle velocity predictions (PVP) may lack accuracy and precision when compared to a representative data set of actual vibration results," said Vincent Slone, senior consultant, DynoConsult.

"The equation is typically weighed down, resulting in a conservative limitation to the pounds of explosives fired per 8 milliseconds," he said. As a result, "in an abundance of caution, as a responsible operator, coal mines will begin decking shots at the first sign of elevated PPVs."

The case study also showed the importance of vetting timing schemes generated by signature hole analysis programs like Dyno42.

"Signature hole analysis traditionally relied on a signature hole wave and the principle of superposition to determine optimum timings for lowering PPV," Slone said. "The timings derived from this approach can lower PPV, but the predicted PPV may lack accuracy due to the variability in the signature hole wave driven by the inherent variability of all the factors affecting the wave form from each blast hole."

To eliminate some of the uncertainty caused by that variability, SignaShot can

create an "extremely accurate" statistical model of the expected PPV, he said.

"SignaShot uses the Silva-Lusk equation to model the signature hole wave, and this along with a Monte Carlo simulation allows the program to provide representations of the variability in the signature wave forms leading to accurate PPV predictions," Slone said.

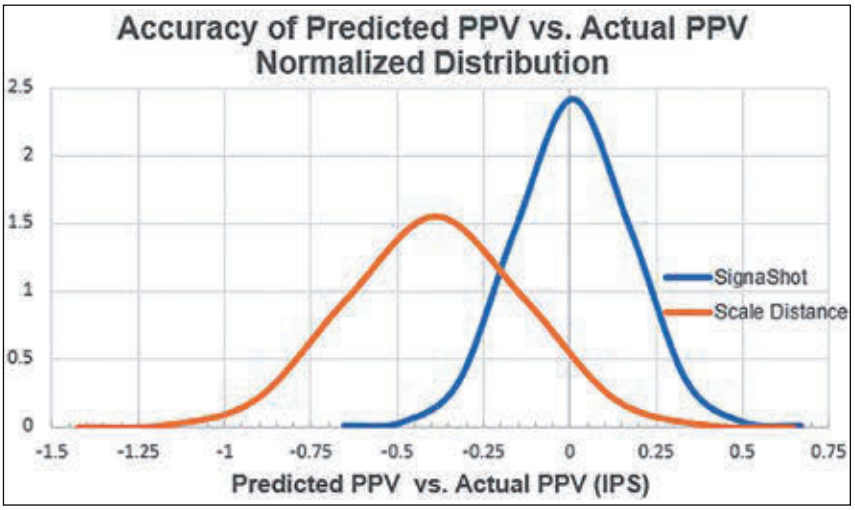
The case study proves it.

"In this project, the average predicted PPV from SignaShot had a difference of 0.00974 in. per second versus the actual results of the shot," Slone said. "Additionally, the maximum SignaShot prediction was never exceeded. This was in strong contrast to the scale distance equation in use at the site, which had been exceeded in the past and was the reason the mine had begun decking ahead of the long-term mine plan schedule."

Dyno Nobel has been supplying the mine with products and services since 2017. The coal operator owns other sites in the Midwest and Powder River Basin that have historically used Dyno42 to lower blast PPV. "This site was the first to utilize SignaShot, and the results of this project have served as a validation of SignaShot for application at the company's other sites," Slone said.

SignaShot was acquired by Dyno Nobel in 2019. It uses the Silva-Lusk equation of 2012 to deduce a signal from signature hole blast data. The program then assigns variability, within a range, to that signal.

Based on the signal, "the prediction of the complete blast output is then found through simulation of the entire blast as designed with simulated variation in the wave travel time, initiation system used, and the timing design," Slone said.



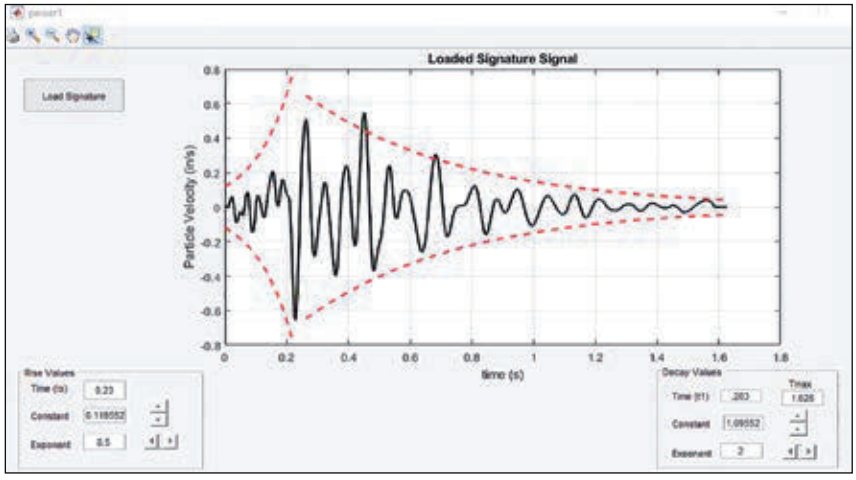
In accuracy, SignaShot predictions outperform scale distance equations-based predictions. That accuracy inspires confidence and allowed the miner to continue with status quo blasting. (Image: Dyno Nobel)

The resulting simulated signals are then graphically superimposed.

"Typically, a minimum of 100 Monte Carlo simulations lead to a normal distribution of PPV," Slone said. "A histogram of this data allows for the determination of maximum, minimum and average PPV."

With that comes confidence, he said.

"It is the sureness of knowing what the PPV will be in a blast that allows mine operators to make the decision to move forward with their blast designs as-is, which postpones vibration reduction measures that increase costs and decrease efficiency," Slone said. "It can provide the confidence needed to blast safely and responsibly without sacrificing money and efficiency."



Above, Dyno42 processes the signature hole signal to generate a range of possible timing schemes in Excel. The range can then be analyzed by SignaShot. (Image: Dyno Nobel)

Both software packages effectively require use of electronic detonators. "Electronic detonators are proven to have sub-millisecond accuracy and precision values of 0.01% to 0.02%," Slone said.

Pyrotechnic delays have varying accuracies, and are not recommended. "The pyrotechnic delays cannot be relied upon to consistently fire at the exact time necessary and therefore negate the modeling and predictions," he said.

The software can be purchased from DynoConsult and run on a Windows PC. Training is included in the price.

"The software works best when used by someone with experience and understanding of the blast process," Slone said. "DynoConsult is often contracted to perform the entirety of the process starting with the collection of the signature hole blast data, the optimization of the timing, PPV prediction and results analysis."

Both programs can be built into routines to regularly audit blasting plans. "Given a representative signature hole, these software suites can be used to lower PPV and predict PPV, but there may still be a time when other mitigation steps such as changing hole diameter and decking are required," Slone said. "SignaShot is the best tool to determine when that point is, and once changes are made, a new signature hole can be fired and the process continued."

For best results, SignaShot should be run on every blast, he said.

With signature hole wave data inputted, Dyno42 analysis can take up to an hour. "The SignaShot prediction process will require a 3- to 6-hour calibra-

tion, and 1 to 2 additional hours for each axis, per blast," Slone said.

Training takes about a day for each program. "The learning curve for achieving ideal results depends on the quality of the data and the user's understanding of the variables," Slone said. If the data is bad, or the software is used incorrectly, the results will be less than ideal.

DynoConsult hosts seminars on both the signature hole analysis process and on the software.

Separately, a case study on field trials at a mine shows the new DigiShot Plus 4G System (DGPS) tags blast holes with an unprecedented level of accuracy. "The sub-1-m accuracy that was achieved ensures the correct hole position is identified and tagged with the right information, eliminating the possibility of human error," Dyno Nobel reported.

The offered accuracy and "ease of use" prompted the customer to trial the system, and attain the desired results, the report stated. "A 0% error/retag rate was obtained in the trials due to the accurate and automated hole-detection ability of the system."

The system is comprised of the handheld CE4 Tagger, the compact Commander beacon, ViewShot 3D software, and ideally the new 4G Detonators.

With a built-in long-range antennae, the Commander is sited on the ground at a known surveyed location within 3,000 m of the planned blast. The Commander can be used as a remote unit, a repeater or a base commander, Dyno Nobel reported.

The electronic Detonators are wired to the Commander. The Commander tests the connection and monitors the energy stored in the last Detonator, detecting and adjusting to leakage.

ViewShot 3D and the Tagger programs the timing. The timing sequence is planned and simulated in ViewShot 3D, which uses GPS coordinates of holes obtained from drill rigs, drones or survey systems. The timing sequence is loaded into the Tagger by WiFi or USB.

The Commander and the Tagger triangulate with GPS to tag blast holes. Multiple Taggers can be used with a single Commander.

Upon approach, the Tagger automatically detects the hole. It "automatically identifies the hole position as the user walks toward the hole so that very little or no interaction is required, which was particularly helpful to the customer," Dyno Nobel reported.

The Tagger writes the delay time and unique ID of the hole directly into the Detonator. The Detonator's memory can also store the downwire wire length and GPS coordinates.

The Tagger can tag and test up to 400 Detonators per line, Dyno Nobel reported.

The Tagger and Commander execute the blasts. Scanning a yellow card arms the Commander. Scanning a Red Card initiates the blast.

A button on the Tagger wirelessly signals the Commander to fire the blast.

The system "is cable of supporting standard and custom coordinate system projections," the company reported.

The benefits offered by the system include efficiency and safety gains.

"The elimination of tag/log errors that the system provides will assist the customer with improved on-bench efficiency and associated downstream cost benefits," Dyno Nobel reported. "The prevention of incorrect timing will also mitigate against the safety concerns of a poor blast result due to tag/log errors."

The representation of the hole layout generated by the system assists in the reconciliation process.

"This semiautonomous system of tagging/logging offers tremendous value to the customer," the report concluded.

Dyno Nobel said some of the intangible benefits include reduced stress for the blaster, fast deployment and minimal infrastructure requirements. "We always wanted to build a system that was not dependent on the backbone of the mine," Mark Dorman, product manager, electronics, Dyno Nobel, said. "So, the system is fully independent of a backbone and can run anywhere in any mine."

Dorman said the case study shows the hole-tagging process supported by the System as almost foolproof. "With the DGPS Tagger, a 0% error/retag rate was

Emulsion System for UG Offers Better Safety, Productivity

Getman Corp. announced the ProCharge Emulsion MAXX configuration for its 3000 and 4000 explosive charger units. "Our integrated emulsion system includes the emulsion, water, and gasser tanks, along with water and gasser pumps, hydraulic valves, and a hose handling system," Mario Tremblay, principal product line engineer, Getman Corp., said.

The optional hose handling system includes hose pushers, a hose reel, and hose guides for up or down holes. Space is also allocated for explosives supplier emulsion pumps and their process control system. "The system can accommodate all known explosives companies' components," Tremblay said. "Once the explosives supplier is identified, we are involved up front to ensure successful integration."

The system offers the maximum emulsion capacity available for each vehicle model, he said. It will reduce trips to the magazine, clutter on the ramps, and wear and tear on equipment.

Fully operational vehicles can be put into service in weeks instead of months after delivery, he said.

In the field, the system has yielded promising results, the company reported. "Using the largest of our designs for a face-charging application, our mine customer was able to sustain operations for three days without returning to the magazine for tank refills," Tremblay said. Since then, a second truck and a retrofit kit was sold.

The ProCharge Emulsion MAXX Integrated Emulsion system for the ExC 4000 explosive charger includes the emulsion, water, gasser tanks and a hose handling system. (Photo: Getman Corp.)

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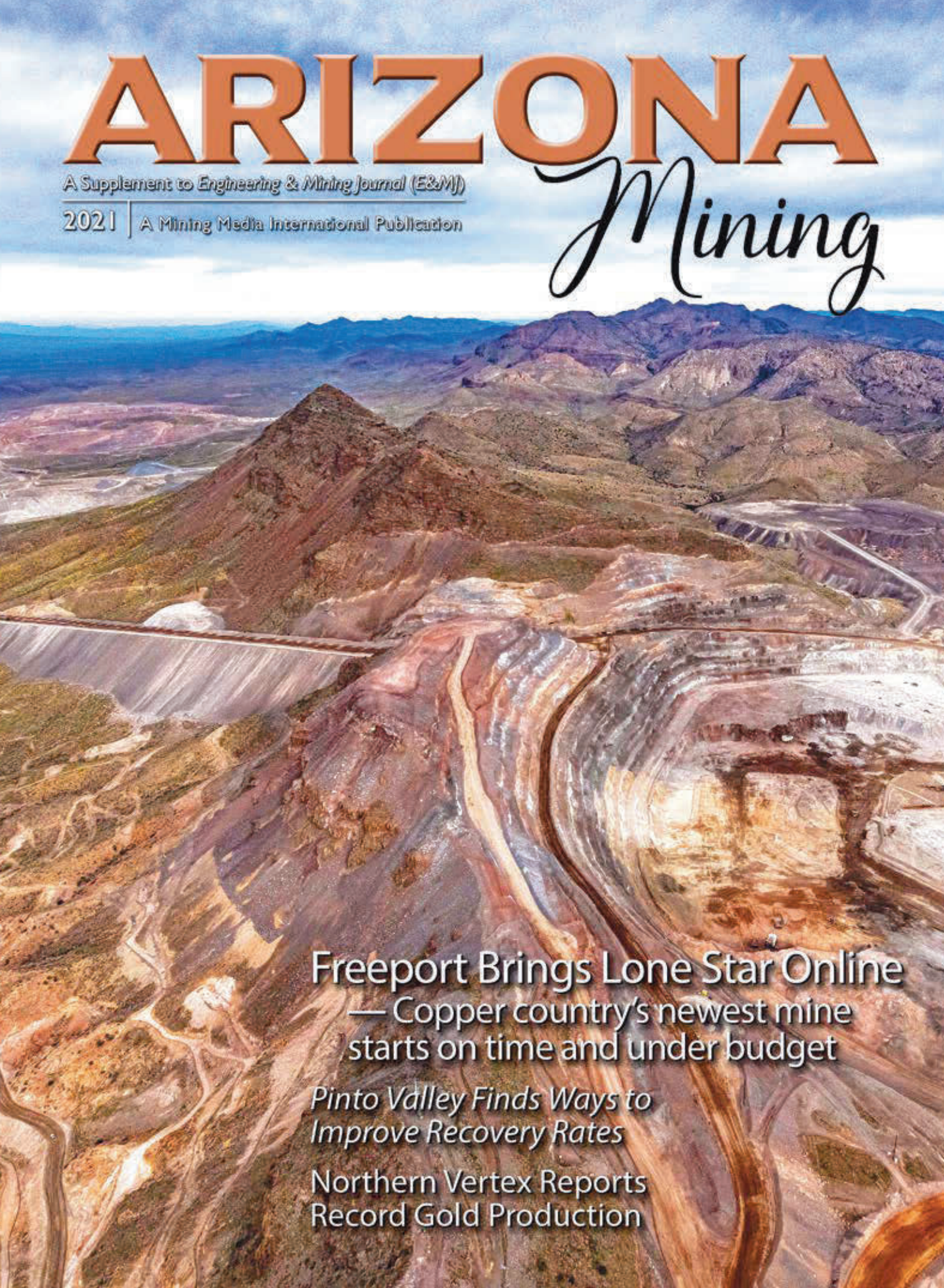

Freeport Brings Lone Star Online — Copper country's newest mine starts on time and under budget

Pinto Valley Finds Ways to Improve Recovery Rates

Northern Vertex Reports Record Gold Production

A Message From Arizona Mining and Industry Get Our Support – AMIGOS

Brett Tanner, Chairman

Sydney Hay, President

AMIGOS. Friends. Founded more than 45 years ago, AMIGOS stands for Arizona Mining and Industry Get Our Support. And that's what we, the members of AMIGOS, do. We re-earn the moniker, "The mine's best friends" every day by providing the best-of-the-best in goods and services to mines close to home and around the globe.

Over the years, AMIGOS members have come up with amazing state-of-the-art technologies so that mines can create wealth and quality of life.

And we, the AMIGOS, are pretty good at creating quality of life, too. Our members employ tens of thousands of our Arizona friends and neighbors in high-paying jobs with good benefits. We are committed to a long and prosperous future for mining in our state.

AMIGOS members are an important collection of firms working on projects worldwide, yet, we have a strong employment presence in Arizona. Our members include heavy equipment and machinery suppliers, engineering and construction firms, manufacturers, transportation and logistics firms, tire dealers, chemical companies, mining and environmental consultants, insurers, staffing firms, steel suppliers and much more — a job creation engine.

And, while we do work throughout the world, mining must continue to thrive here at home. Our members will do all that we can to get new projects like Rosemont, Resolution, Florence Copper, South 32 Hermosa project and others up and running. We will continue to support longtime Arizona stalwarts like Freeport-McMoRan, Capstone Pinto Valley, ASARCO and others. And we will continue to help our member companies get known in this industry in order for them to thrive themselves. Our Zoom meetings now connect our members face-to-face with mines near and far. Our reverse expos and online "speed dates" between suppliers and mine procurement personnel are hugely popular — and effective.

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We are more than 300 of the best-of-the-best in mining suppliers. We are AMIGOS. We invite you to be one, too.

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Pinto Valley's Optimization Program Pays Dividends

Continuing to invest during a period of uncertainty, the operation reaps rewards with safety and productivity records

By Steve Fiscor, Editor-in-Chief, *Engineering & Mining Journal* (*E&MJ*)

Vancouver-based Capstone Mining operates the Pinto Valley mine in the historic Globe-Miami mining district of Arizona. It's the only mine currently operating in the district and it has produced more than 4 billion lb of copper since its inception in 1975. After acquiring Pinto Valley from BHP Billiton in October 2013, Capstone has invested steadily to improve its operation, a practice that continues today with the PV3 Optimization initiative.

The PV3 Optimization focuses on a series of low-capital, quick payback projects to de-bottleneck operational performance. The objective was to improve copper production by 10% and lower costs by 10% by 2021. Not only are they going to exceed this goal, they will have done it during the COVID-19 pandemic. A period that has been exceptionally difficult for all business, including copper mining in Arizona.

"The whole organization kept with the investment plan for the mine, knowing that to be competitive over the long haul we needed to complete our optimization plans," said Jerrold Annett, vice president, strategy and capital markets, Capstone Mining. "This pandemic reminded us that, at a moment's notice, the price of copper can drop, so we need to invest in the mine and various technologies that allow us to be more efficient."

In addition to improving blasting, loading and haulage, along with some mill upgrades, Capstone has also embraced some novel technologies to improve recovery and they are paying off as well. One of those is the patented catalytic technology from Jetti Resources that has allowed them to jumpstart historic dump leach sites and essentially recover more copper from waste. They are also pilot testing new coarse particle flotation technology that could boost overall copper recovery by as much as 6%. Processing coarse particles has the potential to lower grinding costs, water usage and energy consumption, while increasing the stability of the tailings storage facility.

When 2020 began, no one expected COVID-19 or that copper prices would briefly dip below $2/lb in March. And from that low point, no one thought copper would be trading at more than $3.50/lb by the end of 2020, but all of these events happened in one year.

"Dealing with this pandemic and all of the related distractions, this mine has delivered at or better than what was planned for 2020," Annett said. "That's incredible and makes you wonder how could this happen in such a difficult environment? It just speaks volumes about the quality of the people we have. We're really proud of what they have accomplished."

Better fragmentation at Pinto Valley is improving downstream processes.

Staying the Course

When other miners were spooked by dark clouds on the horizon in the form of a COVID-19 pandemic and low copper prices, Capstone decided to stay the course. It didn't deviate from its plan to invest in its assets and continuous improvement.

"We cut as much discretional spending as we could," said Mike Wickersham, general manager for Capstone Mining's Pinto Valley. "We kept moving forward with our optimization program, which included installing crushers and screens, and upgrading ball mill shells."

"COVID-19 began to disrupt logistics in March when a ball mill shell, some screens and crushers parts that we were expecting were delayed," Wickersham said. "These were key to the PV3 Optimization and subsequently delayed a planned installation for April until July. Additionally, some of the machines that we intended to refurbish caused some unplanned downtime issues in May and June. But, we got through all of that and managed it, and what has been so impressive is the way the people stepped up to keep the operations running and they did it while keeping health and safety top of mind."

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"Sadly, due to the virus, more than two dozen people who were close to our small Pinto Valley team perished, including family, friends and neighbors," Wickersham said. "It's taken an emotional toll. Overall, it's been difficult, especially when the kids could not attend school or when employees were quarantined, but we have managed through it."

"Thank goodness we didn't slow down or stop our operations," he said. "We had to deal with COVID-19 and all of the negative consequences, but we're in a much better position now, especially considering the recent improvement in copper prices."

Finding the Right Mix

Wickersham explained the PV3 Optimization strategy simply as improving the three R's: the run time (hours), the rate of operations (measured in tons per hour), and recovery.

"When this PV3 Optimization work is done, we are going to improve the run time and improve the rate of production, especially with the ball mills, which are the bottleneck for major rate increases," Wickersham said. "We're also improving the recovery of copper in the float plant and from our leaching SX-EW [solvent extraction-electrowinning] operations. Everything we are doing is geared toward making step-change improvements in those three characteristics of performance."

Capstone is also using geometallurgy to try to connect the characteristics of the ore in the block model, such as grade, hardness and mineral characterization, with how the ore will behave when it passes through the ball mills to maximize its production profile. The exercise has proved to be surprisingly complex, Wickersham explained.

A ball mill shell is replaced at the Pinto Valley plant.

"The more we get into it, the more we realize all of the parameters that affect operational performance such as geology, mineralogy, blasting, the particle size distribution resulting from each crushing stage, ball mill liner variables (the design and age), cyclone pressures and slurry density," he said. "It's a complicated subject and we're in the middle of really trying to understand that in greater detail, so that we can take a block of ore from the mine plan and make an accurate prediction for what we can get for rate and recovery in the ball mills and float plant. If we get it right, we can decide on future plans for creating value by modifying throughput."

"Pinto Valley's ore body is fairly uniform with 94% granite and 95% of the copper mineralization occurs as chalcopyrite," Wickersham said. "Even with this consistent mineralogy, it isn't as simple as you would think, but this exercise has greatly boosted our understanding of how we can optimize our operation."

Processing Improvements

Jetti Resources approached Capstone Mining about three years ago because Pinto Valley was an ideal candidate for its proprietary process that uses a catalyst to improve leaching kinetics. Pinto Valley has an SX-EW plant that was built in the 1980s to recover copper from low-grade stockpiled ores that was below the cut-off grade for the mill. The previous mine owners recovered what they could through a dump-leaching process over the years, but leaching copper from chalcopyrite can be difficult.

"You're lucky if you can get recoveries greater than 30% and it takes a considerable amount of time, as much as seven to 10 years to accomplish it," Wickersham said. "The SX-EW plant was running at 10% to 15% of capacity. The thought at the time was that it had run its course and we were considering a shutdown due to the economics. Jetti Resources explained that with this catalytic technology, for very little risk on our part, they could revive the leach kinetics of the historic dump. We tried it for about a year and we saw a large spike in copper recovery."

Overall copper production levels have increased as a direct result of implementing the Jetti Resources process. "We were so convinced that this was going to work that we announced it publicly in July 2020," Wickersham said. "We are now adding more mineralized waste to the dump leach area and we intend to recover 350 million lb of copper over the remaining 19-year mine life. That is 350 million lb that was not in the mine plan and at a cost of less than $2/lb, so it is truly copper recovered from waste. It's a big win for the mine."

The process itself also represents sustainable environmental improvements. Running lower grade ores through the mill requires more water, reagents and energy. Implementing this process required no major capital expense, Annett said. "Jetti erected a building to introduce the cata-

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Umut Erol, metallurgy, lab and process control superintendent for Pinto Valley, is pilot testing the Eriez HyroFloat technology.

lyst to our raffinate, and no changes to our existing SX-EW plant are necessary," he said. "Chalcopyrite does not leach well, it is a slow process of many years and ultimate recoveries are traditionally low. The reason is because after extended periods of leaching, a passivation layer forms on the chalcopyrite, which protects it from the bioleach process. The Jetti catalyst breaks down this passivation layer and prevents it from forming again thereby allowing for copper extraction to take place unimpeded."

Plans for Phase 2 of the PV3 Optimization Plan are under way for three projects to be completed in 2021: the CV04 conveyor upgrades, some tailings thickener upgrades and some cyclone cluster upgrades for the ball mills. "There is also one other big piece of work under way in a pilot phase in the flotation plant, the Eriez HydroFloat technology," Wickersham said. "This process was lab tested about four or five months ago and it's showing very promising results."

Pinto Valley's ball mills produce a fairly coarse feed for the float plant, which results in significant copper losses because some particles are too large and heavy to float in our conventional cells. The Eriez HydroFloat technology is particularly adapted to clawing back those copper losses. "In Pinto Valley's case, that could amount to an additional 6% of copper recovery," Wickersham said. "That's huge! After we have invested all of this time and money to drill, blast, load, haul, crush, crush, crush and mill… and now to possibly get an additional 6 points — that is just tremendous. It looks like it's doing at least that in the pilot testing phase that began in December 2020."

This is also in line with Capstone's strategy for reducing power costs per ton, Annett explained. "If you can crush to a coarser consistency, that consumes less power," Annett said. "It also improves our water usage per metric ton of ore. Obviously, the main thrust of this exercise is to recover more copper and the difference between 84% and 90% recovery is an extra 10 million lb/y of copper for at least 19 more years."

Referring to the Pinto Valley mill, Annett offered a resto-mod analogy: a '67 Mustang Fastback shell with new technology under the hood. "Pinto Valley's mill is a vintage early-1970s operation with new technology platforms throughout, which is steadily improving its performance," Annett said. "We didn't tear down an old mill and build a new one from scratch. We are looking to modern day performance from our 50-year-old operation. That's an efficient use of capital."

Handling Material More Effectively

Pinto Valley's process improvements are not limited to the plant. The company has been testing teleremote D10 dozers to work the stockpiles. The mine has two areas with stockpiles: the coarse stockpile generated by the primary crusher and a fine ore stockpile that holds the feed for the ball mills. "On both of these piles, we have to push material around because it doesn't naturally flow into the feeders," Wickersham said. "Those feeders are located below the bottom of the stockpiles and they pose an engulfment hazard. It's a potential source of fatalities in the mining business. We wanted to find a way to use those dozers to manage the piles without an operator in the cab."

In July, Capstone purchased a Cat 994K wheel loader and they are using it to load run-of-mine ore and waste into 180- and 240-ton haul trucks. It's reaching the same productivity levels as the hydraulic excavators and is burning 20 to 30 gallons per hour less diesel, Wickersham explained. "That reduces the diesel burn by nearly 250,000 gallons per year, which equates to a reduction of 4 million lb of CO_2 entering the atmosphere," he said. "We have lower operating costs on a machine that has greater mobility. It's been a fantastic investment." Capstone was so excited about the machine's performance that they decided to buy a second one.

Breaking records is a great source of pride for Wickersham, especially when they are related to safety and production. "When you're producing pounds of copper or tons of ore safely at higher rates than anyone has ever done, that's always exciting," Wickersham said.

Compared to 2017, Pinto Valley's recordable injury rates are down 90% — that includes a COVID-19 year. During December 2020, they set a shift and daily record for tonnage through the ball mills and they did it with minimal crews.

"These results are absolutely outstanding," Wickersham said. "The mine tripled their ability to generate fines with better fragmentation, which increases the capacity of and reduces the maintenance cost for the downstream operation of the crushers and ball mills."

What really motivates Wickersham is the operation's ability to sustain these changes. "For a lower ore grade operation like Pinto Valley, we have to keep pushing those unit costs down," Wickersham said. "If we can break records and sustain these levels of capacity and productivity, we will weather any commodity cycle that comes our way."









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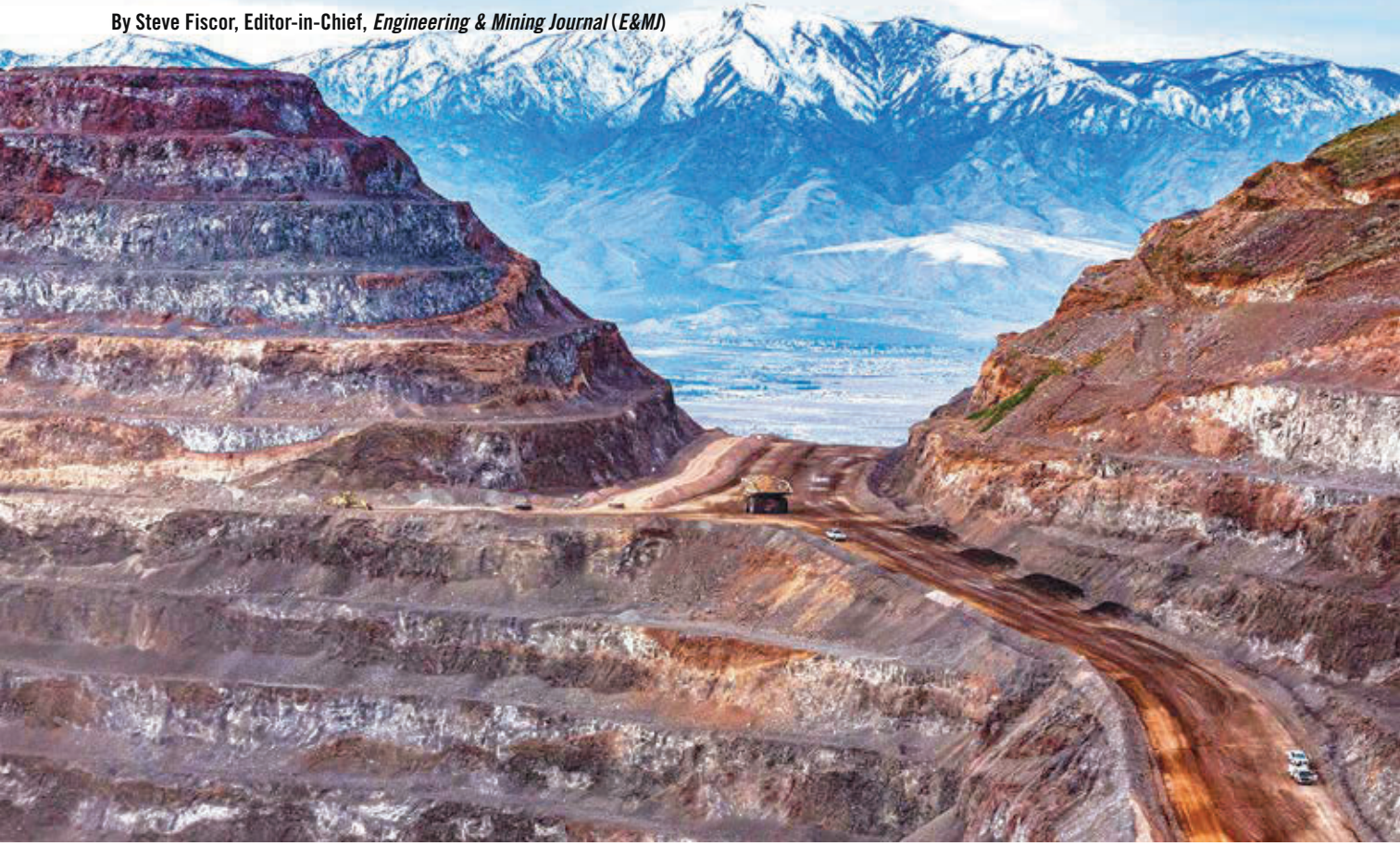
Freeport-McMoRan's Operations Recover

The company brings the Lone Star project online and relies on its strengths to maintain year-on-year copper sales from its North American ops despite the COVID-19 disruption

By Steve Fiscor, Editor-in-Chief, *Engineering & Mining Journal* (*E&MJ*)



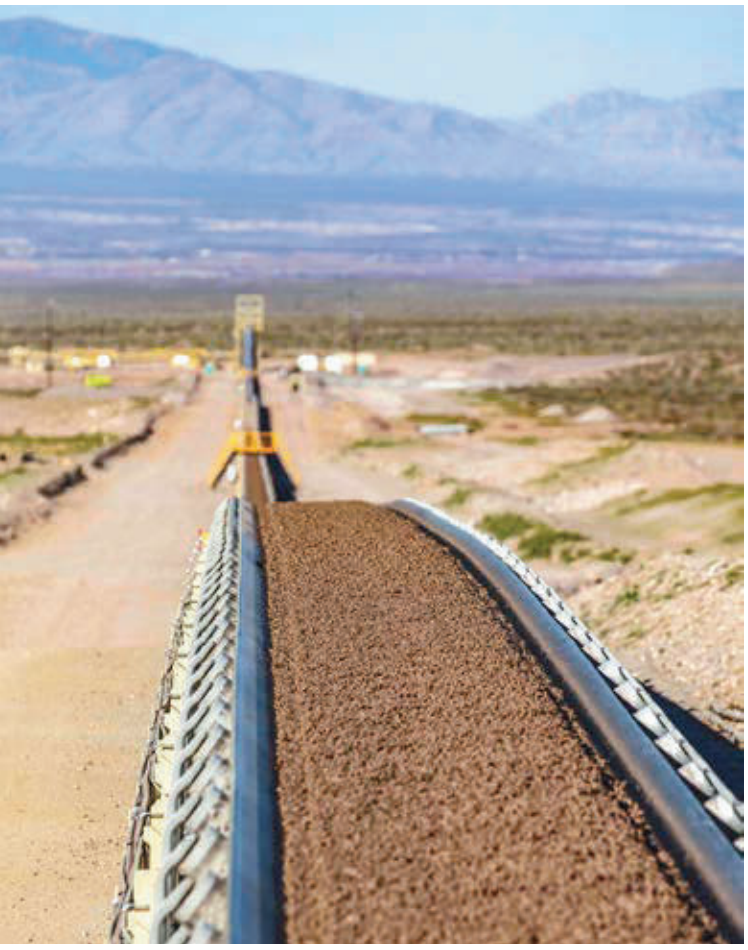
Last year, Freeport-McMoRan commissions the Lone Star operation.

Freeport-McMoRan operates seven open-pit copper mines — the Morenci, Bagdad, Safford, Sierrita and Miami operations in Arizona, and the Chino and Tyrone operations in New Mexico. The company also recently brought the Lone Star project online. Using the established infrastructure at Safford, it is recovering copper from leachable ores at Lone Star and the project is expected to eventually produce 200 million lb/per year (lb/y) of copper with the potential for future expansion options. Freeport also has considerable undeveloped copper reserves in Arizona.

In 2019, Freeport sold 1.4 billion lb of copper from its North America operations. Morenci is the company's leading producer (730 million lb/y) followed by Bagdad (218 million lb/y), Chino (175 million lb/y), Sierrita (160 million lb/y) and Safford (110 million lb/y). Production in 2019 was up across most of the operations except Safford, which received a boost in 2020 from the Lone Star project. The company was hoping to grow copper sales from its North American ops to 1.6 million lb in 2020.

Last year, however, did not play out as many businesses expected. Freeport was on a roll during Q1 2020 benefiting from a humming global economy, and then the COVID-19 pandemic upended its plans. In addition to disrupting day-to-day business for the company, the pandemic clouded the markets with uncertainty and copper prices dropped below $2/lb during March. Facing many difficult decisions, Freeport decided to pivot. They moved to a more austere operating plan in April 2020. Discretionary spending was cut, expansion plans were tabled, some employees were laid off and some executives took a haircut. A minor outbreak at the Chino mine forced them to idle that operation.

In August amid this tumult, Josh Olmsted was promoted to lead Freeport's operations throughout the Americas. Spending considerable time with many operations in both North and South America, he and his team began to chart a path to get production and copper sales back on track while simultaneously dealing



An overland conveyor delivers copper bearing ore to the leach pad.

with the issues that COVID-19 presented. They relied on technology that allowed people at the Phoenix headquarters to work remotely and communicate with field operations. They also used some of the tools they had developed during the company's Innovation Initiatives and agile thinking exercises.

The Lone Star project was completed on time and under budget and is now contributing to copper sales, and Freeport is now in the process of developing a plan to restart Chino.

By the end of Q3 2020, Freeport's copper sales from its North American operations had reached 1.1 billion lb, a little more than the same period in 2019, despite the lower mining rates associated with the revised operating plans and partly offset by the new production from Lone Star. Freeport is now estimating that its 2020 North American copper sales will be approximately 1.4 billion lb, very much in line with 2019. Considering all that happened in 2020, that's an amazing outcome.

The Lone Star Project

The Lone Star copper project is located near the Safford operation in eastern Arizona. The initial work to develop the project began in 2018. It delivered saleable copper during Q3 2020, and it's expected to have a 20-year mine life with the potential for future expansion. Total capital expense for the initial project, including mine equipment and preproduction stripping, amounted to $850 million. Lone Star makes use of the existing Safford infrastructure, which helped Freeport minimize the capital expenses. As it mines the oxide cap, it exposes a significant sulphide resource, and the company plans to incorporate that into future development plans.

"We have a lot of super exciting things happening here, and I'm looking forward to writing this next chapter for Freeport-McMoRan," said Olmsted, president and COO-Americas for Freeport-McMoRan. "2020 certainly has been a challenge, but the Lone Star project has been a real bright spot for us. It has come to fruition with respect to project completion, and it's generating copper and cash flow. It represents the culmination of a lot of hard work over the years, from getting the mine stripped to delivering ore to the crusher and then the leach pad. All of that is now starting to pay off. The project came online on time and under budget, and that's saying something in this day and age."

The Safford operations, which includes the Dos Pobres and San Juan ore bodies, built its facility around those two deposits, Olmsted explained. "As we developed Lone Star, one of the great things about the project is that we were able to leverage a lot of the existing facilities that were constructed in the original project, which reduced the capital burden when compared with other similar projects," Olmsted said. "It's also in a district where we have a high level of confidence that it will continue to grow."

Freeport knows the mineralogy in this district well. "We know how to best take advantage of productivity, efficiency and costs," Olmsted said. "Beyond the low capital burden, the timing of the project fit well with the sequencing of mine plans. While it's a lower grade deposit, that facility was built around heap leach."

Learning to Adapt

A year ago, Freeport was discussing America's Concentrator, a concept that combined digital technology, data analytics and artificial intelligence (AI) as well as the company's workforce. The object, Olmsted explained, was to think about how to build a modern concentrator without actually building it and applying that technology to existing operations instead. "Then COVID-19 arrives in March 2020. The world changed, and we had to pivot," Olmsted said. "But a lot of what we learned as a part of that process has allowed us to be extremely successful this year."

Freeport continues to use innovation, data analytics and AI technology. Many of these programs started with Bagdad and then expanded to Morenci and Safford. The

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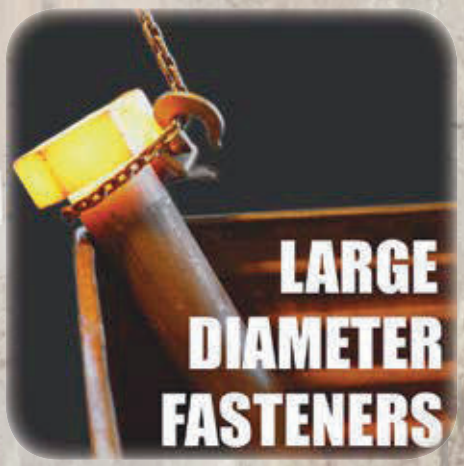

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Copper Mark

Freeport recently announced its commitment to the Copper Mark, a new, comprehensive assurance framework that demonstrates the industry's responsible production practices and contribution to the U.N.'s Sustainable Development Goals. It is the first and only framework developed specifically for the copper industry and enables each site to demonstrate to customers, investors and other stakeholders their responsible production performance. The company commenced the process for six of its operating sites in September and in December received the mark for its two South America mines, Cerro Verde in Peru and El Abra in Chile, and its Atlantic Copper smelter in Spain. The company has future plans to validate all of its operating sites against the Copper Mark requirements.

Lone Star project is using some of these agile mindset philosophies as well, Olmsted explained. "We haven't used AI at Safford, but we have used this high-performance culture of thinking that has allowed us to debottleneck a lot of operations and apply innovations at all levels of the organization.

"These programs allowed us to see improvements in efficiency and productivity and drive costs down," Olmsted said. "All of these things that we have learned have helped us be more successful during these trying times, and we have a lot more things in the hopper."

Olmsted pointed to the recent recognition from the National Institute for Occupational Safety and Health (NIOSH) in conjunction with the National Mining Association (NMA) on Freeport's use of the Haul Truck Operator's Scorecard, a tool they developed in-house as a way to drive safety through technology. "It creates value from the data that has accumulated over time," Olmsted said. "It's a culmination of data analytics, feedback loops, and OEM data systems, that allow us to provide direct feedback to haul truck operators regarding technique from a productivity and efficiency stand.

Dealing With COVID-19

Looking at Freeport's operations and the changes that were made as a result of all of that happened earlier in 2020, Olmsted explained that the company's response was based on "what we needed to do to protect our employees and our business from COVID-19 as well as the pandemic's impact on the global economy and copper prices. We have worked through two quarters under the new operating plan and the operations have responded.

"In addition to plan execution, they have also managed the protocols to keep employees and suppliers safe from exposure," Olmsted said. "From that perspective, things are

going really well. With the recent uptick in infections, we have had to redouble our efforts. We are now looking at restarting Chino in 2021 under a modified mine plan. We are currently getting organized and preparing for that restart."

As far as Freeport's corporate headquarters in Phoenix, most of the employees (95%) are working remotely. "When you consider that daily we must move 700 people to the top floors of an executive tower, the elevators alone pose a sizable risk for transmission," Olmsted said.

For Olmsted, safety is an absolute No. 1 priority. "If a project, job or task can't be done safely, we are not doing it," he said. "The best way to improve safety is by listening to input from every employee in the organization. Whether it's a job in the field or an administrative process, everyone has ideas on how to do things better. The best solution is one that includes all of those perspectives: safety, business and efficiency.

"Within Freeport, we have a high level of collaboration, involvement and interaction between the mine sites and central support," Olmsted said. "The level of interactive communication is better now than it has ever been, and that bodes well for the future. We're really focused on inclusivity and diversity and that just adds an additional layer of improvement to a great program."

Looking toward the future, Olmsted has set four goals for himself and his team, which include safety performance, plan execution, technology use and inclusion (diversity). "We will operate safely, and we need to execute according to plan to achieve financial success for the company and its employees," Olmsted said. "We're not using technology for technology's sake; we are putting the information in the right person's hands to help them make the best decisions for the organization." Freeport has already kicked off engagement groups across the organization to determine areas for potential improvement, and Olmsted said he expects this program to bear fruit in 2021.

Safford's SX-EW facility recovers copper from the leachate.

Moss Mine Achieves Record Gold Production

Northern Vertex builds a platform for future growth

By Steve Fiscor, Editor-in-Chief, *Engineering & Mining Journal* (*E&MJ*)

Northern Vertex's Moss mine (above) is the largest primary gold and silver mine in Arizona. (Photo: Northern Vertex)

Northern Vertex Mining Corp. owns and operates the Moss mine, currently the largest primary gold and silver mine in Arizona. Founded in 2012, the company has since gained considerable experience across all areas of operations, including mine development, exploration, acquisitions and financing of mining projects. With promising results from its flagship Moss mine, the company intends to consolidate additional gold assets within the western U.S. The company has set its sights on becoming a midtier gold producer.

The Moss mine is an open-pit, heap-leach gold mine. It's the first open-pit mine to operate in the Oatman District in northwest Arizona, which is part of the larger Walker Lane gold trend that extends into northern Nevada along the border with California. Following feasibility studies, a capital raise, permitting and construction, Northern Vertex brought the Moss mine online in late 2017. By February 2018, they were stacking ore on the leach pad and the mine poured its first gold in Q1 2018.

Production quickly ramped up to 5,000 metric tons per day (mt/d) and the Moss mine achieved commercial production in September 2018. At the end of its second year of production (2019), the Moss mine produced about 40,000 ounces (oz) and Northern Vertex is hoping to grow gold production to 55,000 to 65,000 oz in 2020. The mine currently employs 150 people. They are moving 25,000 to 50,000 mt/d, processing 8,000 mt/d of ore and placing it on the leach pad. They operate a Merrill Crowe facility onsite, which allows them to pour gold and silver doré. The doré is shipped to Asahi Refining in Utah.

The third quarter of 2020 was the company's strongest yet. The Moss mine produced a record 14,673 gold equivalent ounces (geo), a nearly 30% quarter-to-quarter increase. Third quarter revenues reached a record $26.8 million with cash costs averaging $954 per ounce (oz). The mine also established a new processing record of 683,706 mt crushed at an average gold grade of 0.69 g/mt during the third quarter of 2020, which yielded a record 13,083 oz of gold and 119,257 oz of silver.

The mine recently completed a powerline project, connecting it to the grid and reducing power costs. The company has started development of the West pit and is also looking at expanding its heap leach pad. Meanwhile, exploration drilling is further delineating its reserve base.

"Having financed and built the Moss mine during a challenging market environment, the Northern Vertex team continues to exceed expectations with numerous production records, including the completion of key capital projects such as the powerline connection and West pit pioneering," CEO Ken Berry said. "Through an ambitious exploration program that is under way, we continue to see significant opportunity to expand the resource through the drill-bit." With the success they saw with the Phase I exploration results, the Northern Vertex Board approved a 32,000-m Phase II drill program and it has already made some important discoveries. So much so, that the next resource update could lead to a revised mine plan. Exploration is now a priority and Northern Vertex believes the Moss mine may someday become a multimillion-oz mine.

Beyond the Moss mine, Northern Vertex announced a merger with Eclipse Gold at the end of 2020. "Our two goals were organic growth with the Moss mine and growth through consolidation of U.S. gold projects," Berry said. "Eclipse has the Hercules gold project, which is also in the Walker Lane gold trend closer to Reno." The transaction was expected to close at the end of January.

Mining and Exploration Activities

With a strip ratio of 2.15, the Moss mine produced more than 700,000 mt of ore during the third quarter of 2020. The proportion of total ore being sourced from the East pit continues to increase as operations transition out of the Center pit, while pioneering in the West pit is nearly completed, Berry explained.

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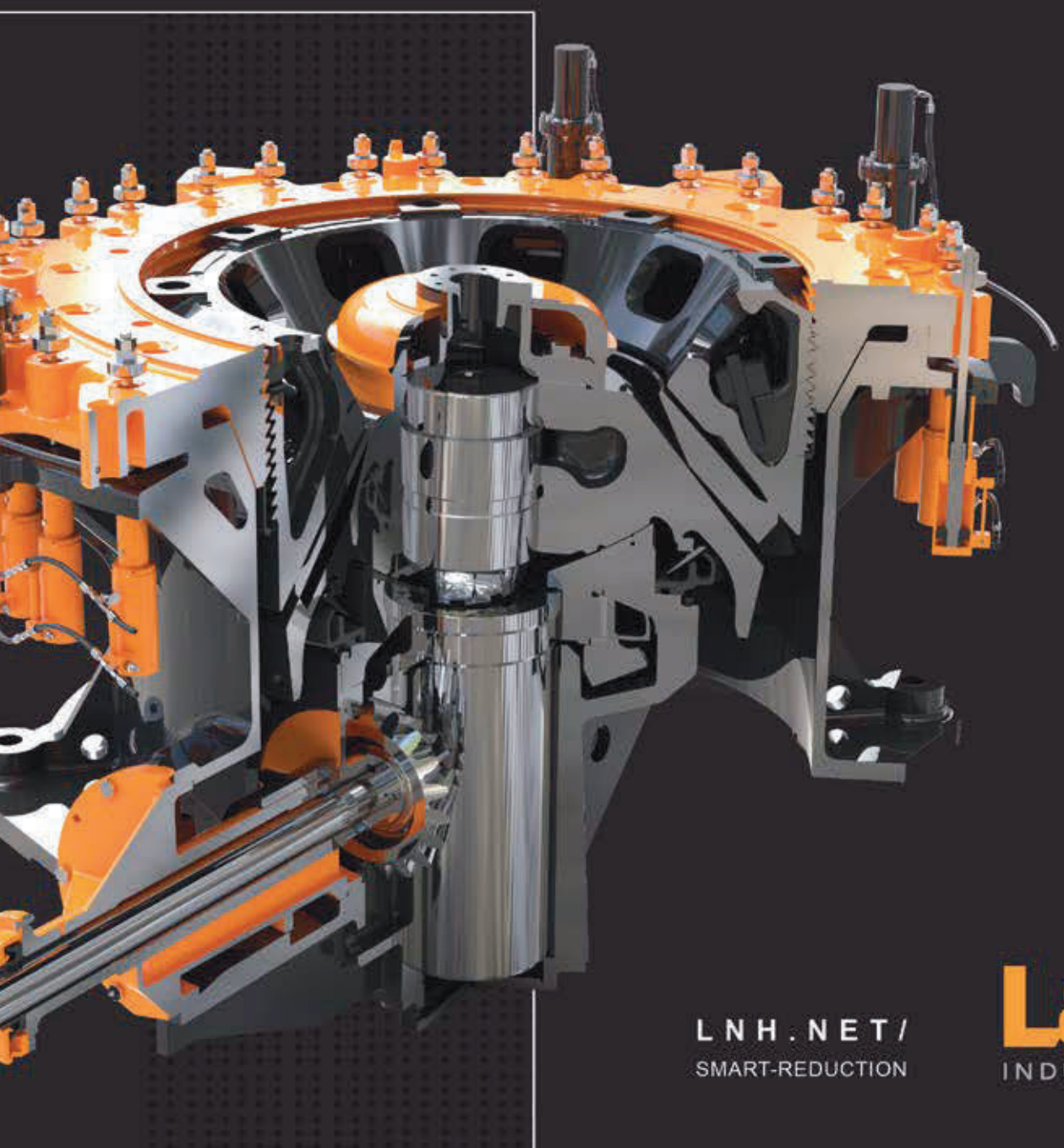

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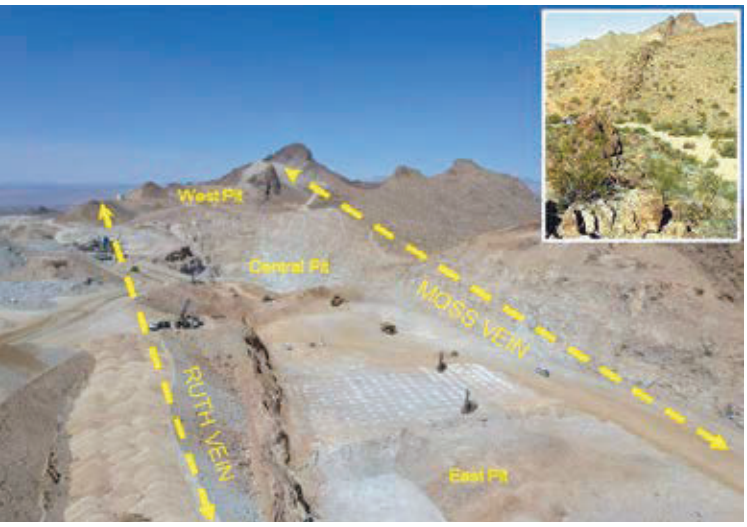


Mining is transitioning from the Center pit to the East pit. Phase II exploration identifies additional prospects with the Ruth vein (inset).

The Moss team advanced several important capital projects during 2020. They completed the construction of a 6.9-mile power line early (September 9). That project connected the Moss mine to the Mohave Power grid and eliminated eight diesel-gensets, reducing power costs from $0.31 per kilowatt hour (kwh) to $0.08/kwh.

"The completion of the powerline and successful connection to the grid further reduces our operating costs, improves reliability, and is a demonstration of Northern Vertex's commitment to sustainability by reducing our carbon footprint," Berry said.

In addition to the direct savings on power costs, which are estimated at $2 million per year, and the environmental benefits, the Moss mine will also save $15 to $20 million that would be spent operating and maintaining those diesel gensets over the life of the mine. Altogether, the powerline project is expected to reduce the Moss mine's all-in sustaining costs by $50/oz.

The Moss mine also constructed and commissioned an Intermediate Leach System, which accelerates gold recoveries from the heap leach pad. A second leach pad was commissioned in February 2020 and the prefeasibility engineering for a third leach pad is under way. Northern Vertex is currently studying the impact of increasing the crush size from 1/4-in. to 3/8-in., which could increase throughput rates for the crushers and reduce costs by as much as 30%. It could also affect gold recovery. Berry said they should know the results of that test work soon.

During May, Northern Vertex embarked on its ambitious Phase II exploration drilling program. So far, the drilling campaign has discovered wide-spread mineralization and high-grade intercepts in the Ruth vein, which also intersects the Moss vein.

Three drill rigs, one core and two reverse circulation (RC) are currently turning on the Phase II program. During December, Northern Vertex reported results from 37 new RC drill holes from the Ruth vein area, which hosts multiple high-grade zones within larger zones of typical Moss mine bulk-tonnage grade mineralization.

"Drilling at the Ruth vein, which runs parallel to our Moss mine, continues to encounter encouraging drill intercepts," Berry said. "The Ruth vein is located just 160 m off the southern edge of our open-pit mine and dips north toward the Moss vein, which dips to the south, with the two veins intersecting at a contact zone approximately 225 m below surface. This Ruth/Moss Contact Zone is a prime geological drill target for our ongoing resource expansion program." The exploration drilling program will transition to target the intersection of those two veins in the coming months.

Berry is optimistic that they will see a significant increase in resources for the operation. "This could take the mine from a small 50,000-oz/y operation to 100,000 oz/y or more," Berry said. In March 2020, Northern Vertex reported total measured and indicated mineral resources of 360,000 oz of gold and 4.5 million oz of silver within 20.6 million tons at an average grade of 0.0175 oz/ton gold and 0.2171 oz/ton silver.

Operations at the Moss mine continued uninterrupted throughout 2020. Northern Vertex said it continues to meet or exceed the recommendations and guidelines of public health authorities at the state and federal level at its operations in Arizona and its headquarters in Vancouver, Canada. The Moss mine set numerous production records during 2020. The first was announced in July when the operation reported record monthly production of 4,713 geo (4,218 gold oz and 37,171 silver oz).

Pioneering of the West pit started in June, with first production coming online soon. Eventually the East, Center and West pits will be unified to optimize mining operations, and to drive down costs.

Northern Vertex is building a platform for growth and Berry foresees further consolidation among western U.S. gold projects. The Moss mine is hitting its stride as production continues to ramp up. Despite issues related to the COVID-19 pandemic, 2020 was an exceptional year for Northern Vertex and this year is shaping up to be even better, Berry said.

Florence Copper Receives Aquifer Protection Permit

Taseko's Phase 1 Production Test Facility will demonstrate to local residents and regulatory agencies such as the EPA and Arizona DEQ that in-situ copper recovery is a safe process.

Taseko Mines Ltd. reported that the Arizona Department of Environmental Quality (DEQ) has granted its Florence Copper project an Aquifer Protection Permit (APP). "This is a key milestone in the advancement of the company's next operating asset," Taseko CEO and Director Russell Hallbauer said. "By issuing this permit, the Arizona DEQ has endorsed the environmental integrity of our project and is confident that the commercial operation will meet all state environmental laws and regulations. The U.S. Environmental Protection Agency (EPA) continues to advance their permitting process and our expectation is that the Underground Injection Control Permit will be issued in early 2021. With construction anticipated to commence in 2021, the timing could not be better with copper being highlighted as the metal of the future as the world aggressively transitions to a green economy."

Florence Copper is proposing to build and operate an in-situ copper recovery (ISCR) facility in Florence, Arizona. This process occurs 400 to 1200 feet beneath the surface, far beneath the drinking water aquifer. The in-situ process uses a mild mixture of 99.5% water and 0.5% sulfuric acid that slowly dissolves copper in the bedrock. This diluted solution, which is the same acidic strength as common household vinegar, is pumped under low pressure through injection wells to dissolve the copper within the copper oxide zone. A copper-rich solution is pumped to the surface through recovery wells for processing into pure copper-cathode sheets.

"When in production, Florence Copper will produce 85 million lb of copper annually at $1.13/lb C1 cash costs over its 20-year mine life," said Taseko President Stuart McDonald said. "Based on our latest technical report, and supported by nearly two years of successful operation of the test facility, the project has an after-tax NPV (8%) of $680 million at a copper price of $3/lb. At today's copper price, the NPV rises dramatically to $920 million, which is roughly three times our current market capitalization. We have de-risked the project significantly since its acquisition in 2014 and believe we are on the cusp of having one of the best low-cost, fully permitted and financed copper projects in the world."

"This state-of-the-art copper production facility will have an environmental footprint smaller than any conventional open-pit or underground mining operation of its size, with water consumption 14 times lower, carbon emissions six times lower and energy consumption three times lower," Hallbauer said. "These attributes make Florence Copper an exceptionally green project, which will supply the U.S. domestic market and offset current copper imports."

Construction of Taseko's $25 million Phase 1 Production Test Facility (PTF) is almost complete. The PTF

Florence Copper's SX-EW plant recovers copper from the Phase 1 PTF.

is a small-scale test facility with 24 wells, including four injection wells, nine recovery wells and 15 groundwater monitoring-related wells. This pilot test has demonstrated to local residents and regulatory agencies such as the EPA and Arizona DEQ that ISCR is a safe and proved process. During the PTF period, Florence Copper has demonstrated and enhanced the best water management practices employed at the site to maximize efficient water use and optimize new water treatment technologies.

This won't, however, be the first ISCR facility on this property. The EPA and Arizona DEQ approved a similar test project that operated successfully in the late 1990s. Florence Copper's PTF has further tested and refined the in-situ method of extracting copper underground and has demonstrated to regulators and the community that this process can be done responsibly and effectively while protecting water quality at all times.

The next step is full commercial production, which is expected to last 25 years. Over the full commercial life of the Florence Copper project, it is projected to start up at an annual production rate of 55 million lb/y of copper and then reach an average of 85 million lb/y until the 20th year. The remaining five years will be dedicated to clean closure of the facility in full compliance with applicable federal and state laws.

Ray Land Exchange: A Win-win for Miners and Outdoor Recreation

At the Yavapai County Courthouse during May 2020, Secretary of the Interior David L. Bernhardt was joined by Congressman Paul Gosar, Bureau of Land Management (BLM) Arizona State Director Ray Suazo and other public and private representatives to announce the transfer of lands between the BLM and ASARCO through the Ray Land Exchange. This final step allows for the expansion of hunting and recreation access, responsible mineral development and significant benefits for endangered species, riparian habitat and established wilderness areas in Pinal, Gila, and Mohave counties.

Department of the Interior Secretary David Bernhardt, Rep. Paul Gosar and BLM State Director Raymond Suazo meet with representatives from ASARCO.

"President Trump knows that public lands must be managed in a way that provide opportunities for communities to thrive," Secretary Bernhardt said. "This action allows for the hundreds of mining jobs to continue to produce American-made minerals — reducing our dependence on for-

eign producers — while also enhancing recreational and hunting access on public lands in the West."

"The BLM is pleased to complete the Ray Land Exchange," BLM Arizona State Director Ray Suazo said. "This land exchange balances the public need for hunting and recreation access, the mining company's need to continue responsible mineral development and Arizona's need for continued economic viability."

"This administrative land exchange, which began 26 years ago, is a prime example of an equitable exchange that provides many benefits to the public," ASARCO Vice President and CFO Oscar Gonzalez Barron said. He thanked President Trump, Secretary Bernhardt, his staff and the BLM for all the hard work that was required to complete this exchange.

The Ray Land Exchange received strong support from elected officials and local administrators due to the potential for job creation and economic benefits. Sportsmen, recreational users and ranchers will also yield significant benefits, including increased access, from the lands conveyed to the United States by ASARCO. The majority of input received during the comment period strongly supported this land exchange.

The BLM issued two patents transferring 9,339 acres of public land adjacent to ASARCO's Ray Mine Complex and Copper Butte properties for mine expansion.

In exchange, the BLM acquired 7,298 acres of ASARCO-owned land in Pinal and Mohave counties through a general land deed, consolidating checkerboard land ownership in those areas, allowing better management of wildlife migration corridors, and improving access to existing public lands for hunting and other family recreation.

Federal law requires that the lands exchanged be equal in value, with no more than a 25% cash equalization payment included. In addition, ASARCO spent more than $15 million to finalize the land exchange, $12 million of which was directed to the BLM and BLM required third-party contractors.

Ultimately, it took 26 years to complete the Ray Land Exchange. During this time, frivolous litigation, and a 10-year National Environmental Policy Act (NEPA) process unnecessarily delayed hundreds of jobs and a minor expansion of an existing mine from taking place, Bernhardt explained.

Arizona Metals Begins Phase 2 Expansion Drilling at Kay Mine

Drilling is under way at Arizona Metals Corp.'s Kay Mine Phase 2 expansion drill program. The 11,000-m Phase 2 program will consist of up to 29 core drill holes, to test for new volcanogenic massive sulphide (VMS) lenses in the steeply dipping deposit.

Arizona Metals contracts with Boart Longyear for exploration drilling on its Kay project.

Permitting is currently under way for these targets and is progressing well. Arizona Metals has contracted with Boart Longyear, who mobilized the first drill to the Kay mine.

"We believe the Phase 2 program has the potential to significantly expand the scope and scale of the Kay project, well beyond the historic estimate," Arizona Metals CEO Marc Pais said. "Our successful Phase 1 drill program greatly increased our confidence in the model. Drilling encountered massive sulphides in 19 of 20 holes. This work has identified a number of high priority drill targets, which we believe have the potential to host additional VMS lenses, as well as wide mineralized hinge zones."

The Kay project in Yavapai County consists of a combination of patented and BLM claims totaling 1,300 acres that are not subject to any royalties. A historic estimate by Exxon Minerals in 1982 reported a "proven and probable reserve of 6.4 million tons (t) at a grade of 2.2% copper, 2.8 g/t gold, 3.03% zinc, and 55 g/t silver. *Editor's note: The historic estimate has not been verified as a current mineral resource.*

In addition to the Kay mine, Arizona metals also owns 100% of the Sugarloaf Peak Property, in La Paz County, which is located on 4,400 acres of BLM claims. Sugarloaf is a heap-leach, open-pit target and has a historic estimate of 100 million t containing 1.5 million ounces gold at a grade of 0.5 g/t.

Resolution Restores Historic Mining Land

Resolution Copper has completed a $75 million restoration and reclamation project of 475 acres of land impacted by close to a century of historic impacts from the Magma copper mine near Superior, Arizona. The company voluntarily committed to accelerate the reclamation work to demonstrate its commitment to cleaning up the historic mining impacts well in advance of any new mine development activities.

"We're proud to deliver this significant piece of environmental remediation work decades earlier than required, to make our community a cleaner and safer place to live and work," Resolution Copper Project Director Andrew Lye said. "Cleaning up the historic Magma copper mine ahead of time demonstrates our commitment to operating safely and responsibly, in a way that brings lasting benefits to the entire community. This work was completed by local contractors and ongoing post-closure monitoring and maintenance activities will continue to provide local jobs as an important part of our business."

In total, the reclamation project has supported more than two dozen local jobs with businesses such as Oddonetto Construction, based in Globe, Arizona. "Resolution Copper has been an important source of business for my firm for more than a de-

Resolution Copper restores 475 acres of land impacted by the Magma copper mine near Superior, Arizona.

cade, and I look forward to continuing to work with the company to grow our business," Oddonetto Construction Owner Mike Oddonetto said.

The Magma Copper Co. ran mining and processing operations between 1910 and 1996, including smelting operations on the site between 1924 until 1971. Since 2005, reclamation work by Resolution Copper has included more than a decade of soil cleanup, placing a cover with soil and vegetation over the historic tailings, restoring and establishing drainage for the conveyance of stormwater, reshaping and vegetating development rock piles, and removing the old concentrator complex and smelter structures. Reclamation and restoration have included shaping landforms to a more natural landform and vegetating with a native seed mix characteristic of the surrounding Sonoran Desert landscape.

Recently, the completed restoration and reclamation was approved by the Arizona Department of Environmental Quality (DEQ). As required, Resolution will continue post-closure monitoring for the next three decades, including groundwater monitoring, surface water monitoring, regular inspection of all facilities and monitoring of the vegetative cover.

Resolution Copper also recently completed a $200 million project to deepen the Magma copper mine Shaft No. 9, originally constructed in 1971. Over the last four years, the shaft has been sunk a further 2,000 ft to more than 6,800 ft below the surface. It connects to the newer Shaft No. 10 in two places, improves ventilation, and increases safety by providing a second exit for workers.

Resolution will now focus on the maintenance of Shaft Nos. 9 and 10 and continuing the underground characterization study to increase ore-body knowledge, as the project continues to progress through a multiyear federal, state and county permitting process. After the permitting process, a detailed feasibility study will be completed. When an investment decision is made, Resolution Copper is expected to take around 10 years to begin production.

The new DigiShot Plus 4G System includes the handheld CE4 Tagger (left), the compact Commander beacon (right), ViewShot 3D software, and the new 4G Detonators. Benefits include improved efficiency. (Photo: Dyno Nobel)

obtained in the trials due to the accurate and automated hole-detection ability of the system," Dorman said.

In contrast, at mines using competing systems, the retag rate can be as high as 51% due to the user incorrectly tagging holes on the first attempt, he said.

By eliminating those errors, "the system will assist the customer with improved on-bench efficiency and associated downstream cost benefits," he said. "The prevention of incorrect timing will also mitigate the safety concerns of a poor blast result due to tag/log errors."

The development of the system was driven by customer feedback. "Our users are continuously asking for a simpler, easier electronic system from what was out in the market," Dorman said.

"We then developed DigiShot Plus 4G with its tag-by-plan method. This method made it much easier and user friendly for our users," he said. "With this development, one of the features we added was GPS tracking to locate a hole after tagging the hole and it would get you in the general vicinity. This is when we realized the potential benefits of a system that could get within 1 m of a hole."

That level of accuracy will prove to be disruptive, Dorman said.

"Dyno Nobel has introduced the world's first ever sub-1-m tagging and hole identification system using DGPS technology," he said. It "eliminates potential human error, ensures fast and accurate tagging that speeds up the blasting process, and delivers improved blast outcomes. With the invention of DGPS, we have once again changed the world of blasting."

Record Blasts Save Time, Resources

South Africa-based BME reported its BLASTMAP blast-planning software helped mines reduce paperwork, facilitate social distancing and support remote work amid the 2020 lockdowns.

The lockdowns highlighted the capabilities of the software to streamline processes and improve efficiency, BME said.

"Mines are often based in remote locations anyway, so BLASTMAP is frequently used by blast planners who are not physically on site," said Tinus Strauss, senior software engineer, BME.

"Mines already conduct much of their planning and operations monitoring through software tools, and COVID-19 has accelerated the pace at which digital technology is being adopted," he said. "The ability of BLASTMAP to share data with other software platforms, and to integrate wherever necessary, makes valuable contributions to the mining sector's quest for efficiency and productivity."

The software integrates with BME's XPLOGLOG platform and the AXXIS electronic detonation system and can import and export a range of file formats.

"Various reports can be generated also for digital and cloud-based sharing, helping mines to observe social distancing regulations and facilitate remote working," Strauss said. "Sharing data between platforms allows mines to streamline data analysis for quicker decision-making and continuous operational improvement, even with fewer people regularly meeting face-to-face."

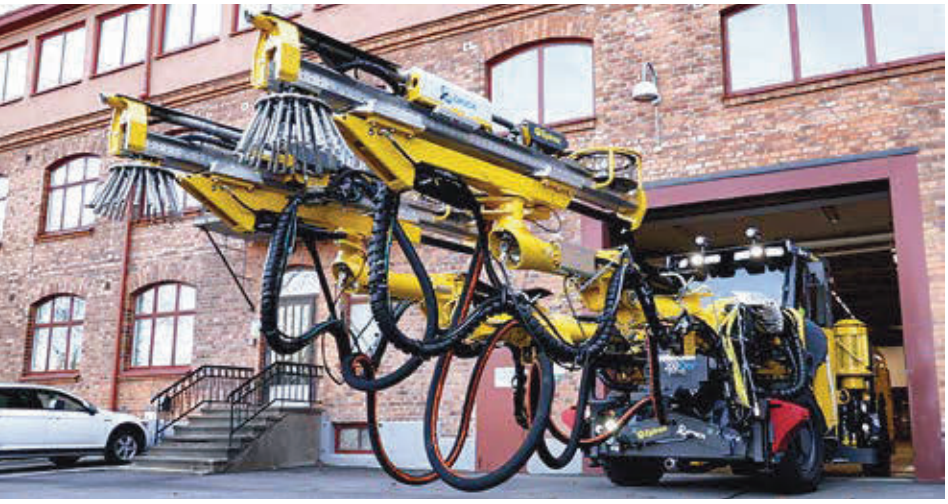
BLASTMAP can be customized to certain specifications, he said.

The software was first released in 1999. Development for the current generation launched 2012. It now offers tools for initiation timing design, initiation sequence simulation, blast hole loading design, fragmentation distribution predictions, vibration predictions and blasted rock range predictions.

The software has evolved to support maximum collaboration, Strauss said. "BME believes the way forward in 21st century mining is through collaboration, so we are always open to partnerships with other providers if this can add value to our mining clients."

Currently, the company is developing BLASTMAP Underground to be released in

BME's AXXIS electronic detonation system offers tools for initiation timing design, initiation sequence simulation, blast hole loading design, fragmentation distribution predictions and vibration predictions. (Photo: BME)



Above, the side perspective of Avatel at Epiroc's factory in Stockholm, Sweden. (Photo: Orica)

2021. "We are working on improving the underground design tools. In addition to standard tunnel designs, we are developing capacity for functionality in up-hole and ring designs," Strauss said. "We are also ensuring that BLASTMAP is fully integrated with the latest generation of AXXIS."

BME reported the AXXIS blasting system has also served customers well amid the lockdowns. Its ease of use pays dividends at operations under restrictions that limit the number of personnel on site, the company said.

"It can be operated by only one blaster on the block, so there is less proximity between people on the pattern itself," Tinus Brits, global product manager, AXXIS, BME, said.

"For the blast design, no contact is needed between the blasters in the field and the engineers doing the timing design in the office," he said. "The logging and testing can also be uploaded into a cloud database for further analysis by experts elsewhere."

The lockdowns have helped usher in the end of analog blast timing, Brits said. Government restrictions increasingly are nudging miners to adopt digital solutions, like AXXIS.

"The COVID-19 pandemic has encouraged greater use of software to design the blast patterns, which provides the timing automatically for download into the logger," he said. "Australia's mining sector, for instance, is already quite strict about this, requiring all designs to be done through software."

The trend coincides with AXXIS being used to repeatedly best records for largest number of detonators used in a single blast. "In the latest record, 3,780 detonators were initiated in a blast at a mine near Hotazel in South Africa's Northern Cape province," Brits said. "These large blasts offer considerable value because they reduce the number of blasts a mine must conduct, which in turn means less disruption from mine stoppages during blasting."

Such blasts help prove AXXIS is reliable and accurate. "Among the features of AXXIS that ensure this reliability is the easy fault-finding of missing or damaged detonators, and the identification of leakage in the system," Brits said.

"The loggers can accommodate complex blast designs with multiple detonators in the same blast hole, as required in through-seam blasting," he said. "BME's robust AXXIS down-hole cable resists damage during charging and stemming operations and is regarded in the market as the strongest wire available; this also helps ensure reliable blasts."

The current AXXIS system available can initiate 10,000 detonators in one blast. The next generation, with BME's Titanium initiation system, is in trials through Q1 2021, Brits said. "The design principles remain safety, innovation, quality and functionality."

Separately, BME released the Blasting Guide, an Android app that replaces traditional paper booklets carried and referenced by users, enabling users to quickly calculate and check blast designs in the field. It has a blast design calculator, quick calculators, prediction calculators, surface blast design rules of thumb, environmental guidelines, a table of common rock properties, and an expert contact directory.

The design calculator automatically generates results from formulas that would otherwise have to be done manually.

It offers expedited decision-making, simplified planning, mobility and ease of use in the field, BME said.

"The Blasting Guide app is a powerful means of verifying blast design outputs and making important blast planning decisions," said D. Scott Scovira, global manager, blasting service, BME. "It could be used, for example, to investigate potential blast patterns for a greenfield site where numerous scenarios may be quickly generated, and calculations checked."

The release is consistent with the company's history of developing Industry 4.0 solutions that cut paper usage, streamline processes, optimize value chains, and add value, Christiaan Liebenberg, product manager, software, BME said.

"BME strives to enable integration and seamless reporting throughout the blasting and explosives value chain," he said. "Our software and technology development are an enabler of this integration with the ultimate objective of optimizing value for our customers."

Semiautonomous UG Delivery System

Orica announced Avatel, a first-of-its-kind explosives delivery system for underground that allows an operator to execute the development cycle entirely from the safety of an enclosed cab of an Epiroc M2.

Avatel is a twin-boom, semiautonomous and fully mechanized development charging solution. It combines the latest in technology from both Orica and Epiroc to deliver a self-contained unit designed specifically for lateral development applications.

It uses Orica's WebGen Encoding System for wireless initiation. The LoadPlus intelligence platform drives the charging, inventory and tracking functions. SHOTPlus, for blast design, supports automated loading functions. Epiroc's M2 features the latest iteration of Rig Control System (RCS), and a dual diesel-electric plug-in power solution.

The automation and efficiencies offered by those solutions result in a process that requires significantly fewer personnel than do predecessor solutions and processes, Orica said.

"Prior to tramming to the face, explosives inventory is loaded onto the unit," John Cooper, vice president, explosives,

services and automation, Orica, said. The HandiLoader emulsion process body is filled with Subtek Control Ammonium Nitrate Emulsion (ANE) and disassembled WebGen primers are loaded into the onboard WebGen magazine.

"Once Avatel is in position at the face, the operator clears process water and debris via in-cabin controls for the onboard pumping, compressed air and clearing hardware," Cooper said. An in-hole signal test is conducted by the LOADPlus smart control system to confirm the firing signal from the WebGen remote firing equipment.

Charge plans and other important data can be communicated between RCS and LOADPlus, Orica reported.

For example, "at any point prior to the beginning of the charging cycle, as-drilled data or a drill design file can be transferred to RCS to enable precise hole navigation," Cooper said. A predesigned charge plan is loaded into the LOADPlus smart control system, specifying the energy characteristics and timing of each hole.

"If drilling or charging plans are unavailable, or if blastholes have been drilled in addition to design, the operator has the option to navigate the face manually, add holes and assign the respective loading characteristics and timing," Cooper said.

"When preparing to charge, the operator navigates the booms, guided by RCS and cameras positioned on each boom, to a blasthole," he said. The LOADPlus control system starts the charging, and the charging cycle progresses semiautonomously, with charge weight and timing automatically assigned according to the charge plan, or manually by the operator.

"Following up, WebGen magazine autonomously dispenses, assembles and encodes WebGen primers immediately prior to deployment into a blasthole before the remainder of the blasthole is loaded with Subtek Control bulk ANE," Cooper said. "Once the face is completely charged, a secure and unique code is assigned to the blast, and Avatel is trammed away from the face.

The heading is set to be blasted by WebGen's remote firing system.

The solution offers significant efficiency gains and optimized blast outcomes. It represents a step change in safety by removing people from the face, Cooper said.

"A single operator can prepare and charge a development heading without ever leaving the safety of an enclosed, air-conditioned, ballistic-protected cabin," he said.

"A mechanized development charging solution has long been desired by the mining industry, but until the introduction of WebGen, the ability to deliver this has been constrained in part by the manual connections required between the various components of traditional initiating systems," he said.

"To continue managing the risks to personnel, operators have been forced to use various control measures, ranging from the installation of additional ground support in the face to extended re-entry delays," Cooper said. "These controls are costly, time consuming, and at times ineffective, while having a negative impact on downstream activities."

Avatel will redefine work at the face and is a "significant step in the journey toward eliminating risks to personnel, while unlocking substantial value and opportunities for our customers," he said.

Future iterations of the solution can be extended to other Epiroc carriers, including battery driveline-based machines, Orica reported. Extensive trials will take place throughout 2021.

The Year Mining Went Electric

E&MJ *reviews some key battery-electric vehicle developments from 2020 and looks at what the future holds*

By Carly Leonida, European Editor

BEVs are edging ever closer to mainstream adoption in underground mines. (Photo: MacLean Engineering/ Mining Industrial Photographer)

Last year was undoubtably the year of the battery electric vehicle (BEV) in mining. From new product launches and mine deployments to dedicated events, there was no shortage of announcements, and that trend looks set to continue in 2021 as technology adoption increases.

From the mining company perspective, many conversations are currently centered around site suitability, technology selection and building a business for BEVs in different environments.

GMG Promotes Discussion

A good example of this was at the GMG's Electric Mine forum held virtually in September, where participants gathered to discuss the merits and challenges associated with BEVs in greenfield, brownfield and expansion projects. GMG said the outcomes from the meeting would be fed back into the third edition of the BEV guideline, which is currently in development.

The event also included an interesting Q&A session (the notes from which are available to read online) with some of the panelists, including Ron Miller, director for asset management, energy, at Newmont; Steve Holmik, mobile equipment specialist at Glencore's Sudbury Integrated Nickel Operations (Sudbury INO); and Peter Wan, technology and innovation lead at Teck Resources.

During the discussion, Miller raised the question of potential costs associated with BEV infrastructure and power grid infrastructure given the increased demand for electrical energy. Could these be a barrier to adoption at certain operations?

"Transitioning to BEVs could significantly increase electrical demand at a mine site, so there could be significant upgrades required to both generating and transmission assets," Wan replied. "Another big consideration will be how to smooth demand from charging infrastructure. Energy storage is likely to a critical investment."

Indeed, energy storage technology could be deployed at certain mines to accept energy from the grid in periods of low demand, and to relieve demand on the grid during times of peak demand caused by BEVs.

Miller pointed out that some underground mines could actually see a net zero effect of mine electrification as the incremental energy demand from switching to BEVs could be offset by savings in ventilation and cooling.

The panel also discussed total cost of ownership, comparing BEVs with their diesel counterparts.

"Electric motors require virtually zero maintenance and are traditionally far more reliable than diesel engines," Holmik said. "Even with some traditional drive train components, due to the reduced vibrations and shock loadings, modelling and forecasts that I've seen have shown they will last longer. Hydraulically driven pumps can be utilized as required and, in some cases, turned off while not in use so the wear on these components is reduced as well."

Wan weighed in: "BEVs have substantially fewer moving parts than ICE [internal combustion engine] vehicles, so there will be a reduction in maintenance costs in that area."

Holmik added that, at this point in time, one of the biggest unknowns relates to battery replacement cycles given that many factors will impact battery life (e.g., depth of discharge, charge rate, operating temperatures, etc.)

"The useful life of a battery pack will be contingent upon the number of charge/recharges required to do the necessary work at the mine. This, in turn, is contingent upon the length of haul, height of haul to destination, and the payload moved by the truck," Miller said. "Frequent charge cycles will take a toll on the battery with eventual degradation so that the work energy per recharge declines toward replacement."

All three agreed, however, that the industry definition of TCO needs to consider more than just the CAPEX and OPEX life cy-

cle cost of BEV equipment, with the scope widened to include savings from other areas; for example, in mine design as well.

The panel was also questioned about the business case for BEVs at remote operations where power is provided by diesel gensets.

Wan explained that BEVs will still deliver a reduction in carbon emissions due to the increased efficiency of electric motors and, for underground operations, OPEX through ventilation costs reductions.

However, Miller stated: "I don't see a lot of value for BEVs at a mine site that is powered by diesel gensets," he said. "The inefficiencies of generation of power from diesel (different fuel efficiencies and different load factors on engine generators) will then be compounded by inefficiencies in converting that energy generated in AC to battery energy in DC. BEVs should only be employed where there is an alternative energy source other than diesel gensets."

Progress at Onaping

In early December, Glencore published its 2020 Climate Report that set out the miner's plan to achieve net-zero emissions by 2050.

In it, the company gave an update on the development of its Onaping Depth nickel project, part of the Sudbury INO, which will soon welcome a BEV fleet. Ambient rock temperatures at the mine can reach 40°C, so Glencore has had to think outside of the box to create a safe working environment.

"Onaping Depth… has been designed to utilize state-of-the-art battery-electric mobile mining equipment, maximized real-time remote operation, monitoring and management utilizing advanced Wi-Fi systems," the company said in the report. "The benefits include the elimination of diesel emissions and the reduction of noise pollution. The design includes the use of innovative ventilation technology, with cooling systems designed to be energy efficient.

"We expect that BEVs could play an increasingly important role in underground operations and that going forward new mines will look to utilize this technology. The benefits of battery-electric power in an underground mining operation are numerous. There are a number of industry initiatives promoting the development and uptake given the environmental benefits and the collective goal to reduce employee exposure to airborne diesel particulates.

"There will also be greater energy efficiency in operating a fleet of electric mobile equipment as the use of BEVs enable savings in ventilation and cooling costs which can be a significant portion of a mine's cost structure."

Glencore said that Sudbury INO continues to work with a few major OEMs to advance battery technology for Onaping Depth. The project will test a number of models before settling on the technology that will be most practical and cost effective.

Vale's Green Energy Vehicle Program

Glencore has also been working with its Sudbury neighbor, Vale, on some BEV guidance and specifications.

At the High-Performance Mining Conference in November co-hosted virtually by German mining association, the VDMA, and RWTH Aachen University's Institute for Advanced Mining Technologies, Sean Kautzman of SRK and Natalie Kari, principal engineer for Vale Canada's Strategic Electric Vehicle Implementation, provided the keynote for the session entitled *The Green Mine*.

Kautzman opened the presentation by discussing some of the challenges that mining companies face when transitioning operations from diesel to electric equipment and the ways in which they can be managed.

Kari then explained how Vale has addressed some of these challenges through its Green Energy Vehicle program; a comprehensive and holistic initiative designed to ensure swift and successful integration of BEVs into the company's operations.

The program is just one way in which Vale aims to reduce its fossil fuel consumption and move toward net zero CO_2 emissions by 2050.

"We called it the Green Energy Program because not only does it include battery-electric equipment, but also trolley-electric equipment, tethered electric equipment, trolley-battery combinations, fuel cell equipment and hybrid equipment," Kari explained. "The portfolio is all inclusive."

To ensure the program was a success, Vale needed to ensure that business support, a proper program structure and KPIs were all in place.

"We did lots of work on leadership endorsement and buy in on-site at all levels so we could really focus our resources on the initiatives at hand," she said. "We also needed internal governance to maintain the program vision and align with the business drivers. If we found any gaps in those we highlighted and addressed them to mitigate risks."

KPIs included those around health and safety, air quality, fossil fuel elimination, financial resources, operational feedback and fleet information. While business drivers included environmental stewardship, worker health, financial improvements and a sense of doing what is right.

"There were lots of considerations," Kari said. "This was a really complex project and there were a lot of processes that needed to happen in parallel in order to make the project happen in a six-month timeframe as opposed to two to three years."

Collaboration was key both internally and externally, and Kari explained how Vale's mobile fleet management team worked on a BEV specification with their counterparts at Glencore in order to develop a document that was industry representative and could be fed back to OEMs.

The teams are also working on a project coordinated by Natural Resources Canada called the 100% Electric Mine Collaboration. The aim is to benchmark diesel equipment performance against that of BEVs. The initiative was set to conclude at the end of December and Kari said she expects some information around TCO to be available by mid-2021. The project is also feeding into the GMG's updated BEV guideline mentioned earlier.

In addition, Vale is working with local colleges to devise BEV upskill training courses and ran a BEV workshop for its leadership team in October to ensure inclusivity.

During the presentation, the question was also raised as to whether Vale was considering battery-electric technology for its surface mining operations.

Kari explained that both the Creighton and Coleman mines have Kiruna trolley trucks already, adding that Vale has procured and is testing a 40-t BEV haul truck which is set to make its debut at Creighton in Q1 2021.

"We will have a battery-electric truck and we're also working with the OEM to develop a battery-electric truck with trolley assist as well," she said. "We're looking forward to trialing that. At Coleman, we also

have a BEV that is not trolley assisted; it's utilized on a specific run that can manage the timeframe the battery is available for."

Nouveau Monde Starts Procurement for Matawinie

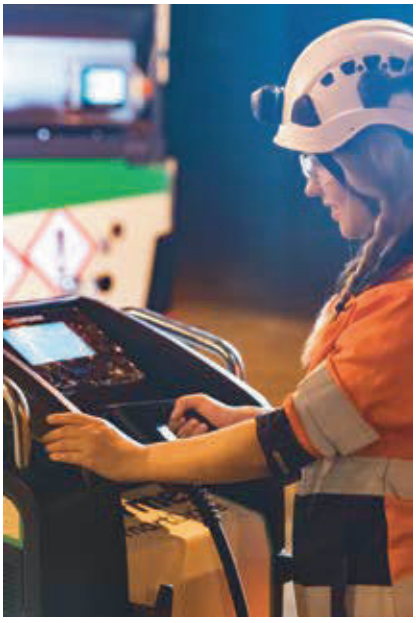
Following Kari and Kautzman's presentation was one from Nouveau Monde Graphite President and CEO Eric Desaulniers. The company, which started as a grassroots exploration venture in 2021, has plans to develop the world's first all-electric open-pit mine, which will be carbon neutral in the first five years of production. Construction on Matawinie will start this year and the mine is expected to be operational in 2022.

Nouveau Monde operates two production facilities in Bécancour, Québec, and supplies high-purity battery anode material and advanced materials to battery producers and automotive manufacturers. Desaulniers said the company's vertically integrated business model and geographical location were key factors in the decision to implement BEVs at Matawinie.

"We have a lot of incentives [to use this technology], more than most mining companies," he told the audience.

Matawinie will be a relatively small surface mine, although it has a large, near-surface resource of 120.3 million mt measured and indicated. The size and topography of the mine mean that 45- to 65-mt capacity haul trucks will be used, and the mine will be operated 16 hours per day, five days a week, which suits a BEV fleet well because the batteries can be placed on a long, slow charge every night to help preserve their life.

The mine will phase in a fleet of 60 BEVs over the first five years of its life as it transitions from mining and dumping waste to backfilling the pit, which reduces the number of uphill journeys the fleet will have to make.



Fast charging underground. (Photo: Normet)

Desaulniers said he visited e-Mining's Swiss test site in 2017 and drove the first eDumper battery-electric haul truck, which is based on a 65-mt Komatsu HD 605-7. Having seen that the technology was feasible, the Nouveau Monde team embarked on a full feasibility study for Matawinie in 2018 based on 100% diesel operation during the first five years then a further 21 years of all-electric operation.

The company began the procurement process for its fleet and charging infrastructure through an international call for pre-qualification in late November 2020, which detailed the desired scope and specs of the future fleet — interested parties can find the list on the Nouveau Monde website.

Discussions with manufacturers have already enabled the team to identify existing machinery in development and/or available, notably for the ancillary fleet where purchasing agreements are now being finalized.

Desaulniers explained that, while the project will require more CAPEX upfront to implement BEV technology, in the long term, an electric fleet will be cheaper to run than a diesel one thanks to Québec's ready source of cheap hydroelectric power. The site will have a dedicated 120-kV power line.

Hydrogen as Well?

Nouveau Monde has done a lot of work analyzing different technologies for both up and downhill haulage applications, and hydrogen fuel cells are another promising technology for the 60-mt truck class, although less well advanced than lithium-ion batteries.

Canadian gas company, Air Liquide, is currently building a 20-MW membrane electrolyzer in Bécancour, which could potentially provide a low-cost, green source of hydrogen close to the mine site, so Nouveau Monde is keeping a close eye on the technology as it develops.

"We might end up using a hybrid solution with fuel cells for the excavators and li-ion batteries for the trucks, but a lot could change in the next few years," said Desaulniers.

Compared to a base case made on diesel equipment, Desaulniers said Nouveau Monde expects a battery-electric fleet to reduce GHG emissions from Matawinie's haulage fleet by 48% once the mine has made the transition. This equates to saving around 12,000 mt/y of GHGs.

"If we total up emissions from all extractive processes in Canada, including oil sands, they equate to around 80 million mt/y of GHGs," Desaulniers said. "We're hoping to enable transformation in the market. If we can show others that it's possible [to go all-electric] and convince them to copy us and work with us, we can increase demand for the OEMs, drive down costs and save a lot of GHG emissions."

Not content with just purchasing BEV solutions, the Nouveau Monde team is also working to develop its own haul truck. The company is part of a project, partially funded by the Canadian and Québec governments, that aims to develop a new propulsion system with rapid recharging capabilities for open-pit mining. The consortium is converting a Western Star XD 6900 truck and plans to test the prototype at Nouveau Monde's test ground in spring 2022.

Boliden's BEV Plans

In an October 2020 interview with *E&MJ*, Jonas Ranggård, manager for Boliden's Mine Energy Program, told *E&MJ* the company is working with Chalmers University in Gothenburg, Sweden, on battery technology to complement the trolley assist technology used for haulage at its Aitik and Kevitsa mines.

The idea is to take out the diesel engine and fill the space with a really large battery pack. The battery pack will be used to power the trucks up ramp until they reach the trolley line. The truck will then connect to the trolley line, continue up ramp to the crusher, dump and return into the pit. While traveling down ramp, the regenerative energy from braking will recharge the battery pack.

Ranggård hopes to see battery-electric haul trucks in operation at Boliden's open-pit mines within the next five years.

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BEV Technology: What's Next?

E&MJ presents a roundup of key product and technology launches in the battery electric space and asks some OEMs what they have in store for 2021

By Carly Leonida, European Editor

The new battery-powered SS5 shotcrete sprayer and TM3 tumbler are put through their paces at the MacLean test mine. (Photo: MacLean Engineering/Mining Industrial Photographer)

In addition to much discussion and various battery electric vehicle (BEV) adoption announcements, 2020 also saw a record number of new product launches and technology tweaks. Many OEMs have further developments planned for this year and a few key players joined *E&MJ* to discuss their R&D work…

Aramine Adds Quick Replacement System

During 2020, Aramine focused on developing new tools that ease the usage of battery technologies.

"Many of our customers have asked us to provide a simple solution to safely change batteries," Aramine Co-president Marc Melkonian said. "That is why we have created a charging station in fixed or mobile versions with a hydraulic crane and a radio control that is easy to use.

"The mobile charging station requires very little space and does not need a special setup in the mine. This station also allows you to move batteries from one face to the other but can also help move other equipment."

Another recent development is the new Quick Replacement System (QRS) that allows batteries to be changed in and out of the miniLoader L140B in less than 15 minutes. Aramine said it is the first OEM to launch this type of battery changing system for underground mining.

"Changing the battery is stress-free, doesn't require a lot of equipment, and can be done quickly. With the QRS version, it's possible to have only one machine running in the mine," Audrey Beurnier, Aramine communication and marketing manager, explained.

The QRS is available as an optional extra on new miniLoader L140Bs and can be retrofitted to operational machines with a fixed frame thanks to a spare kit. Because the battery charger is located on each battery module, the replacement can be done anywhere as long as there is a 220V or 380V electrical plug.

"In 2017, the Aramine design office carried out research and development studies on customer feedback requesting long-lasting productivity," Melkonian said. "The aim was to achieve unlimited machine operation in mines with safe, easy and quick battery replacement by the operator.

"Unlimited autonomy or quick battery charging is usually achieved with complex systems like battery cooling and high-power chargers. We considered these features not applicable for underground mining and decided to go for the simple, safe and efficient QRS. Changing the battery is now faster than filling the fuel tank."

To use the QRS, mines only require one or more additional battery modules — while one module charges, the other powers the machine and vice versa, allowing continuous machine operation. A simple mechanism ensures self-guiding and locking of the battery module on the machine.

"Our R&D department has worked hard to reorganize all the components inside the machine and selected an extremely reliable and safe connection system with maximum power in order to keep the strength of the Aramine miniLoader L140B," Beurnier added.

Will the system be rolled out to other Aramine models in the near future? *E&MJ* asked.

"Aramine is always innovating and in 2020 we launched a new diesel 3.5 tonne loader, the L350D," Melkonian said. "There is already a battery-powered version under development, the L350B. This will feature a similar QRS system to the miniLoader L140B and will also use the same charging station and crane."

Aramine plans to debut the L350B at the next MINExpo event, which is set to be held in Las Vegas in September.

Like its diesel counterpart, the L350B will feature a ROPS/FOPS approved open or enclosed cabin, a steering and boom-up locking device, wheel chocks, audio-visual reverse alarm, easy and anti-skid access, and an emergency stop as well as an automation ready CANBUS system.

The frame has been designed for long life and easy maintenance and, overall, the compact design makes the L350B ideal for narrow vein operations.

From Loaders to Drill Rigs…

"The next step for Aramine is to develop the perfect drilling complement for

the miniLoader L140B," Melkonian said. "We've developed a very reliable battery powered system for the L140B, and we will rely on this technology to develop our first battery-powered drill rig."

The DM901HBE will use battery technology to move the arm of the drifter and a tethered source of electricity for drilling. The battery pack will be fixed (no QRS system included) as the batteries will recharge themselves autonomously during drilling.

The new drill rig will be adaptable to each mine's requirements and the drifter can be specified by the customer. However, Aramine recommends as standard the Epiroc RR14 drifter and feed.

"Nowadays, there is a real need for zero emission machines in underground mines and particularly in narrow vein operations," Melkonian said. "This version is already eagerly awaited by our customers around the world, especially those in South America, Australia and Europe.

"We have always been very concerned about environmental issues and health and safety," he added. "This is why battery powered machines are a must-have in our industry, to reduce ventilation and infrastructure costs and improve the air quality in mines to protect the workers. As Aramine is making it simple to adopt and use daily, battery powered technology will have a big place in the future of mining."

The miniLoader L140B QRS5 — the Quick Replacement System allows the battery to be changed out in less than 15 minutes. (Photo: Aramine)

Epiroc Rigs Shine at Kittilä

In Finland, Agnico Eagle's Kittilä gold mine provided a testing ground for Epiroc's next generation BEVs as part of the European Union-funded SIMS project. The project, which came to a close in April 2020, lasted three years and was tasked with developing smart and environmentally friendly systems for the mining industry.

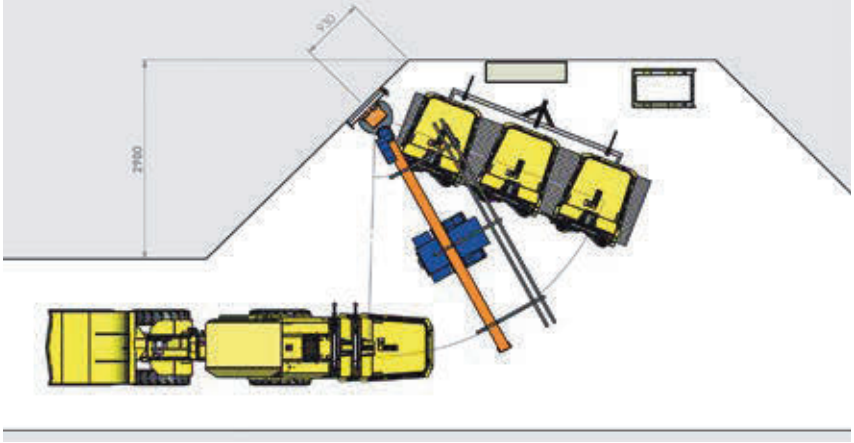
Following the tests, the mine decided to purchase two Boltec E battery-powered bolting rigs. The first unit arrived at Kittilä in early November, and the second a few weeks later.

Jari Kolehmainen, Kittilä's production manager, said the team's first impressions were very positive.

"The performance of the machines is at least at the same level as that of diesel machines. Productivity has improved with the development of equipment," he commented. "The change in air quality [underground] is clear. In the future, we want to reduce our carbon footprint and move toward zero-emission technology, as well as move forward in well-being at work. The SIMS project showed that battery technology has made great leaps forward."

The mine has had to reconfigure its electrical infrastructure to accommodate the new machines and a battery replacement bay has been added to allow for swapping but otherwise, no other special requirements were needed.

The Kittilä team is also keen to introduce other new technologies in addition to battery-powered equipment. A remote-control room has been added to the office, from which several machines are controlled simultaneously by two operators since the beginning of October.



The charging station — tunnel layout for Aramine's battery-electric L140B loader. (Photo: Aramine)

First Batteries as a Service

In July, Epiroc also announced it had signed the world's first Batteries as a Service (BaaS) agreement with Vale in Canada.

With BaaS, Epiroc works directly with the customer to define a battery plan that suits the needs of their operation. The lifespan is guaranteed, and the battery status is monitored to ensure predictive maintenance with reduced downtime. If a customer wants to increase or decrease their capacity, they can adjust their plan and the service will be tailored to meet their requirements.

In line with its keen focus on sustainability and circularity, Epiroc will remove old batteries from site and replace them with new. The older batteries are then used for secondary applications and are recycled at the end of the process.

"A key component to the success of this offering is the flexibility it allows our cus-

The new LH518B, Sandvik's first 18-t battery-electric loader. (Photo: Sandvik)

tomers. We take ownership of the battery itself and automatically replace and update the units as needed, which means the mine site can breathe easier and continue to focus on heightened production," Shawn Samuels, product manager, Rocvolt, Epiroc Canada, commented on the announcement.

Additionally, Epiroc will be providing Vale with 10 BEVs for two of its Canadian mine sites. These include four Scooptram ST14 loaders, two Boomer M2C drill rigs, two Boltec MC bolting rigs and two Minetruck MT42 trucks.

To complement the new battery fleet, Vale will also be adding three of Epiroc's charging cabinets and seven charging posts for equipment support. Delivery will be completed in Q1 this year.

Ann-Sofie Andersson, global manager for branding and communication, said Epiroc aims to offer battery-electric versions of its entire product portfolio by 2025. The battery system Epiroc uses is modular and designed to be scalable for larger and smaller products as well as for new applications.

"Our current offering includes 7-t, 10-t and 14-t loaders; 20-t and 42-t trucks; and a range of (currently 11 models) battery-electric midsized drilling equipment including face drilling, production drilling and rock reinforcement rigs," she said. "We also have a 4-t loader specifically for the Chinese market."

In addition to the Kittilä and Vale projects mentioned above, Epiroc is also testing an 18-t battery-electric loader at the LKAB-led Sustainable Underground Mining (SUM) project.

MacLean: New Batteries, New Machines

MacLean Engineering already offers battery-electric versions of many of its underground hard-rock equipment models, and the team is currently working on battery technologies that will extend or improve their performance. First up is a new battery chiller that will allow MacLean BEVs to operate in hotter conditions.

"We'll be releasing that in 2021, particularly with the Australian and African markets in mind," said Maarten van Koppen, product manager for mine operations at MacLean.

The team is also working on additional battery options, which are currently being tested and are planned for launch later this year.

"What we've seen over the past couple of years is that one battery size for all machines and all applications is not the most efficient way to put these machines to work," van Koppen said. "So, we're working on options, based on the same chemistry we've been using since 2016, but which provide both lower and higher energy capacities to the market.

"That's important, for example, on sprayers or bolters, which can plug in and charge their batteries whilst operating. They don't typically run far so putting a large battery on them doesn't make sense. Conversely, concrete trucks that drive up and down the ramp, could probably benefit from a larger battery. For us to continue with only one battery solution didn't make sense anymore. We saw that we needed to provide more granularity in that, and it's going really well."

MacLean was outfitting one of its machines with a new battery when the team spoke to *E&MJ* in December with testing set for early January.

MacLean also has plenty of machine launches in the pipeline for 2021, including a road grader and a new shotcrete sprayer-tumbler pairing.

"The road grader is primarily designed as an electric machine, although we'll also be offering it in diesel," van Koppen said. "To our knowledge, it's one of the first purpose-designed underground hard-rock graders that falls into the heavier size class.

"We're also evaluating an articulated, heavy-duty forklift with multiple attachments like tire handlers, etc."

The new battery-powered SS5 shotcrete sprayer and TM3 tumbler will also debut in early 2021. Product manager, shotcrete equipment, Jonathan Lavallee, took over to tell *E&MJ* more.

"The SS5 prototype is currently at our Magill Street test mine and R&D facility in Sudbury going through the final performance checks," he said. "That's going really well."

Key features include a new pump that has been designed specifically for MacLean to increase shooting speeds underground. The pump also allows operators to switch from spraying to traditional concrete laying for underground construction purposes, which is an added bonus. The SS5 has a new three-phase thickness monitoring technology for shotcrete, a blockage detection sensor to improve safety during shooting, and a synchronized auto-dosing system for the accelerator.

"We're also developing a new system for accelerator dosing right at the nozzle based on a new way of atomizing the accelerator into the shotcrete itself," said Lavallee. "That will prevent over-dosing and increase savings that are going to be passed on to the mine.

"We're going hard on a 'no-boots-on-the-ground' philosophy with this machine," he explained. "The operator will be able to perform all the shooting applications from the cab without having to exit it and go under potentially hazardous, loose ground."

The SS5 was developed in-house based on the MacLean team's discussions with contractors, miners and operators on what they would like to see, and technology that is key for the future movement of the shotcrete industry.

The MacLean test mine was key throughout the project. The company acquired the facility, which is just down the road from its Sudbury branch, in 2018. And it has proved a solid investment, particularly as COVID restrictions during 2020 hampered the team's travel plans.

"We put some investment in to modernize the mine and now our Advanced Vehicle Technology Team is based there," said Stuart Lister, MacLean's director of marketing and communications. "The mine also has a dedicated team. Having this underground

lab has really accelerated our R&D and training capabilities. Even through COVID, our R&D work never stopped."

New Markets and Applications

What's next? *E&MJ* asked the team.

"In the immediate term, we're working to round off our BEV fleet for underground hard-rock applications," van Koppen explained. "There are still a couple of units that aren't electrified yet like rock breakers and water cannons.

"And then, we'll be continuously improving and enhancing our designs, like we're doing with the additional battery options. And there will be crossover between our automation, digitalization, and electric offerings that we'll start focusing on as well."

"In 2021, we're looking to cast our net a little bit wider geographically, too," Lister said. "We've got a great network across Canada and we want to take that into the U.S., Australia and Scandinavia as well."

"Yes, and to take these vehicles international, we'll be making minor adjustments to suit localization requirements," Patrick Marshall, VP of Product Management at MacLean, joined the discussion. "For example, in Australia we will incorporate how sites want to see their e-stop circuits configured and ensure compatibility with local voltage standards.

"As we go into 2022, we're looking at new applications too — because of the success of MacLean's EV Series drive train, we've got an opportunity to bring to market battery vehicles that aren't in our traditional diesel portfolio. We will also start to diversify into other streams of underground mining, low-profile mining, for example. Platinum and palladium mines in South Africa are very interested in electrification. I think that's the next big customer base to support."

Normet Expands SmartDrive With Fast Charging

Normet launched its SmartDrive, BEV product portfolio at the Bauma exhibition in Germany, April 2019. Since then, the company has added products for concrete transportation and spraying, explosives charging, lifting and installations, and underground logistics for both underground mining and tunneling.

"We have two different battery-electric architectures: a mining architecture optimized for long tramming distances, and a tunneling architecture optimized for needs in tunneling applications," Samu Kukkonen, technology director for Normet's Equipment Business, said.

Normet has recently expanded both architectures to include fast-charging battery technology. This allows for rapid charging without major impact to the battery lifespan.

"Fast charging is a natural option for Normet machinery, and it means there is no need for battery swapping," Kukkonen explained. "By choosing fast charging over battery swapping, we have eliminated the possibility to damage batteries during swapping, and we have designed the machine structure so that batteries are secured and covered to ensure safety.

"In addition to safety benefits, battery swapping is also much more tedious and expensive to implement. We believe that fast charging is the future, as it is for electric cars. And we are supporting the common CCS fast charging standard."

Normet demonstrated battery-electric emulsion charging at Pyhäsalmi during 2019 and the technology is now commercially available.

"We already have multiple sites globally where SmartDrive's are being operated," Kukkonen said. "In addition to Pyhäsalmi, the first BEV for underground explosive charging on Australian soil was the Charmec MC 605 VE SmartDrive, which operates with Downer Blasting Services at OZ Mineral's Carrapateena mine in South Australia."

In all SmartDrive machines, safety and efficient performance have been the main drivers for development.

"Combining the most advanced process expertise with the latest BEV technology allows us to offer our customers products to meet today's stringent requirements. In the field of sprayed concrete, for example, we have machines in Norway and Australia, and we were the first company to supply concrete sprayers with BEV technology with our Spraymec 8100 VD SD," Kukkonen added.

"We believe that BEVs are the future for mining. There are many more benefits in using BEVs in the mining industry than in road vehicles."

Sandvik: A New Loader, and More...?

At a virtual event in September, Sandvik presented its first 18 metric tonne battery loader, the LH518B. This model, which brings Sandvik's battery electric LHD range to four models, combines the company's expertise in vehicle engineering with Artisan Vehicle Systems' powertrain and battery technology.

The LH518B was designed from the ground up around Artisan's battery system and electric driveline. The design allows it to work in 4.5 x 4.5-meter tunnels and, in addition to a new boom and bucket system, the LH518B features independent front and rear drivetrains, allowing a high payload capacity while keeping the overall machine height low.

The loader is equipped with three 2000 Nm permanent magnet motors. With no torque converter, transmission or engine to rev up, Sandvik said the loader is fast and agile and there are no emis-

Epiroc's ST14 battery-powered loader in action underground. (Photo: Epiroc)

sion restrictions based on installed power to limit the electric motor selection.

The LH518B is also equipped with Artisan's patented AutoSwap battery swapping system, which requires no lifting equipment or infrastructure. Changing the battery takes six minutes, and the new AutoConnect feature, which makes its debut on the LH518B, allows the machine to automatically connect and disconnect the battery pack. This means that, aside from plugging in and unplugging the charger, the operator doesn't need to leave the cabin.

The battery pack uses lithium-iron-phosphate chemistry (LiFePO4) and is purpose-designed for use in underground mining.

In the LH518B press release, Sandvik hinted that it is working to expand its BEV loader and truck offering and preparing to enter new market areas.

E&MJ asked Katja Rivilä, marketing manager for load and haul technology at Sandvik, what's next?

"One of our guiding design principles is the matching pair thinking," she said. "Considering the payload capacities, you need to be able to load a truck with a loader in an efficient way. Coming from here, we are planning to introduce new trucks to match with the loaders. Of course, in the long run, we are building a comprehensive fleet of battery-electric loaders and trucks of different size classes."

The company is also working to minimize the potential impact of BEVs on mine infrastructure.

"Changing from traditional technology to BEVs needs to be easy and flexible for the mines," Rivilä said. "For this reason, we are focusing on a self-swapping system for batteries, eliminating the need for lifting discharged batteries and swapping to a new one with an overhead crane; our equipment does that all by itself, controlled by the operator sitting in the cabin. Our patented auto-swap technology is also developed to minimize swapping time; changing the battery must be fast enough not to compromise productivity."

Normet's battery electric Charmec MC 605 VE SD at Pyhäsalmi in Finland. (Photo: Normet)

In 2021, Sandvik will be trialing several LH518B loaders at different mine sites to get customer feedback on the loader, plus actual performance data. The LH514BE is also in the pipeline. This is a battery-assisted loader that combines cable-electric and battery technologies; when the LH514BE is mucking, it draws power from an electrical cable, but when travelling, e.g., to a different mine section or to the workshop, the machine gets its power from the battery, and the cable can be unplugged from the mine network. Sandvik believes this combination will significantly increase the flexibility and ability to move the loader, compared to the cable-electric models.

"We believe BEVs is the right direction to take," Rivilä added.

"Diesel engines are not going to disappear overnight, and we are therefore putting significant efforts into that technology too. But, what else will there be? What kind of hybrid technologies will be born…? That is an intriguing question and definitely something that the whole industry is buzzing about. Sandvik is not the exception, but today it is too early to comment about possible future hybrid technologies."

In 2021, Sandvik will be trialing several LH518B loaders at different mine sites to get customer feedback. (Photo: Sandvik)

Barrick, Sandvik Partner for BEVs

Speaking of new trucks… On November 19, Sandvik and Barrick announced a partnership agreement to trial BEVs for hard-rock underground mining.

Over a three-year period, Sandvik will deploy four Artisan Z50 BEV trucks into production at the Turquoise Ridge gold mine in Nevada, part of the Nevada Gold Mines joint venture.

In phase 1 trials, the Z50, which has a 55-ton payload capacity, achieved more than 1,400 hours of production with more than 1,400 loads. It reached 18 hours of operation per day. Speeds of over 10km/h (6 mph) were also observed on the ramp to the tip.

Together with the Barrick team, Sandvik's dedicated site personnel are assessing key performance indicators including the performance of the BEV technology in a production environment, mechanical availability, average lifecycle cost and overall production cost.

Barrick President and CEO Mark Bristow said, "This partnership with Sandvik is exciting and will give us first-hand experience in BEV technology in our own production environment. It is a significant step to furthering our BEV strategy across the group."

China Coal & Mining Expo 2021

China's 19th International Technology Exchange & Equipment Exhibition on Coal & Mining

Date: 26-29 October, 2021

Venue: New China International Exhibition Center (NCIEC)
Beijing, China

Host:
China National Coal Association

Co-host:
China National Coal Group Corp.

Organizers:
Together Expo Limited
China Coal Consultant International

Worldwide Enquiries:
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Adding AI and Machine Learning to Process Control

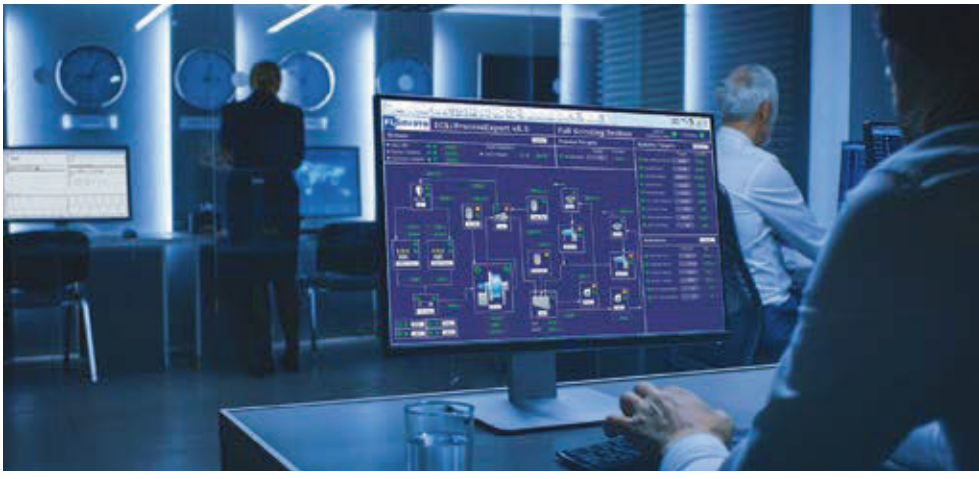
A new platform upgrade allows process control engineers and data scientists to collaborate on improvements for the plant

By Steve Fiscor, Editor-in-Chief

Advanced process control (APC) systems at the mills and concentrators are enabling mining companies to optimize operations and improve recovery rates. These systems offer clear advantages for controlling the setpoints in the plant in real time, which is a game changer for feeds with varying grades. Their use in the plant has also helped identify other areas of possible improvement.

While dreams of a fully autonomous plant for the average operation might be just that, advancements in this area have been significant. APC systems today still require tuning and good maintenance programs that consider regular inspection of the sensors, devices and the loops that control them, along with training for technicians.

As computing speeds increase, system developers are hoping to create smarter systems that anticipate changes and make further refinements to the process using artificial intelligence (AI), data analytics and machine learning. One of the companies leading the way in this area is FLSmidth, which recently announced a major upgrade of its system.



A new software upgrade could improve the plant's ability to maintain its setpoints.

Smarter Mineral Processing

Machine learning and AI are fast becoming a part of everyday life for the manufacturing sector and it's expected to play a larger role for process optimization solutions in mining. To meet this growing trend, FLSmidth has launched the latest version of its APC solution, ECS/ProcessExpert (PXP) V8.5 software, which now includes the ability to integrate new AI cognitive technologies and functions.

"The new AI technologies are based on machine- and deep-learning algorithms that create their own understanding of a process by finding patterns in the raw process data. They then use this understanding to solve problems that help improve performance and sustainability," said King Becerra, global product line manager for FLSmidth's digital group.

As an example of AI at work, PXP V8.5 facilitates predictive modeling of process data signals that can be unreliable or unavailable. These are then used to create a more accurate model and controller of the actual process conditions. This improves the plant's ability to maintain optimal setpoints and a faster response to conditions that may result in undesirable situations.

PXP V8.5 also incorporates new features to promote collaboration and cooperation. The new PXP Data-Books module, for example, allows the automation engineers and the data scientists at the mining operation to integrate their existing machine learning and deep learning algorithms into the PXP applications and control strategies. This function bridges the gap between the process control engineer and the data scientist, Becerra explained. "Often we find that the data scientist speaks one language, while the process control engineer speaks another," Becerra said. "DataBooks allows these two professionals to work together in a more cohesive environment."

While describing the PXP platform, Becerra emphasizes that it enables other applications as well. As an example, a mining operation may have a data scientist who is using deep learning to understand the particle size distribution of the cyclone overflow. Traditionally, that person would use a set of statistical functions. What FLSmidth has developed with the PXP is the possibility of using a machine learning algorithm that might solve this problem and easily integrate it into the APC.

Another new feature of PXP V8.5 is a range of sustainability dashboards that report the system's performance in terms of environmental KPIs (key performance indicators). With these dashboards, operators can see how process improvements, such as more efficient use of energy, translate into lower CO_2 emissions.

AI is already driving technological advances at manufacturing plants and Becerra believes that mineral processing operations could take advantage of these tools, too. However, he also cautioned that AI technologies have not achieved a level of development and maturity to replace everything currently used to control

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and optimize minerals processes. "We identify the problems we want to solve," Becerra said. "We then apply the technology that is best suited to solve that problem, whether that be AI or something else. We think holistically — it's not only about the technology, but also what is required in terms of human and economic resources for the mining companies."

APC systems are very often seen as one of the main drivers needed to reach the dream of autonomous operations, Becerra explained. "In this context, it's commonly heard in the media that AI is replacing APC systems," Becerra said. "But this wrongly assumes that AI is already a synonym for fully autonomous operations. This kind of misrepresentation does not help, as such fully autonomous, continuous-process plants are still not that close to reality.

"However, there are many examples where new technologies and workflows can heavily enhance the level of information that is gathered and analyzed, transforming it into much better actionable insights, to take decisions faster than ever," Becerra said. "This is what we call 'intelligence augmentation' and can clearly assist and elevate the performance of either existing APC systems or human-based control.

Becerra pointed to three main areas where APC could benefit from AI:

Cognitive augmentation. The ability to gather, analyze and combine various data streams in real time can bring relatively quick benefits from operational and safety perspectives. One example would be building new virtual sensors to replace unreliable or unavailable signals, particularly when the instrumentation is placed in risky areas or is often out of service.

Smart controllers. In certain contexts, controllers can be enhanced and complemented by virtual models of machinery or processes, known as digital twins. If the digital twins are done well, they can be used to find the controller's optimum parameters, which leads to more stable processes, achieves higher production and quality levels, or decreases the amount of energy or water used.

Dynamic adaptiveness. Many processes are by nature nonlinear and time-varying: this means that actions that were optimal to achieve specific goals yesterday (or even an hour ago) may be suboptimal or even inefficient now. Varying grades in the ore feed would be a classic example.

The new technologies and collaboration possibilities introduced in PXP V8.5 will bring multiple options for cognitive augmentation and smart controllers, Becerra explained. "For example, we are facilitating techniques to apply neural networks to build smart predictors, replace faulty or missing instrumentation, or forecast the future of certain signals in the form of time series," Becerra said. "This creates the option to connect those new synthetic measurements with controllers, which will thereby react earlier, preventing undesired situations from happening or sticking constantly to optimal setpoints.

Becerra said two main barriers limit adopters from realizing the benefits. First, these new capabilities not only involve new technologies but also require new procedures, work flows and skillsets. It is therefore important to understand that multidisciplinary views and cross-func-

Transform or Be Marginalized

What will the future of mining look like? Why does the industry need to change? How can mining embrace innovation? These were just some of the questions pondered when a panel of mining industry experts came together to discuss the need for change in the mining industry from an operator, solution, technology and investor perspective at IntelliSense.io's recent "Inspirations20."

In the keynote session, IntelliSense.io Founder and CEO Sam G. Bose was joined by Damien Caby, senior vice oresident, Oilfield & Mining Solutions, BASF; Ippei Akiyoshi, CVC Mineral Resources Group, Mitsubishi; and Cleve Lightfoot, head of innovation, BHP.

Central to this discussion was the notion that mining technology and processes have become outdated. "We're dealing with technology and processes that were developed 100 years ago that aren't apt for what comes next," explained Lightfoot. "What we've done in between is we've made them bigger, better and more efficient and we've done a good job at that. What we haven't focused on is how the context in which we operate has changed and it's changing more and more rapidly."

When designing new technologies for the industry, Bose explained that demand for sustainability solutions has become a top priority.

Caby added that from an operational perspective, the demand for ethically sourced and environmentally conscious material is also heavily influencing the direction of the mining industry. "We see that, both as a supplier to the mining sector and a supplier to the battery industry, there are tremendous changes in the nature, the quality of metals that are going to be required for the world, which in itself is a major driver for change," he explained.

"I just don't think we're going to provide the nickel, the copper and cobalt for e-mobility the same way that 20 years ago the industry was able to react to the surge in demand for rare earths, and I think overall that's the biggest driver of change."

With the pressure to innovate or perish, panelists conceded that it may appear difficult for mining companies to know where to start, but prioritizing opportunities was key.

"We're great at building big infrastructure projects, but we need to learn how to figure out how we take little bits and transform through little bits. So, accept the ambiguity, and the risk associated with these things through bites we can actually manage," Lightfoot said.

Caby suggested that for mining operators unsure of how to start their innovation journey, the most pragmatic option may be to start with unlocking the value in their operational data. "In our experience, it really starts with understanding of the situation of the mine and really diving into the situation of what's the challenge, and that's all really data based," Caby said.

"You can have much easier access to information, you can measure the impact of the improvements to make and correct the results for changes in feed and operating conditions, you can make simulations that really help address risk concerns. If you can run scenarios, if you can put boundaries, if you can try and see what can happen worse case on the computer compared to trying it real life, you really have a powerful tool to enable innovation."

Watch the full recording of the session at https://inspirations.intellisense.io/

tional collaboration are more crucial than ever. Process specialists (domain experts), automation and process engineers should open their arms to and work closely with data scientists, data engineers and industrial AI experts to explore potential new solutions to specific process problems. This human and social aspect is commonly overlooked but, in reality, working as a strong team of people with complementary skills is a key element to success.

The second aspect relates to the "hype cycle," especially with emerging technologies and trends in the industrial landscape. "We hear bold promises from marketing materials or sales presentations sometimes inherited from other sectors where maturity levels and/or conditions are far from similar. This can make it very difficult for a non-technical audience to discern hype from what is technically viable and commercially profitable for their specific business needs.

This overinflation of expectations, combined with low resistance to failure, leads to huge doses of frustration and early dropping of the investment, even before the learnings are incorporated into a new iteration or before a good productivity level is reached.

Getting Started

Applying AI and machine learning to the entire plant all at once could be time consuming and would not likely produce the intended results. For mining companies interested in getting started, Becerra suggested starting with a segment of the flowsheet, such as the grinding circuit because of its non-dynamic characteristics. In some cases, he said he has seen significant results, production increases of 6% and decreases of energy consumption of as much as 7%-8%.

Using machine learning with the grinding circuit, process engineers could use predictive modeling and time series forecasting and determine the influence of setpoints. Predictive modeling allows the process engineer to develop models to use in parallel with existing instrumentation. Plants measure P_{80} frequently and the PXP DataBook could add the capability of using six to eight months of data to predict P_{80}.

With time series forecasting, process control engineers would have the ability to predict how the plant will operate in the next five to 10 minutes. Becerra likened it to weather forecasting. If nothing changes, according to the historical data, the mill weight will increase and they need to take action to keep it from overfilling in the next 10 minutes. This is not to be confused with predictive analytics that estimates a motor failure in three months, as an example. Time series forecasting is very short term.

Machine learning can answer questions surrounding setpoints and the optimal parameters of operations. Questions such as: What mill feed and speed would achieve the lowest energy consumption? From those answers, process engineers can compare production as a function of energy consumption.

Looking toward the future, Becerra sees even more improvements ahead for PXP. With FLSmidth's acquisition of KnowledgeScape in October, it now has access to applications related to thickeners and flotation. The company will soon integrate those into the platform.

Driving Mines Forward

E&MJ *explores the impact of digitalization on motors and drives for mining applications*

By Carly Leonida, European Editor

Hägglunds drives for in-pit primary crushers. (Photo: Bosch Rexroth)

Motors and drives for stationary mining and minerals applications are some of the hardest working pieces of equipment on site. Whether powering conveyors or mills, hoists or crushers, smooth, efficient and reliable operation is critical in keeping mines up and running.

There are many applications in these sectors that are unique and therefore require specially adapted or designed drive solutions. For product combinations, the alignment and optimized design of the individual components is essential. As is the ability to operate in a fail-safe manner under harsh conditions and temperatures ranging from freezing to +40°C, while withstanding snow, rain, dust and more.

"Motors and drives have been partners in mining applications for many years," said Chris Diak, senior product sales manager for Electrical/Automation/Linear Products at Motion Industries. "As technology has improved, processors have increased in ability, allowing for more features to be added to variable frequency drives (VFDs). One example is the addition of condition-based monitoring. The drive controls the motor and uses many of the same measurements for control that are needed to provide the health of a motor.

"When designated firmware is combined with a vibration sensor, the predictive aspect begins to materialize," Diak said. "The drive not only controls the motor but can also monitor the motor's health as well. As the industrial Internet of Things (IIoT) continues to evolve and develop, more and more will be asked of the processors in drives. These asks will calculate motor analytics and provide information in order to maintain a solid uptime percentage in the field."

Andreas Evertz, CEO at mechanical drive specialist Flender, spoke about the biggest advances he has seen in motor/drive technologies over the past 10 years. "Certainly, we've seen increased efficiency in drive solutions," he said. "This is still a key focus area. It is most important to develop high-efficiency products specifically adapted to customers' requirements. The product quality must allow for the highest availability.

"In addition, digitalization has been a game-changer in the mining industry," Evertz said. "At Flender, all our product information is now available through our online product configuration tools with just one click. We use state-of-the-art condition monitoring systems to oversee our drive components and use cloud services for data analysis."

Wolfram Ulrich, vice president for sales and service of the Hägglunds products and solutions at Bosch Rexroth, also reported a growing focus on reliability throughout product life with the use of digitization. "We have seen an increased interest for highly reliable solutions — something that has always been a focus for us and, not least, the need for digitalization and connectivity," he said. "We have developed our Hägglunds Inside Intelligence Suite to meet these needs.

"We've also seen a trend toward bigger machines/applications, and this is of course also reflected in our development of bigger motor and systems, for example, our Hägglunds CBm motor and the recent delivery of the Hägglunds CBm 8000 for the South Flank iron-ore project."

The Digital Revolution

As in many areas of mining, digitalization has transformed the ability of both miners and OEMs to control and optimize the performance of motors and drives. And the need for these solutions became ever more apparent during 2020, as travel restrictions saw many mines turn to remote operations.

"In product specification, the use of digital technologies means it is now possible to better determine system requirements and utilization of machines within a specific application at certain material flows much more precisely," Evertz pointed out.

"With this knowledge, the optimal product design keeps the right balance between reliability, material usage and efficiency," he said. "Together with an efficiently working modern monitoring system, highest availability and almost 100% reliability can be achieved. With the correct design and specific monitoring, unplanned shutdowns belong to the past."

Diak added: "For years, drives have provided energy savings when used in the right application. Add newer motor efficiency designs with faster processor chips and you continue down this path of improvements in energy efficiency, better motor response and better application control.

"The IIoT is growing at an exponential rate to provide the predictive analytics necessary to monitor equipment individually or as a whole. Combine these sensors and systems with VFDs and you have the next evolution in drive benefits. Smart packages will not only control the motor more precisely but also know when it is not running at an optimum level and potentially notify the appropriate department. This all leads to better operations and, ultimately, more uptime."

Ulrich cautioned though that digital solutions are not the be-all and end-all of reliable operations — it's important for mines to choose a service provider that can also provide boots-on-the-ground support when needed.

"With the need for reliability and availability also comes the need for service and this is twofold," Ulrich said. "One is the possibility that connectivity solutions have for preventative maintenance, planned service and increased uptime and, two, there is a bigger focus with actual physical service also being available if needed, and here we see our global team of Hägglunds experts that operates locally as a big advantage."

Inside Flender's new Bayswater facility in Western Australia. (Photo: Flender)

Flender Looks to the Future

Flender provides mechanical drive solutions for almost every application in the minerals and mining sectors. The company's portfolio covers products for in-plant and overland conveyor belts, off-highway trucks, slurry and process water pumps, flotation cells, leach pads, agitators, horizontal ball and vertical fine mills and high-pressure grinding mills.

In December 2020, Flender opened a new state-of-the-art testing and workshop facility at the Tonkin Highway Industrial Estate in the Perth suburb of Bayswater. The 3,500-m^2 facility enables the company to combine sales, project delivery, engineering and training in one location. It will also enable Flender to expand its operations in Western Australia.

Flender said the facility is one of only a few in the world capable of servicing all makes and types of gearboxes and drive train components, and is the only OEM facility on the West Coast with a 1.5-MW load test bench capable of testing complete drive systems up to a voltage of 6.6 KV.

The move follows Flender's $5 million investment into its Rockhampton service center in 2017.

Evertz spoke a little more to the company's R&D focus in 2020 and beyond…"2020 was a tough year for the whole mining industry," he said. "We used our resources to scrutinize our products for any improvements in basic material costs, manufacturing and both engineering and order processing time in order to meet ever-stronger market demands.

"Our focus is on fine tuning many of our products for specific mining applications with the help of smart and reliable monitoring solutions," Evertz said. "We will introduce new products and solutions in 2021, but are unable to unveil them just yet."

Another 2020 highlight for Flender was an installation at a large iron-ore mining project in Australia.

"We supplied large Planurex 3 planetary gearboxes for HPGRs, large FZG helical gearboxes on material process pumps as well as large FZG bevel helical gearboxes. These were assembled as a drive system for conveyors locally in our workshop in Australia," Evertz added proudly. "Most of the gearboxes were equipped with a Flender gearlog monitoring system to both monitor the condition of the gearbox and collect real-time application load data."

Bosch Rexroth Delivers Mammoth Bucketwheel Drives

Australia is also a key market for Bosch Rexroth and, in 2019, the company was selected by thyssenkrupp Industrial Solutions Australia as the supplier of the bucketwheel drive system for the largest-ever rail-mounted bucketwheel reclaimer. Featuring an ore-moving capacity of 20,000 metric tons per hour (mt/h), the bucketwheel reclaimer is being installed at BHP's South Flank iron-ore mine in the Pilbara.

Conveyor drives at an LKAB mine in Sweden. (Photo: Bosch Rexroth)

The wheel drive system is based on Hägglunds hydraulic direct drive technology which offers high power density and a flexible drive layout that is well suited to bucketwheel reclaimers. The system will utilize the largest hydraulic motor ever built, the Hägglunds CBm 8000.

Bosch Rexroth said the hydraulic direct drive system provides the high level of torque needed for bucket wheel reclaimers, but with low weight and a high degree of flexibility; only the lightweight hydraulic motor is mounted on the boom to drive the wheel shaft, while the drive unit with electric motors and pumps can be situated in a more central position on the machine. In many cases, this lets equipment manufacturers eliminate steel bulk and counterweight, which results in a leaner, more agile and more fuel-efficient bucketwheel reclaimer.

Bosch Rexroth is also supplying Hägglunds drive systems for the slew function on both the bucketwheel reclaimer and two stacker machines at the same mine site. Each slew drive will comprise four Hägglunds CB motors with torque arms and brakes.

Ulrich spoke more about the company's offering for mining applications.

"We provide customized Hägglunds drive solutions meeting needs ranging from the really small applications to the biggest, like with the Hägglunds CBm 8000 mentioned above," he said. "The modularity of the Hägglunds system design also enables us to go from smaller to larger systems in the several MW range.

"We also have a suite of connectivity solutions for optimizing processes and enabling predictive maintenance, and a global, but local, service organization that provides fast service and support all over the world."

The Hägglunds connectivity suite can be used for predictive and planned maintenance, as well as providing feedback on the status of the drive system remotely or locally.

"Using the detailed information from Hägglunds CMp, we can also help customers understand and optimize the use of their drive systems," Ulrich said. "If a drive is being utilized to the limit of its capability, then we can make adjustments to enable increased production. If a drive is underutilized, we can adjust its configuration for greater efficiency."

Repair Program Delivers Big Savings

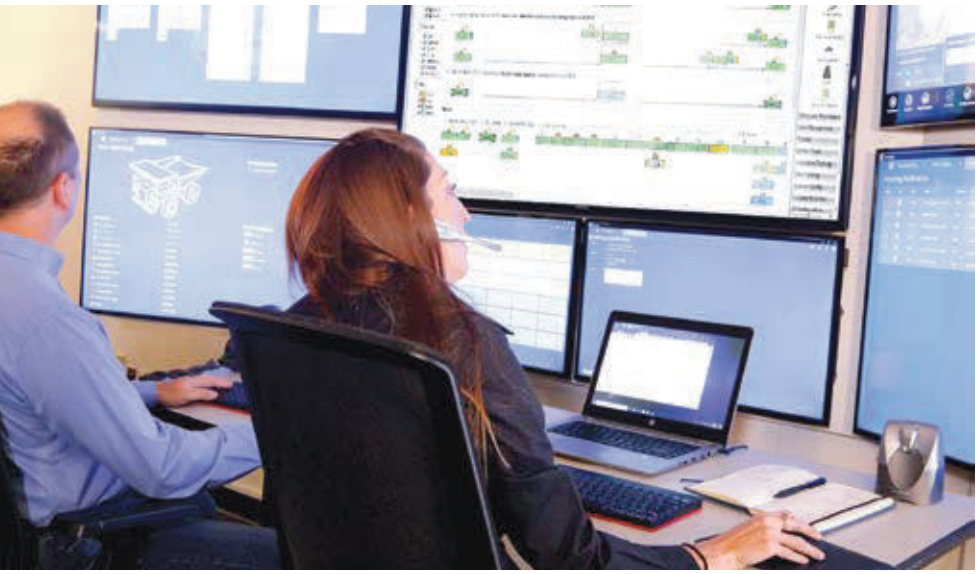
In 2019, Motion Industries joined forces with Alabama-based motor expert, Louis Allis (now part of WorldWide Electric Corp), to deliver a hefty saving for a coal mine near Gillette, Wyoming, USA.

The mine was experiencing repeated failures with its tandem 1,000 HP coal conveyer motors, even after multiple attempts to repair the units at a local shop. After believing the units could not be repaired, the mine decided to move the motors into its scrap yard and called Motion Industries to help find replacement units. Motion contacted Louis Allis, which questioned the failures and had the client send them the units they had thought were beyond repair.

Once Louis Allis inspected the motors, it was apparent that the previous rotor repairs had been improperly executed and, as such, were causing the repeated failures. Through Louis Allis' Renewed Motor Program, the company was able to repair and renew one of the two motors on rushed overtime, and the repair and recondition was completed in just 14 days.

Repairing the motor not only saved the client months of downtime, but also $60,000 in the cost of replacement motors. The client was so impressed that the second motor was also put through the Renewed Motor Program.

Disaster Recovery Planning is Crucial for Cutting Costly Downtime



A Modular Mining customer, concerned about the possibility of lengthy production interruptions in the event of a computer hardware failure, installs two identically equipped data centers — one on-site and one remote — to ensure a quick return to normal operations.

Modular Mining, a subsidiary of Komatsu that develops mine equipment management systems, noted recently that in any computerized work environment, hardware issues are a reality. More often than not, the problems are minor and easily resolved by a server reboot or service restart, and result in little, if any, operational disruption. Unfortunately, more serious problems such as a server failure or prolonged power outage are also a possibility. In these situations, the potential for lost productivity, missed production targets and decreased equipment utilization is high.

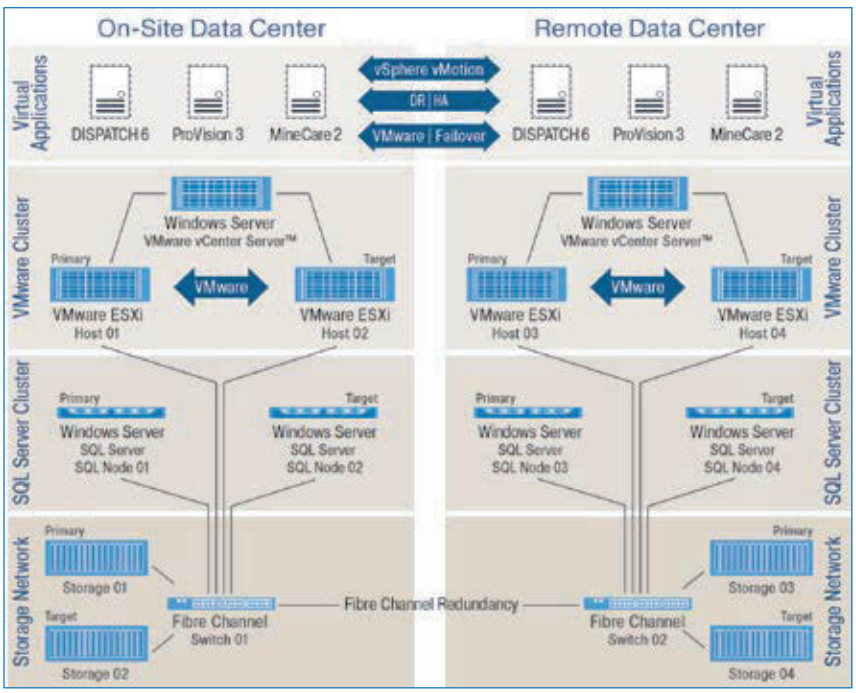
Modular said it recently helped a Latin American mine protect against prolonged downtime from computer hardware issues by implementing improvements aimed at ensuring availability and operational continuity. The mine, a long-time customer and user of Modular's DISPATCH fleet management system (FMS) along with its ProVision and MineCare products, sought help in mitigating operational risk should a severe upset event occur.

In a collaborative effort, deployment and support personnel from Modular, a cross-functional group from the mine, and a local information technology (IT) contractor designed a comprehensive Disaster Recovery (DR) plan to meet the needs of the operation. The team assessed the major factors influencing the DR solution, including the Modular Mining technologies in use, SQL Server database structure, application and virtual machine (VM) structure and interoperability among the applications and hardware. After achieving a thorough understanding of the factors involved, the team formulated a plan that uses Microsoft SQL Server Always On Failover Clustering Instances (Always On FCI) and VMware vCenter for reliable, high-availability capability.

Doubling Up to Ensure Continuity

To execute the DR plan, the mine acquired the hardware needed to outfit two identically equipped data centers — one on-site and one remote. The On-site Data Center contains the mine's DISPATCH System control room. Also housed in this location are the DISPATCH, ProVision, and MineCare System VMware servers (on which the applications and application virtual machines reside), database servers, and fibre channel data storage devices and network switches.

To minimize the operational impact of a server failure or other upset event, the database and application servers are configured in clustered, redundant Primary and Target pairs. Should a Primary



Redundant On-site and Remote Data Center configurations.

The Value of Being Prepared

DISPATCH System optimization is a key enabler in the mine's efforts to achieve the goals set forth in their mine plan. While the mine can operate without the fleet management system, doing so would adversely affect productivity, efficiency and overall performance.

To demonstrate the value that DISPATCH FMS optimization delivers to the mine's operation, Modular's Performance Assurance team conducted a simulation comparing production over 30 days, with and without the DISPATCH system in operation. The results revealed that without the advantages of the FMS, the mine would suffer a 4% decrease in production, representing a substantial loss in tons moved.

Because the DR plan enables full operational recovery in less than an hour, the mine's production losses would be kept to a minimum. The DR plan, according to Modular, also helps ensure the accuracy of data utilized for performance evaluation, trend analysis and reporting following a recovery situation.

database server failure occur, the Always On FCI functionality initiates the failover response, causing the Target server to assume the Primary role. The process requires no human intervention, is nearly instantaneous and is transparent to system users and equipment operators.

In the event of a Primary VMware server failure, VMware vCenter initiates failover to the corresponding Target server in the VMware cluster. In addition, a designated dispatcher, or other mine representative, will contact Modular Mining's local support team to notify them of the situation. A support team member will then remotely start the application system service(s) and VMs on the Target application server to restore the DISPATCH, ProVision and MineCare System functionality.

The Remote Data Center, located about a third of a mile from the mine, replicates the configuration in the On-site Data Center. Because the servers and storage units in the Remote Data Center maintain data continuity with the On-site facility via the fibre channel network, the data centers are always in sync, enabling rapid recovery response.

Should a catastrophic upset event render the On-site Data Center's hardware resources unavailable, SQL Always On FCI and VMware vCenter will initiate failover to the Primary servers in the Remote Data Center. Again, a designated dispatcher (or other mine representative) will contact Modular Mining's local support team to notify them of the situation. A support team member will then remotely start the application system service(s) and VMs on the Primary application servers in the Remote Data Center to restore the DISPATCH, ProVision and MineCare system functionality.

Online in 60 Minutes

Hardware failure, be it a single server or a more catastrophic incident, is a real possibility at any mine. The time needed for recovery and resumption of normal operation determines the extent of production degradation and profit loss. Now, according to Modular, because of the mine's commitment to establishing fully equipped, redundant data centers, it has the ability to recover from a catastrophic failure in 60 minutes or less, ensuring that downtime of crucial technologies is kept to a minimum.

Without a comprehensive DR plan in place, the time required to obtain, install, configure, test and deploy the replacement hardware at this site or most others would cause a significant delay in the return to normal status. The DR plan developed and implemented collaboratively by Modular Mining, mine personnel and the local IT contractor enables the mine to minimize any interruption in haulage optimization and asset health monitoring capabilities provided by Modular Mining. In addition, according to the company, its success in this implementation will serve as a model for Modular's future DR efforts at other mine operations.

Wärtsilä Wins Big Power Contract From Lihir

Wärtsilä wins a 10-year contract for power plant maintenance and services for Newcrest's Lihir Gold, in Papua New Guinea. Above, Wärtsilä engines in a power plant. (Photo: Wärtsilä)

Newcrest Mining's Lihir Gold Ltd. awarded technology group Wärtsilä a 10-year, $183 million contract for power plant maintenance and operations advisory services. The agreement includes full technical support, real-time monitoring of the equipment, condition-based maintenance and asset diagnostic reporting, operational advisory support, and all planned and unplanned maintenance of the generator sets and auxiliaries.

The 170-megawatt (MW) power plant provides a critical electricity supply to the mine. It has 22 Wärtsilä engines. The last was commissioned in 2013.

The agreement, which goes into effect at the end of Q1 2021, has shared business case incentives targeting fuel and oil consumption and power availability metrics. They are designed to reduce operational cost, enhance power availability and support production targets.

Wärtsilä's track record in Papau New Guinea, where the mine is located, merited the agreement, Lihir said. "This is a flexible solution that delivers incentives and benefits to both parties," Daniel May, manager, utilities, Lihir, said.

By total gold produced annually, Lihir is one of the top gold mines in the world.

Sandvik to Acquire DSI for $1.2 Billion

Sandvik signed an agreement to acquire DSI Underground, a supplier of ground support and reinforcement products, systems and solutions. The deal is valued at $1.2 billion and will close by mid-2021 after regulatory approvals.

DSI Underground is in 70 countries. Offerings include bolting systems, injection chemicals and resin capsules.

Sandvik described the development as an important strategic step. "DSI Underground's track record of driving progress and safety in underground operations and its global reach will further strengthen our world-leading market position within mining and rock solutions," Sandvik CEO Stefan Widing said.

With 2,000 employees, DSI Underground's revenue for 2020 was roughly $635 million.

Separately, Sandvik partnered with De Beers Group on technical solutions for the Venetia Underground Project (VUP). The mine has ordered 19 items, including LHDs, trucks, drills and bolters.

Sandvik will supply several technology solutions, including its Digital Driller, to De Beers Group's Venetia Underground Project. (Photo: Sandvik)

For example, VUP will adopt 17-metric ton (mt) LH517i and 21-mt LH621i LHDs, 51-mt TH551i ADTs, DD422i face drills, DS412i roof bolters and DS422i cable bolters.

De Beers Group is investing roughly $2 billion to start mining underground from 2022, extending the mine's life beyond 2045.

The mine will use sublevel caving. The ore will be hauled by underground and surface trucks. The mine will later transition to an automated truck loop in combination with vertical shafts for steady state production, Sandvik reported.

Sandvik said it plans to support the project for the duration. "The expectation is for a technology partner who will help apply, develop and fine-tune the systems, over a period of time," Simon Andrews, managing director, Southern Africa, Sandvik, said. "This way, the technology is assured to deliver the safety, efficiency and other positive results that the new mine will demand."

FLSmidth to Deliver Tailings Solution to Rajasthan Mine

FLSmidth reported it will deliver an integrated dry stack tailings solution and a paste fill plant to a Hindustan Zinc Limited (HZL) lead-zinc mine in Rajpura Dariba, Rajasthan. The order includes design, engineering, procurement, supply of equipment, and commissioning. The supplier will deliver two Automatic Filter Presses, two E-Disc filters and one 26-m-diameter High-Density Thickener.

The solution will be completed by February 2022, and is designed to ensure environmental sustainability, the supplier reported. HZL could recover around 85% of process water for reuse. The low-moisture cake from the E-disc filter can be used for backfilling.

FLSmidth said the order proved the quality and flexibility of the technology. "This project resolves the customer's challenge through optimum utilization of available space and ensures the paste backfill requirements are met with the lowest pos-

sible operating and capital costs," Manfred Schaffer, mining president, FLSmidth, said. "Importantly, it also secures a high level of reusable water for the mine site, which helps their sustainability efforts and supports our own MissionZero ambition."

In 2018, HZL contracted FLSmidth for solutions for Zawar mine.

Separately, FLSmidth reported it sold its fabric filter technology business to Simatek. The latter will supply FLSmidth with fabric filters. FLSmidth will become a supplier of filter bags and filter cages to Simatek.

Weir Wins Iron Bridge Order

Weir Minerals won a $128 million order to provide aftermarket components and service to the Iron Bridge magnetite project in Western Australia. This follows a 2019 order for its Enduron High Pressure Grinding Rolls (HPGR) for the project. The supplier now has $270 million worth of orders from the project.

Weir described the sale as a landmark order. "Having helped design an energy and water efficient magnetite processing plant, we are delighted to provide operational support for Iron Bridge from 2022," Ricardo Garib, president, Weir, said. "It is an excellent example of the value that Weir's innovative engineering and close customer support can create for all our stakeholders and reflects the key role we have to play in making mining operations more sustainable and efficient."

The Iron Bridge magnetite project is a $2.6 billion joint venture between Fortescue Metals Group's subsidiary FMG Magnetite Pty Ltd. and Formosa Steel IB Pty Ltd. and is located in the Pilbara region, around 145 km south of Port Hedland.

Guardhat hardhats will be used in a system co-developed by Caterpillar to track the wearer's movements. (Photo: Caterpillar)

Weir will provide operational support for the project starting in 2022.

Cat, Guardhat Partner on Worker Tracking

Caterpillar partnered with Guardhat on developing Cat Connected Worker, a system that uses wearables to track workers. The system will deliver event-based monitoring and mapping for analysis purposes, and will be equipped to detect, alert and help prevent incidents.

Connected Worker will provide the precise location of workers, in near-real-time, and will allow communication between individuals, teams and sites. The data collected will enable monitoring personnel to understand the environment workers are facing in near-real time, which will facilitate decision making, Cat reported.

That data can also be used in worker safety and productivity programs, Cat said. It will "provide insight that will enable managers to create safer operations, and to respond quickly if an incident does occur," said Bill Dears, marketing manager, Cat MineStar Solutions, Caterpillar.

Connected devices in the Guardhat line include hardhats, personnel tags, asset tags and smartphones. The system is Wi-Fi and cellular compatible.

The partnership will speed the development of the system, Cat reported.

Connected Worker will be supported by Cat dealers, who will be equipped to supply Guardhat technology to surface mining operations of all types.

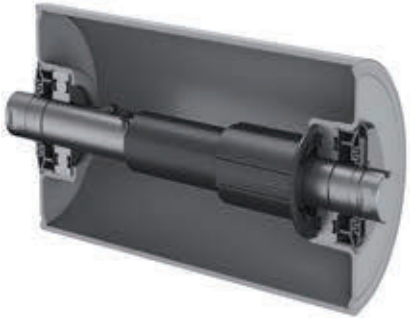
PPI to Rep Vayeron

Vayeron signed Precision Pully & Idler (PPI) to distribute the Smart-Idler product line to customers in Canada, the U.S. and Latin America.

Vayeron said the partnership is a signal that digital technologies are increasingly in demand in the bulk handling space.

"Our Smart-Idler system, used for the elimination of conveyor roller-related downtime on bulk materials handling conveyors, is receiving significant industry demand from customers located glob-

In 2019, the Iron Bridge magnetite project in Western Australia orders Weir's Enduron High Pressure Grinding Rolls, above. (Photo: Weir)



Precision Pully & Idler will offer the Smart Idler by Vayeron to customers in North America. (Photo: Vayeron)

ally," Ryan Norris, CEO, Vayeron, said. "Any end-users who are looking to create a step change improvement in how they maintain their conveyor systems can obtain their solution from PPI."

ABB Develops Sustainability Solutions at SUM

ABB reported supporting the LKAB Sustainable Underground Mining (SUM) project. The supplier has provided electrification, connected control and operations management systems, high-visualization and mobile operator workplaces.

ABB said SUM will allow it to develop and bring to market new sustainable mining solutions. "We are taking significant strides toward a vision of the future operator environment through smarter working and demonstrable results," said Jan Nyqvist, global product manager, underground mining automation, ABB.

Separately, ABB and Talga Group signed a Memorandum of Understanding to jointly develop the latter's Vittangi Anode Project in northern Sweden. The project will effectively marry a scalable battery-anode production facility to an integrated graphite mining operation.

The facility will supply coated anodes for lithium-ion batteries. It will be located 15 km from Vittangi, Sweden, and is expected to begin anode production at 19,000 tons per year starting in 2023.

The project offers the opportunity to showcase leadership in industrial automation and smart electrification, ABB said. "This is another milestone for us and our customers in our aim for more sustainable operations and a fossil fuel free society," said Björn Jonsson, division manager, North Europe, process industries, ABB.

A representation of the Vittangi facility, which will marry an anode production plant to a graphite mine. (Photo: ABB)

BIA to Rep Robit in 17 African Countries

Robit Group contracted BIA group to represent and distribute its products in 17 countries across West and Central Africa.

BIA will offer Robit top hammer and down-the-hole drilling consumables in Senegal, Mali, Burkina Faso, Democratic Republic of Congo (DRC), Zambia, Mauritania, Guinea Conakry, Sierra Leone, Liberia, Ivory Coast, Togo, Benin, Niger, Chad, Cameroon, Central African Republic, and Republic of the Congo.

With the deal, the companies partner to become major players in the market, BIA said. "With trust, shared values, and common success stories, we are delighted to start our long-lasting partnership with Robit," BIA Group CEO Vincent Bia said.

Epiroc Donates Bolts, Test Kit to School

Epiroc donated a Ground Support Pull Test Kit and Swellex bolts to the Montana Tech mining engineering program for students to test the bolts.

Sleeves will be used on the bolts to qualify the critical bond length of Swellex bolts under forced displacement without loss of bolt integrity. The Pull Test Kit will be used in testing the bolts' load and deformation characteristics.

An Epiroc team provided installation and hands-on training support. The school will publish the findings.

Epiroc said the donation was to help future miners understand the limitations and capabilities of Swellex bolts. "It gives Epiroc additional insights so we can continue our ongoing quest for improvement in mining," said Shawn Cheney, business line manager, rock drilling tools, Epiroc.

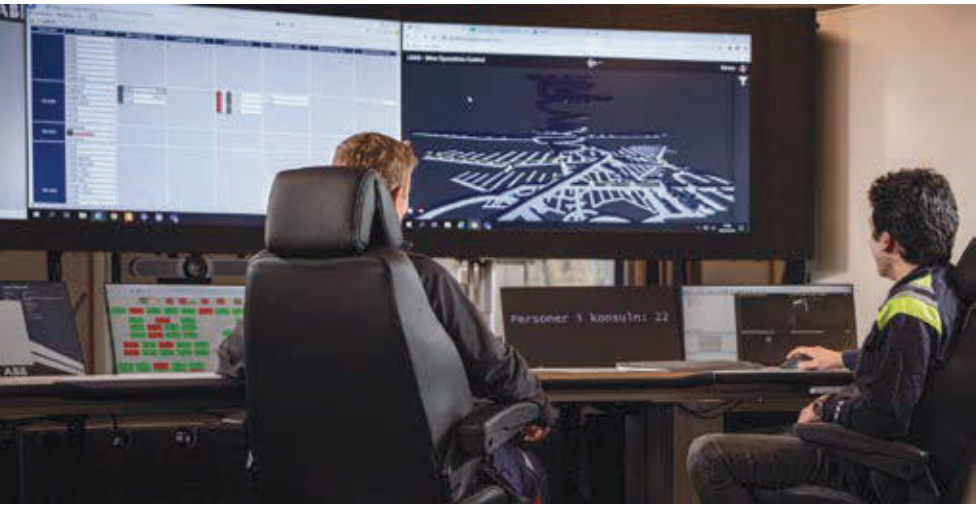


ABB reports developing electrification and automation solutions as part of LKAB's SUM project. (Photo: ABB)

Students in the Montana Tech mining engineering program will qualify critical bond length of Swellex bolts donated by Epiroc. (Photo: Epiroc)

New Sources of Needed Metals

Historically, mining has been strongly associated with, and driven by, infrastructure demands. Mineral products and metals extracted from conventional deposits have traditionally been the source of construction materials and industrial commodities needed by nations to function efficiently. It's unlikely that the relationship between mining and the primary industrial sectors that provide the basic building blocks of successful economies will ever be severed, but evolving market trends and cultural issues may alter some of the ground rules. For example, rising concerns regarding sustainability, environmental preservation and more efficient use of natural resources appear to be converging with expanding societal awareness of corporate practices in a way that could shift the forces driving mining investment and development in a new direction — specifically, toward consumer-driven priorities. Consumers, regardless of whether they're individuals or large consumer-oriented companies not typically linked to mining, are paying more attention to the origins of mined materials. In turn, producers are gradually broadening their view of what constitutes a potentially valuable mineral resource.

Turning metal-rich tailings and waste into profit is nothing new for the mining industry. However, increasingly rigorous scrutiny of mineral provenance and responsible mining practices has producers and researchers alike paying more attention to finding less-traditional resources and developing processes that can safety and economically extract the valuable components they contain. Two recent announcements underscore the level of activity by teams looking for new methods and sources that will allow the industry to meet market demand for mundane metals such as zinc as well as more-exotic metals used in cutting-edge electronics, in these examples by harvesting useful residual metal values from industrial fly ash and mine tailings.

In Sweden, a unique method developed by researchers at Chalmers University of Technology reportedly can extract useful metals such as zinc from fly ash, the residue left over from coal burning and incineration of solid waste materials. A process developed at Chalmers and tested at pilot scale involves treating fly ash with an acid wash to separate the zinc from the ash. The zinc can then be extracted, washed and processed into raw material. Zinc is recovered from leachate as zinc hydroxide using chemical precipitation. The method was originally pioneered at Karlsruhe Institute of Technology in Germany in the 1990s.

Results reported from pilot testing of a new extraction method developed by a Swedish research team indicate that fly ash could be used as an economical, plentiful source of zinc.

During the pilot study, 75 to 150 kg per hour of fly ash from a Swedish waste-to-energy plant were mixed with scrubber liquids from a flue gas treatment system in a continuously stirred vessel. The resulting slurry was dewatered in a vacuum belt filter. Hydroxide precipitation of the resulting leachate, followed by filtration of the formed crystals in a membrane filter press, produced a filter cake with up to 80% weight zinc hydroxide.

"In our pilot study, we found that 70% of the zinc present in fly ash can be recycled. The zinc is not extracted as a pure metal, which would be a much more intensive process, but instead as a zinc-rich product, which can be…processed further in currently existing industry production lines," said Karin Karlfeldt Fedje, associate professor at Chalmers University of Technology, and researcher at the recycling and waste management company Renova AB.

Researchers also have been able to significantly reduce the level of toxicity. "After extraction, we incinerate the residual ash again to break down the dioxins. Ninety percent of this is then turned into bottom ash, which can be used as a construction material, for example," explained Fedje.

In Sweden, incineration of household waste in waste-to-energy plants is common and produces around 250,000 metric tons (mt) of fly ash annually that could potentially be treated by the new method. Incineration of waste in the rest of Europe accounts for around 10 times that amount, according to researchers.

"The technology for extracting zinc from fly ash could have several positive effects, such as reducing the need for mining virgin zinc raw material, lower levels of toxicity in the ash, and greatly reduced landfill contributions. It can be a vital contribution to society's efforts towards a more circular economy," said Sven Andersson, adjunct professor at Chalmers and R&D manager at Babcock & Wilcox Vølund AB.

In the United States, a federal agency reported it believes waste rock from long-closed mines in the eastern Adirondack Mountains of New York may prove valuable due to its rare earth element content. The findings resulted from airborne and ground

A USGS scientist collects samples from tailings piles at an historic iron ore mine site in Essex County, New York.

surveys conducted by the U.S. Geological Survey and collaborators.

"The possibility of accessing rare earth elements from mine waste and mill tailings is attractive partly because the minerals have already been excavated from the ground," said USGS Scientist Ryan Taylor, who led analyses of rock samples from the region. "This would reduce mining costs by making it easier to access the minerals. It also allows 'recycling' of discarded materials, which could help to remediate these mined areas," he said.

USGS scientists were able to detect both mineral deposits and larger mill tailings piles from airplane surveys of old iron mines that occurred in late 2015. They then analyzed samples that showed rare earth content from the deposits, waste and mill tailings.

The eastern Adirondack Mountains in upstate New York were mined for iron ore in the 1800s and 1900s and played an important role in industrialization of the northeast prior to and during World War II. The mining activities resulted in piles of waste rock and mill tailings in various areas throughout the region.

The rare earth elements are mostly contained in millimeter-size crystals known as fluorapatite that are found in iron ore deposits. When the ore was processed, fluorapatite was usually left behind as waste because it was considered an unwanted impurity. As the need for certain mineral resources changed with time, these waste products are now of interest. The fluorapatite has elevated levels of heavy rare earth elements such as gadolinium, which is used in medical imaging; terbium, which is used in cell phones; and yttrium, which is used in lasers.

The amount of total rare earth elements varies from deposit to deposit, but each deposit is enriched in the heavy rare earth elements, which are far less common than the light rare earth elements. Total rare earth elements range from zero to nearly 2.2% for the waste and tailings piles and zero to nearly 4.8% for ore. Although seemingly low, these concentrations actually indicate significant potential, with the higher grades even comparable to other heavy rare earth element deposits, such as the clay deposits in South China, which are one of the primary sources for China's rare earth elements and the primary source of the world's heavy rare earth elements. These grades are also higher than those reported for coal fly ash, a residual of coal combustion that has also been considered a potential source of rare earth elements.

"There may be some challenges to processing the tailings for rare earth elements," said USGS Scientist and Project Chief Anji Shah. "While the fluorapatite contains recoverable rare earth elements, it also contains thorium, a weakly radioactive element which has economic uses but also requires careful handling."

That thorium, however, makes mill tailings easier to locate by airplane surveys since natural, low-level radioactivity can be seen on the images, Shah explained.

The USGS said airplane surveys were also helpful for detecting the iron ore bodies themselves because the iron is contained in highly magnetic crystals of magnetite. By measuring subtle variations in Earth's magnetic field from the sky, the researchers created 3D models showing the size and shape of the deposits beneath Earth's surface.

Reamer Lifting Gantry System

PYBAR partnered with Carrapateena mine and an equipment manufacturer to develop the SL100 Reamer Lifting Gantry system for removing large-diameter reamers in an underground environment.

The SL100 is a remotely operated, track-mounted gantry system with hydraulic lifting units capable of lifting up to 80 metric tons (mt). Once out of the shaft, the reamer is trammed away and the shaft is covered.

PYBAR reported the solution sets the standard for removing large-diameter reamers safely in an underground environment.

pybar.com.au

Stout, Mobile Pump Available Globally

Weir Minerals launched the mobile Multiflo LF pump range, designed to handle liquids from water to sludge. With a proven, enclosed impeller design, the pump is designed for efficiency and to dramatically lower the total cost of ownership.

The Multiflo LF pump is available in different configurations to meet varied demands. Mounted on either a trailer or a skid, it is available with either a Tier 3 or 4 diesel engine, or an electric motor drive.

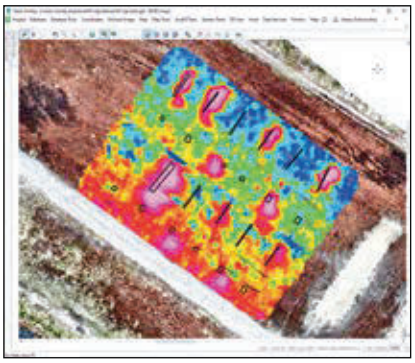
Constructed of cast steel and cast CD4MCu stainless steel, the pump handles flow rates ranging from 100 m^3/h to 3,200 m^3/h, and discharge heads of 10 m to 210 m. A stout bearing frame and a large-diameter pump shaft allow it to efficiently handle large solids and cut operating and maintenance costs, Weir Minerals reported. The design is proven to result in fewer seal failures and far fewer instances of shaft breakage in extreme conditions.

www.global.weir

Drone-mounted Metal Detector

SPH Engineering launched a drone integrated metal detection system with a Geonics EM61Lite metal detector to find metallic objects in hard-to-reach or dangerous areas. The system is capable of detecting metallic items in the first few meters under the surface.

Applications include UXO search, detection of underground infrastructure and archaeological needs.



Separately, SPH Engineering announced its UgCS (Universal ground Control Software) drone software for surveying is compatible with the Parrot ANAFI drone.

UgCS is a data acquisition instrument for professional drone pilots with a mixed multi-vendor fleet in large-scale surveying projects. It offers the capability to plan and execute flights to collect high-quality data. Features include custom elevation data import, terrain following mode and georeferenced video streaming.

The development is part of a Parrot effort to create a global ecosystem of drone software providers.

sph-engineering.com

Fastener Tension Monitoring Meter

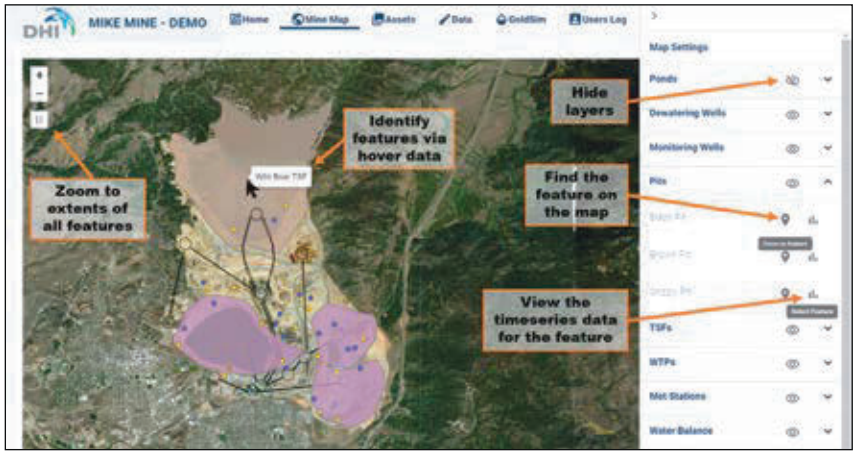
Valley Forge & Bolt announced the UHF Band Remote Tension Monitoring (RTM) Meter, a wireless bolt-monitoring system based on SPC4 load indicating technology. The meter operates in 433/868/915 MHz frequencies and relays tension-level data to a facility's condition monitoring system.

SPC4 fasteners measure actual joint tension and performance in near-real time.

The RTM Meter can be programmed to collect measurements from fasteners at prescribed intervals and send alerts if a bolted joint falls out of set parameters. It can be set for rapid readings, down to one per second, Valley Forge & Bolt reported.

Using a web-based interface, users can change parameters.

www.vfbolts.com



Water Modeling Platform

DHI announced upgrades to MIKE Mine, operational software designed to help mining companies with water-related decisions and risk analysis. The upgrades help the system provide real-time monitoring, forecasting, reconciliation and reporting.

The upgrades include improvements to its mapping capabilities. It has new time-scaling features and zoom capabilities, and offers improved visibility of layers and faster access to information.

The data page upgrade enables importation of more file formats.

A new accounts page gives the power to add and edit user accounts.

MIKE Mine offers modeling, predictions, and real-time data on dashboards accessed by PC, tablet or handheld device.

www.dhigroup.com

Kit Converts Toyota Truck Into Tembo

GHH launched 10-person and six-person electric carrier conversion kits for flatbed Toyota trucks. The kits convert the trucks into Tembo 4 x 4 e-LV personnel carriers that offer strength that surpasses that of the original bed, and the toughness and flexibility required for mine site applications, GHH reported.

The carriers are equipped with a 65-kW electric motor, a 1:3 transmission, and a battery designed for 8,000 charging cycles. They can go 200 km on a 72 kW-hour (h) battery pack. Top speed is 80 km/h. The carriers can climb gradients of up to 45°.

The batteries charge to 80% in less than three hours. With a three-phase charger, the time decreases to an hour. Aside from the supplied charging cable wall box, no external infrastructure is required.

Heat and air conditioning come standard.

www.ghh-fahrzeuge.de

New OptiMine Modules

Sandvik announced the newest modules for OptiMine. The latest iteration of the digital mine solution includes Evacuation Assistant, Playback and Smart Scheduling.

Evacuation Assistant visualizes an evacuation mode and determines the nearest safe places underground. It guides personnel to the nearest rescue chamber.

Playback is built on the 3D Mine Visualizer module and offers views of historical data on locations and statuses of all assets and people during a selected time.

Smart Scheduling allows the automatic adjustment of production plans based on actual shift completion results. It helps determine the process for the most efficient execution of a production plan, Sandvik reported.

www.rocktechnology.sandvik

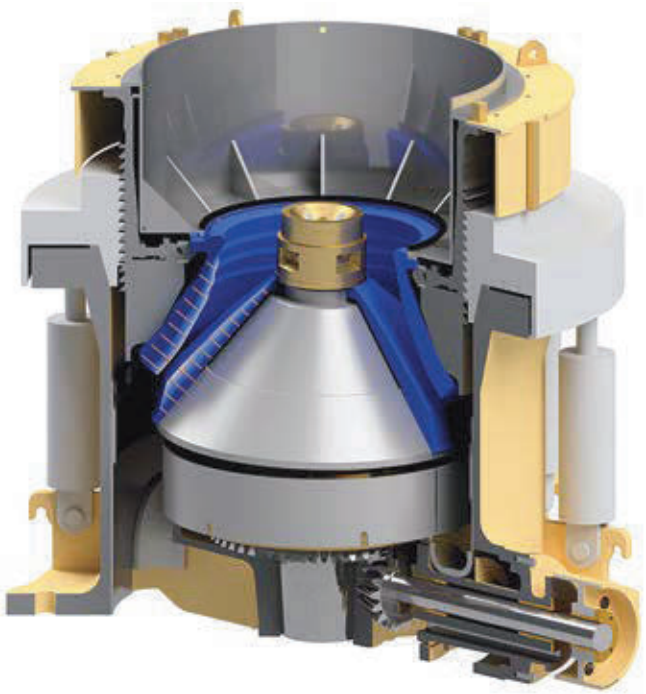
Crusher Liner Monitoring System

H-E Parts International announced the WearVision crusher liner monitoring system, which can provide near-real time information on the condition of wear liners. The data can be used to optimize a crusher's performance, and to schedule liner change times.

WearVision utilizes sensors along the complete liner profile and can be monitored locally or remotely. It offers greater ability to generate full wear maps, the actual gap setting and the percentage of time spent at optimal gap setting, wear rate trends, end-of-liner-life predictions and threshold alarms.

The system changes the liner into a high-precision digital tool and gives users new potential to optimize, monitor and forecast crusher wear performance, the company reported. WearVision is set to be launched at MINExpo 2021.

www.h-eparts.com



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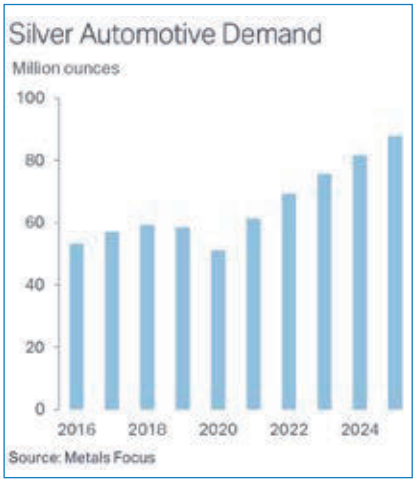
Future Auto Sector Silver Sales Could Rival Solar Sales

Automakers today are increasingly relying on silver to enable the vast technological advances incorporated into modern vehicles. This has generated another major demand center for silver, with projections of nearly 90 million ounces (oz) consumed annually in the automotive industry by 2025. Notably, by that time, this will rival silver consumption in the photovoltaic industry, forecast to be 98 million oz this year, and currently the largest application of global industrial silver demand. This year's automotive demand for silver is projected to be 61 million oz.

To provide a better understanding of silver's important function in the automotive sector, the Silver Institute, as part of its series of *Market Trend Reports*, released "Silver's Growing Role in the Automotive Industry," produced on its behalf by Metals Focus, a leading independent precious metals consultancy. The report examines trends in automotive production, including the evolution of hybrid and battery electric vehicles. It also addresses transportation policies that favor vehicle electrification in some of the world's most important vehicle markets. The report provides an



analysis of silver automotive demand in a range of vehicles and the growing importance to silver demand of ancillary automotive services.

Silver's widespread use in automobiles reflects its superior electrical properties, as well as its excellent oxide resistance and durability under harsh operating environments. It is used extensively in vehicle electrical-control units that manage a wide range of functions in the engine and main cabin. These functions include, among others, infotainment systems, navigation systems, electric power steering, and vital safety features, such as airbag deployment systems, automatic braking, security and driver alertness systems.

The average vehicle silver loadings, which are currently estimated at 15 grams (g) to 28 g for internal combustion engine (ICE) light vehicle, have been rising over the past few decades. In hybrid vehicles, silver use is higher at around 18 g to 34 g per light vehicle, while battery electric vehicles (BEVs) are believed to consume in the range of 25 g to 50 g of silver per vehicle. The move to autonomous driving should lead to a dramatic escalation of vehicle complexity, requiring even more silver consumption. Ancillary services that require silver are also increasing, including charging stations and charging points for electric vehicles.

The report concludes with an assessment of current and forecast silver demand in automobiles through 2025. The report stated that each stage of the transition, from ICE to hybrid vehicles to BEVs and eventually to autonomous driving, will be a net positive for silver demand.

The report is available at www.silverinstitute.org.

E&MJ PRICES INDEX

(January 5, 2021)

Precious Metals ($/oz)		Base Metals ($/mt)		Minor Metals ($/mt)		Exchange Rates (U.S.$ Equivalent)	
Gold	$1,950.50	Aluminum	$2,027.50	Molybdenum	$22,375	Euro (€)	1.229
Silver	$27.51	Copper	$7,914.00	Cobalt	$35,000	U.K. (£)	1.362
Platinum	$1,088.00	Lead	$2,043.50			Canada ($)	0.787
Palladium	$2,433.00	Nickel	$17,517.00	Iron Ore ($/dmt)		Australia ($)	0.775
Rhodium	$18,500.00	Tin	$21,350.00	Fe CFR China	$166.08	South Africa (Rand)	0.067
Ruthenium	$270.00	Zinc	$2,785.00			China (¥)	0.155

Gold and silver prices provided by KITCO Bullion dealers (www.kitco.com). Platinum group metals prices provided by Johnson Matthey (www.platinum.matthey.com). Non-ferrous base and minor metal prices provided by London Metal Exchange (www.lme.co.uk). Iron ore prices provided by Platts Iron Ore Index. Currency exchange rates were provided by www.xe.com.

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