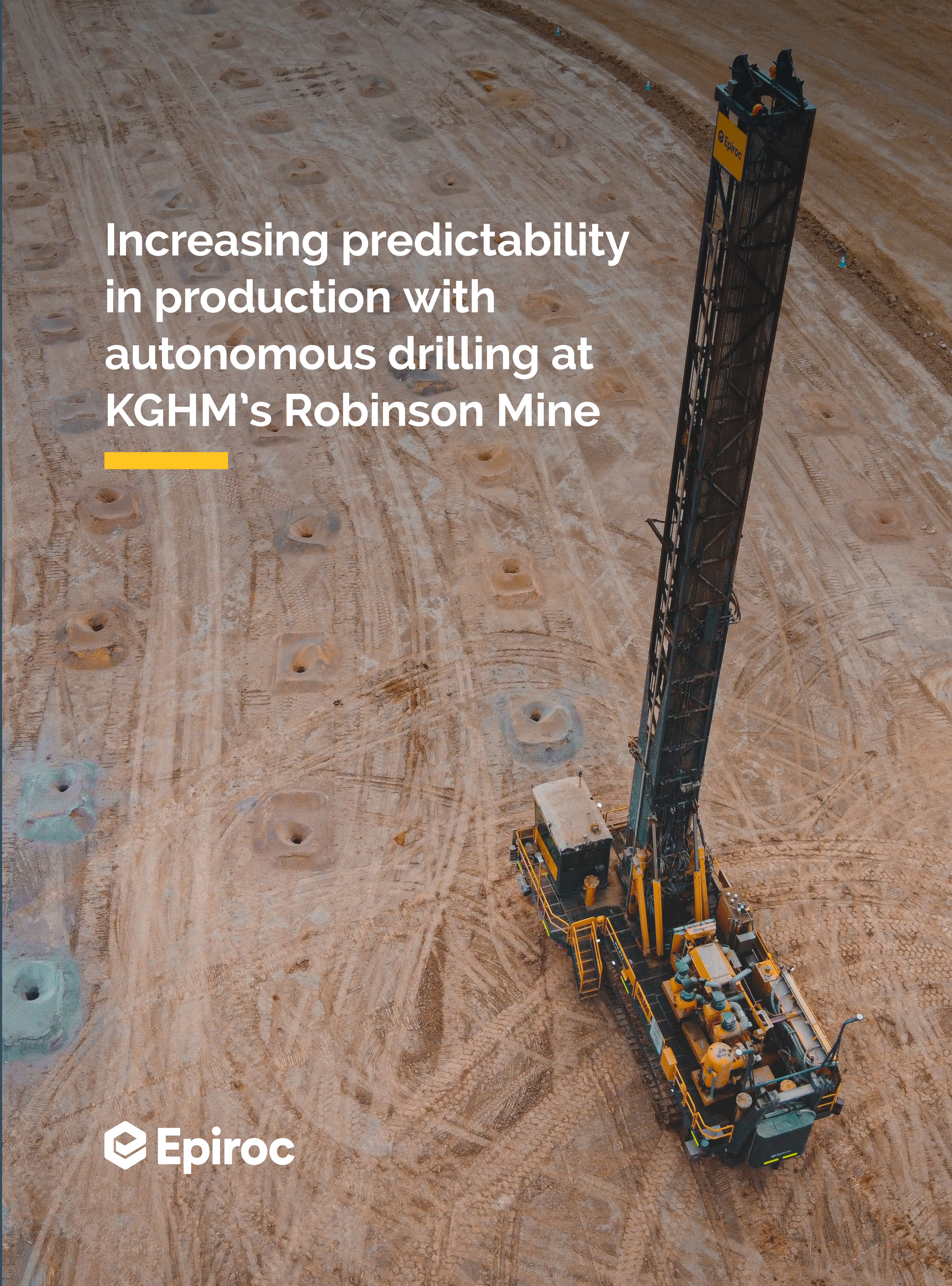
Robinson Mine

White Paper

Increasing predictability in production with autonomous drilling at KGHM's Robinson Mine



Epiroc

INTRODUCTION

KGHM is a global leader in the sustainable extraction and processing of precious natural resources, including copper, silver and other metals. KGHM's Robinson Mine, located in White Pine County, Nevada, USA, has been extracting copper, gold, silver and more recently molybdenum, since the late 19th century. Today, the conventional open-pit surface operation nearly 7,000 feet above sea level produces an average of approximately 125 million pounds of copper per year. Mining consists of drilling and blasting the in-situ rock, then loading and transporting it out of the open pit with haul trucks to a processing plant. The ore is then crushed, ground and subjected to the flotation process. After being thickened and filtered, produced concentrate is transported to Wendover, Nevada, for distribution to customers.

CHALLENGE

The KGHM's Robinson Mine team was tasked with ensuring a productive and efficient operation while evaluating opportunities for the update of the aging equipment. Key players were charged with the monumental challenge of finding equipment that would not only measure up in terms of efficiency and productivity, but also bring the operation into the next generation by upgrading an aging blasthole drill rig fleet. With a 15-year-old drill nearing the end of its life expectancy, some stakeholders were interested in replacing it with an autonomous machine to increase safety, productivity and identify utilization gaps and other operational pain points that could be solved with autonomous technology.

Equipped with a general understanding of the major advances in autonomous technology, it was important for the management team to research and test various equipment solutions to ensure that they were making the right investments for their operation. Productivity, cost efficiency and safety gains of implementing autonomous drilling would need to be proven outcomes of any investments in technology or business partnerships.

While the potential benefits of automation can be attractive, joining the worldwide industry shift to autonomous mining would require significant technology and mindset changes. For mine management, it is important to have confidence in the performance that an autonomous drill rig could deliver – and in the support an automation partner would provide.

SOLUTION

Selecting the technology

Mining companies are looking for safe and predictable production that removes workers from the drills, takes them out of the open pit, and allows those personnel to operate drills from a safer location. Automation benefits include:

- Removes workers from areas where there are higher risks, such as ground stability and other mobile equipment in operation.
- Reduces worker exposure to other hazardous conditions, including noise, dust, vibration and heat.
- Drives higher machine utilization and increases production rates through more reliable and better control of equipment, along with a higher amount and quality of data.
- Enables machines to operate accurately, even during shift changes, personnel breaks and clearance time, and improves the efficiency of equipment usage.
- Eliminates fatigue, distraction and error associated with manual operation, delivering precise, consistent and repeatable performance.
- Lowers costs through gains in safety, productivity and predictability.

Robinson Mine considered several manufacturers in its search for an autonomous solution for drilling production holes in ore and waste zones at the mine's active Ruth pit. The company conducted an in-depth market study of automation suppliers before aligning with Epiroc, a leading global productivity partner for the mining and infrastructure industries.

Epiroc had the proven ability to deploy automated machines safely and effectively. Sweden-based Epiroc has successfully installed more than 50 autonomous blasthole drills with more than 65 million feet (20 million meters) drilled autonomously in copper, gold, iron and coal mining operations across a worldwide portfolio. Their experience and expertise include a variety of climates and geological characteristics as well as the process to implement automation.

SOLUTION (continued)

Robinson was also interested in the capabilities of the Epiroc Pit Viper PV-271 XC single-pass rotary blasthole drill rig that featured Rig Control System (RCS5) software and would come factory-equipped to drill autonomously. The drill would enable Robinson to replace a 15-year-old, much larger PV-351 (from Epiroc predecessor Ingersoll Rand) because the PV-271 XC featured an increased pulldown of 80,000 pounds and increased torque capability. Robinson would be able to drill maximum-size 12¼" holes in hard-rock conditions with a smaller rig, lowering their overall cost. The implementation of autonomous technology had the potential to further lower their operating cost and fleet size by increasing the net penetration rate over traditional operations.

Robinson calculated the number of holes needed to maintain stripping and delivery schedules, taking into consideration rock hardness and the burden and spacing. The findings revealed that the Epiroc PV-271 XC could meet the performance requirements on a daily basis, replacing the work of two machines with one machine.

Implementation and support of autonomous projects

Conversations with the Robinson team began in late 2018 and were centered around taking a broad look at all equipment options, including the Epiroc PV-271, PV-351 and the brand-new PV-271 XC. This analysis of both traditional and autonomous solutions was extremely important for the decision-making team. In 2019, this analysis ultimately led to a decision to incorporate autonomous drilling equipment into the fleet. Robinson commissioned an Epiroc PV-271 XC with operator-assist technology and deployed automation in August 2020 to become the first copper mine in the U.S. to run a fully autonomous Epiroc blasthole drill, according to 2019 data. It would be the 32nd mine on a global scale to implement full autonomous Epiroc blasthole drilling equipment.

"Successfully implementing teleremote and autonomous mining requires thorough project planning, primarily to handle the change management of switching from manned equipment to remote operation," said Chris Peters, Epiroc product and application specialist.

According to Peters, there are three things that are necessary for supporting autonomous equipment — technology, people and processes. All three legs of the stool carry equal weight in setting a stable foundation for autonomous operations, and it always works best when all three are prioritized equally. This is a key reason why Epiroc will not simply provide autonomous Pit Vipers to customers without ongoing support on site, including a resident technician.

"If we were to simply commission the autonomous drills, provide training and leave, that doesn't set our customers up for success in the long run," explained Peters. "That's an additional differentiator for us — we aren't looking to simply deliver our customers a drill. We have a shared interest in the success of the mine and bringing that technology to more mines across the globe."

> **"Working with Epiroc has been a positive experience," said Mark Beres II, Robinson chief mine engineer. "They have provided the necessary support, both in the field and on the technical side, to make the project a success."**

Drawing on experience implementing automation in dozens of mines and applications around the world, Epiroc assisted Robinson with establishing the necessary autonomous-capable infrastructure, training drillers and supporting technology adoption.

"The best way to overcome these changes is by working closely with customers to address challenges and concerns as they arise, and most important, not trying to change too much too fast so that people can adapt and become comfortable with each new step along the way," said Peters. "We see different types of people and different speeds in adapting to the technology. As with any change management process, there are people who are early adopters and some who are skeptical but then begin to recognize the benefits."

To help ensure smooth implementation for Robinson, Epiroc placed a resident technician on site for six months to support the technology. This added to Epiroc backing from the Elko, Nevada, service center, the U.S. Customer Center headquartered in Broomfield, Colorado, and the Epiroc Drilling Solutions Division based in Garland, Texas.

Additionally, a team from Robinson visited Epiroc's Surface Automation Center in Garland, which features a specially equipped classroom and a full-scale automated drilling rig. The Robinson team was able to become immersed in every phase of the drilling process using the same state-of-the-art autonomous equipment that would be used on the job.

Baseline data, predictive automation modeling boost confidence

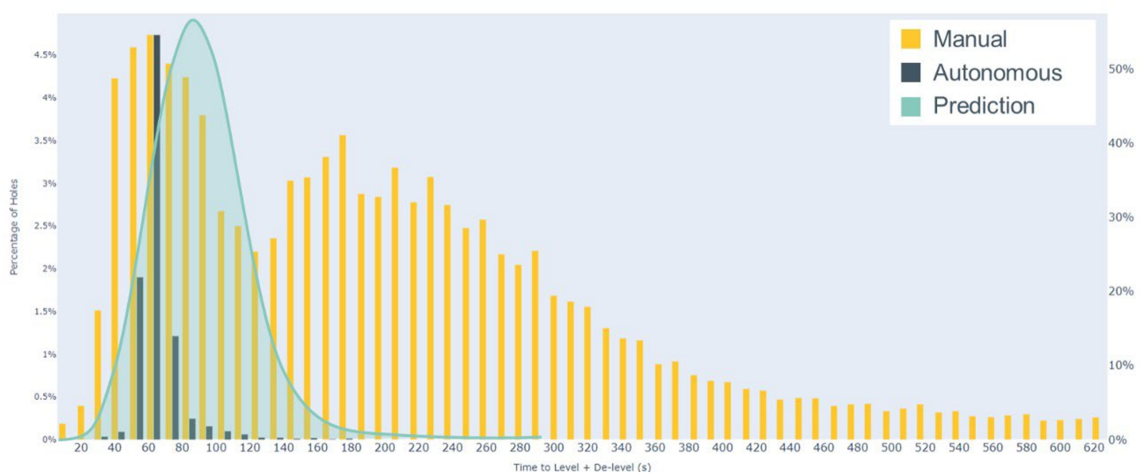
Epiroc leveraged that global experience to bolster Robinson's confidence up front. Early in the automation partnership, Epiroc provided proprietary baseline performance analysis and predictive autonomous modeling. An Epiroc data analyst analyzed 18 months of production data from three Robinson rotary blasthole machines: the 15-year-old PV-351, an older-generation DML (from Epiroc predecessor Ingersoll Rand) and another DML (from Epiroc forerunner Atlas Copco). Included in the baseline performance data were drill cycle utilization (cycle times and distributions), drilling performance and penetration rates.

SOLUTION (continued)

Drill cycle utilization

The baseline analysis found that despite their advanced age, Robinson Mine's three well-maintained drills had high mechanical availability of 88%. Epiroc projected that automation could have a positive impact on drill cycle utilization. These included in-cycle non-drilling or propel times (where 20% of all cycles had greater than 5 minutes of non-drilling time per hole compared to a 3-minute average), in-cycle propel times (20% of all cycles had more than 105 seconds of tramming per hole compared to the 67.5-second average) and drilling times (5% of all cycles saw drilling time of more than 27 minutes vs. the average drilling time of 11.43 minutes). With fully autonomous drilling, Epiroc predicted shorter setup time (level and de-level) with less variation.

In Cycle - Setup Times



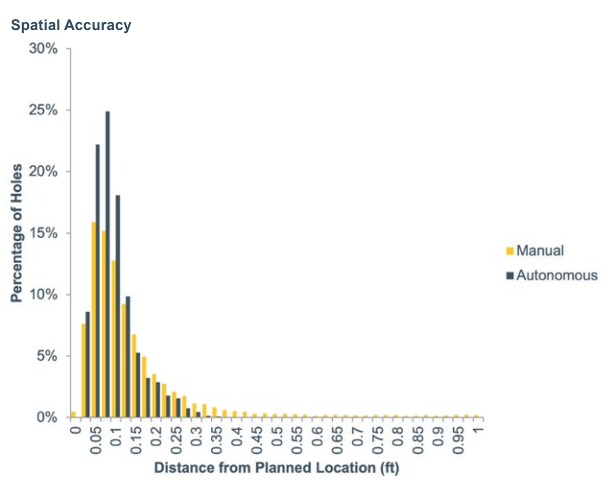
With fully autonomous drilling, Epiroc predicted shorter setup time (level and de-level) with less variation.

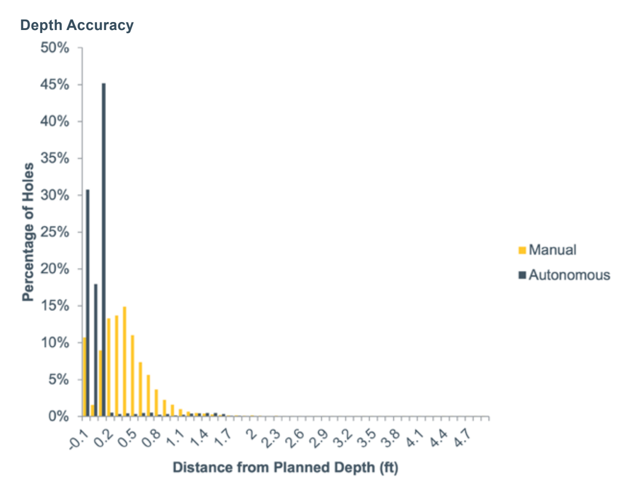
SOLUTION (continued)

Drilling performance

The baseline calculations showed Robinson's spatial accuracy at 89% and depth accuracy at 46% during manual drilling. Epiroc's autonomous modeling projected spatial and depth accuracy at 98%. The increased accuracy of collar location and depth improves controlled fragmentation for consistent and predictable benches. This was an important piece of data for Robinson Mine to consider to minimize the downstream implications of inaccurate collar location and over-/under-drilling. In addition to increased time and/or costs, these inconsistencies can negatively impact blast quality, fragmentation, floor control and comminution.

Hole Quality





98% Epiroc's autonomous modeling projected spatial and depth accuracy.

Penetration rate

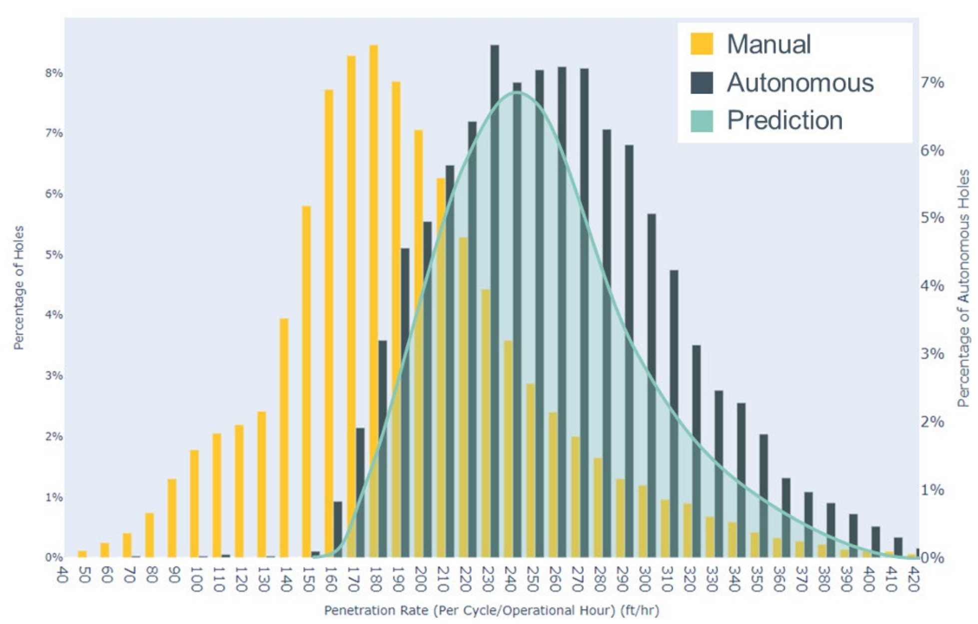
Robinson penetration rates per cycle hour — defined as feet drilled over productive cycle time only (including tramming, setup and drilling) — averaged 174.7 feet per operating hour (FTPOH) in Epiroc's analysis. Epiroc considers penetration rate per cycle hour a better measure of full cycle performance than penetration rate per drill hour, which is calculated using productive drilling time only. Epiroc's autonomous modeling projected increases achieved across key metrics via a shift to autonomous drilling with the PV-271 XC. The model projected a 16.7% increase in FTPOH over Robinson's traditional operations, from 174.7 to 203.87. This projection included:

- 5.8% increase due to time savings from Auto Level (for drill setup), Auto Nav (for tramming) and Auto Drill (for retraction) integrated into the RCS5 software.
- 5.4% increase due to drilling efficiencies delivered through Auto Drill 2.
- 5.5% increase through removal of non-drilling, propel and drilling idle times in fully autonomous mode.

In addition, the model predicted a potential total overall utilization increase of 11.1% of calendar time. This encompassed reductions in delays associated with shift changes (4.1%), handling equipment damages (1.5%), blasting (1.1%) and more, as well as standby reductions in no operator available (2.9%) and waiting for operator (0.7%).

Gathering baseline data on the drill and performance with Epiroc's predictive modeling allowed Robinson the business justifications in terms of performance that could be achieved through autonomous technology. For Robinson, realizing such benefits would mean the ability to drill more footage per year, reach a target footage in less time, and even park two drills with the acquisition of one.

Penetration Rates Per Operational Hour (ft/hr)



RESULTS

Real-world performance surpassed projections

The autonomous PV-271 XC outperformed Epiroc's predictive models, increasing production rates, utilization and predictability while reducing delays and eliminating human error. After the first six months of autonomous operation with the autonomous rig, Robinson Mine had realized the following gains:

Drill cycle utilization

Without a drill operator in the cab, the autonomous PV-271 XC can operate continuously through delays, shift changes and breaks that halt manned machines.

- 25% decrease in drilling cycle time vs. 21% projected decrease
- 17.05 minutes vs. 13.43 minutes vs. 12.75 minutes actual

25%

Decrease in drilling cycle times vs. 21% projected decrease.

RESULTS (continued)

Operational penetration rate

The Robinson Mine's existing fleet had an average baseline of 174.7 feet (53 m) per operational hour. Epiroc's initial projection was 203.87 feet (62 m) per operational hour. The fully autonomous PV-271 XC is achieving 240.59 feet (71.6 m) per operational hour, increasing capacity by more than 37.7%.

- 37.7% increase vs. 16.7% projected increase
- 174.7 baseline vs. 203.87 projection vs. 240.59 actual FTPOH

Drill depth accuracy

46% baseline vs.
98% projection vs.
99.3% actual

Spatial accuracy

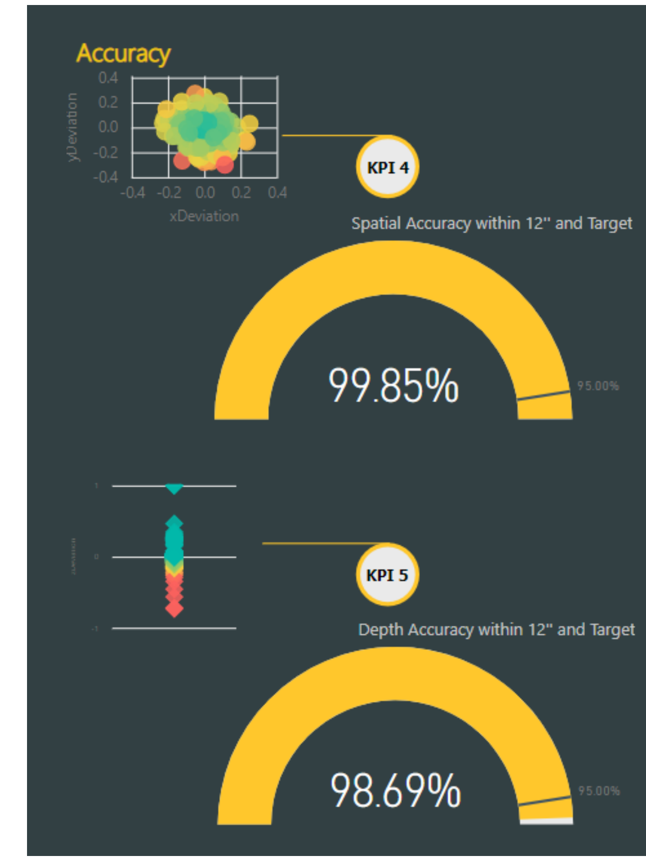
89% baseline vs.
98% projection vs.
99.49% actual

Improving depth and spatial accuracy through autonomous drilling are key data points for the Robinson Mine. In addition to decreased operational time and cost, achieving above 99% accuracy minimizes the potential for inconsistencies in over-/under-drilling and collar location that can have negative impacts downstream such as fragmentation, floor control and comminution.

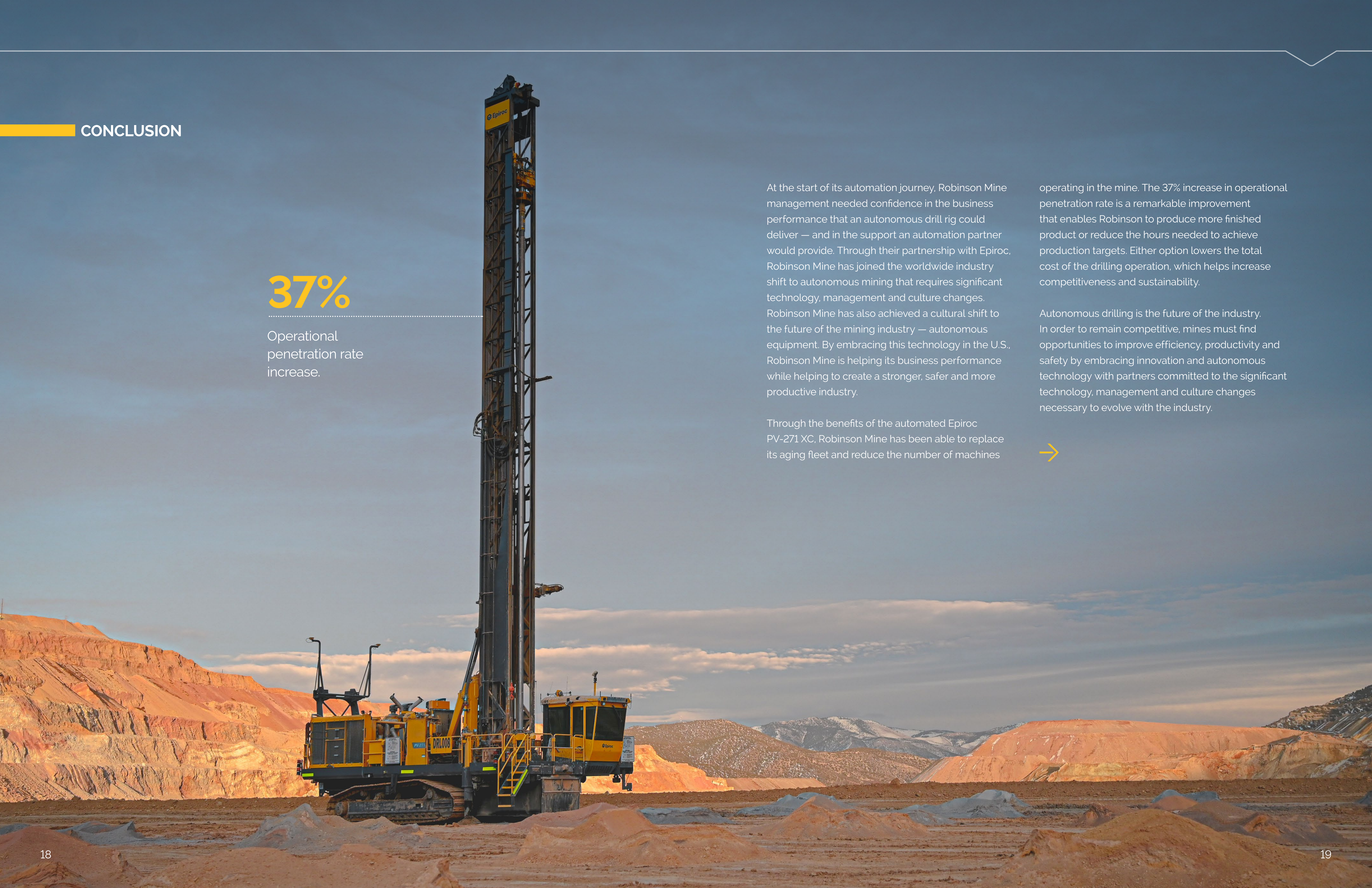
As Robinson operators become more familiar with autonomous operation, the data is still trending upward after the initial six-month period.

"When we're running autonomously, the drill moves from hole to hole faster and more accurately than a human," Robinson drill trainer Mark Hurlbert said. "The drill's hole depths are almost exactly the same, and the holes are neither over-drilled nor too shallow, and they're all within 6 inches of where we need. So, blasting has improved. The autonomous drill sets up faster and drills faster, so efficiency improves. On top of that, it records all the data — critical data we can look at later about the performance of the drill and the operator."

"We continue to put safety as our No. 1 goal every day," said Nathan Trujillo, Robinson mine operations superintendent. "This drill gives us a different avenue, one that we've never been down before, to meet that goal. It has made us even more safety conscious."



One of the Robinson Mine's core values is "Zero Harm," and Robinson operators are now safer than ever before. By moving operators from the cab to a control room with automation, the mine protects them from the potential dangers in the open pit, including noise, dust, vibration and equipment interactions. The Epiroc automation solution has many safety layers and fail-safes to ensure that remote control is always maintained. If the local network experiences issues, the Pit Viper will either suspend operation or shut down to ensure that operator control is never lost. Additionally, there are several administrative controls that a mine will put in place for safe overall operations.



CONCLUSION

37%

Operational penetration rate increase.

At the start of its automation journey, Robinson Mine management needed confidence in the business performance that an autonomous drill rig could deliver — and in the support an automation partner would provide. Through their partnership with Epiroc, Robinson Mine has joined the worldwide industry shift to autonomous mining that requires significant technology, management and culture changes. Robinson Mine has also achieved a cultural shift to the future of the mining industry — autonomous equipment. By embracing this technology in the U.S., Robinson Mine is helping its business performance while helping to create a stronger, safer and more productive industry.

Through the benefits of the automated Epiroc PV-271 XC, Robinson Mine has been able to replace its aging fleet and reduce the number of machines operating in the mine. The 37% increase in operational penetration rate is a remarkable improvement that enables Robinson to produce more finished product or reduce the hours needed to achieve production targets. Either option lowers the total cost of the drilling operation, which helps increase competitiveness and sustainability.

Autonomous drilling is the future of the industry. In order to remain competitive, mines must find opportunities to improve efficiency, productivity and safety by embracing innovation and autonomous technology with partners committed to the significant technology, management and culture changes necessary to evolve with the industry.

Epiroc USA
8001 Arista Place, Suite 400
Broomfield, CO 80021
Phone No: 844-437-4762
Email: info.usa@epiroc.com
epiroc.us