Best Practices for Implementation of a Prescriptive Maintenance Program: Evolution Mining's Mungari Mine

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Introduction

The mining industry is undergoing a digital transformation across the entire mining value chain, from exploration to site reclamation. Innovative technologies are changing the way mines operate, improving operational efficiencies and lowering costs. With many mine operators still using a preventative maintenance approach and original equipment manufacturers (OEMs) designing for the equipment they sell, mobile and fixed plant equipment maintenance costs represent a significant 30-50% of all OPEX expenditure for the industry[1].

In general, mining equipment comes from manufacturers with a detailed schedule for preventative maintenance tasks, stipulating at what frequency to inspect, test and service individual components, including when they should be repaired or replaced throughout the equipment's useful life. These conventional methods for equipment maintenance become a recurring cost rather than a solution that adds additional measurable value to the operation. Time-based strategies like these do not factor in any other operating conditions that have the potential to impact the overall availability of the asset, leaving users in the dark about how varying operating conditions affect asset reliability.

An OEM defining when to service and replace parts could also be considered a conflict of interest since they receive additional revenue on a scheduled basis rather than an as-needed basis.

Mining companies may want to consider taking a more data-driven approach to equipment maintenance across all assets, using technology that improves asset reliability and is optimized to specific work environments, processes and usage patterns. Leveraging asset sensor data to proactively monitor equipment for imminent and future failure adds immediate value to a maintenance program.

With artificial intelligence (AI)- and machine learning (ML)-driven predictive and prescriptive analytics, operators can manage maintenance activities strategically, planning around predicted downtime rather than working through it reactively.

Unplanned downtime leads to lost revenue and profits for the organization, and can potentially trigger human, environmental and other impacts. With advance warning of equipment failure, maintenance teams have more time to order required parts and put together plans in conjunction with other maintenance activities while supporting operational continuity and limiting the impact of these failures on production. Prescriptive maintenance programs provide specific remedies to avoid impending failures, increasing efficiency and giving earlier notice to proactively plan for downtime.

This paper takes an in-depth look at the successful implementation of a prescriptive maintenance solution for Evolution Mining's Mungari operation in Western Australia. As a result of the implementation, the company has seen immediate financial and operational successes due to improved asset availability. In early 2020, Paul Robbins, Group Head for Asset Effectiveness at Evolution Mining, began researching data-enabled business improvement technology to help boost the company's asset performance and productivity. Initially monitoring a small number of assets, the team saw immediate value and began to scale. Evolution's team established the dollar value of a specific unplanned downtime event from an equipment failure, immediately realizing significant savings.
A prescriptive maintenance program enables mines to operate more efficiently, profitably and with fewer safety and environmental risks, while improving ROI.

Asset Management and Prescriptive Maintenance

Traditionally, mining companies rely on reactive preventative maintenance programs resulting in unpredictable asset availability. Mining companies must adopt more proactive maintenance programs to address this, incorporating advanced technologies for improved reliability and operational optimization.

Digitalizing equipment through sensor data is revolutionizing asset performance management (APM) and drastically improving maintenance strategies across the industry. Prescriptive maintenance programs that use real-time information to predict equipment failure and provide actionable solutions, such as AI and ML technologies, enable maintenance teams to identify and address issues before they become major problems. By avoiding unnecessary repairs and preventing costly downtime incidents, prescriptive maintenance programs can help extend the useful life of equipment and improve overall efficiency.

Furthermore, this approach can help mining companies make operational decisions based on new insights into equipment usage and how it is affected by different operating conditions. This ultimately improves equipment performance and reduces future failures.

APM is an area that all mining companies must embrace to improve the accuracy of predicting failures, improve the amount of time to prepare for asset downtime and reduce overall maintenance spend. Longer advance warnings provide more options to mitigate potential asset failure and the associated operational and financial losses. Asset performance management programs provide a strategic advantage over historical preventative maintenance by creating value from historical operational data, providing actionable insights for optimizing asset efficiency and reliability.

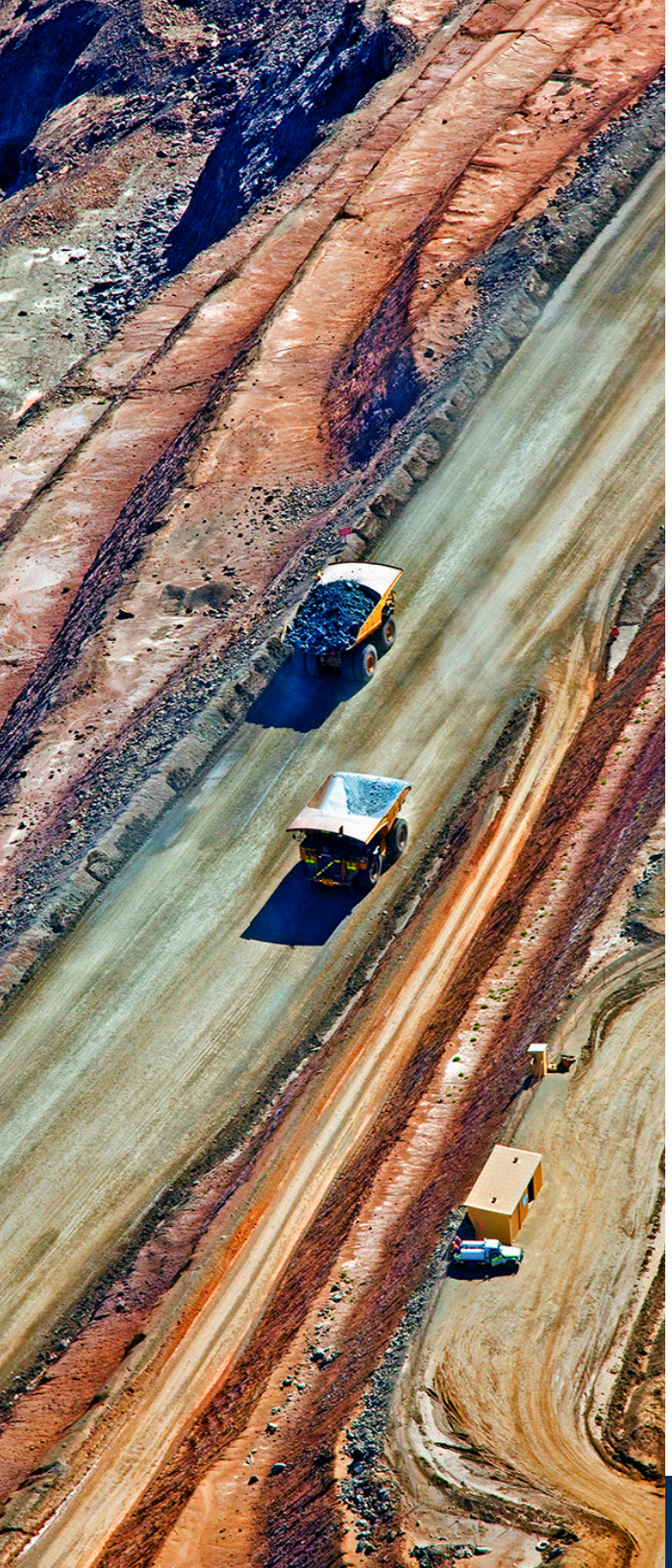
Evolution Mining's Prescriptive Maintenance Journey

Established in November 2011, Evolution Mining has quickly become a globally relevant gold miner with five fully owned mining operations in Australia and Canada with gold reserves of approximately 10 Moz and gold production in 2022 totaled 640 Koz. The willingness to embrace technology and innovation is critical to Evolution's future success and sustainability. This idea is reflected in the company's core strategy to create sustainable value for stakeholders in an environmentally and socially responsible way. They have proven the commitment to this with numerous awards for social responsibility and sustainability.

One initiative in Evolution's efforts to incorporate technology and achieve sustainable goals is implementing a prescriptive maintenance program at its Mungari operation. This operation utilizes both open pit and underground mining methods and is located 600km east of Perth, Western Australia and has gold reserves of approximately 1.2 Moz. With a plant throughput of ffi2.0 Mtpa, Evolution views the performance at this facility as a key highlight. They attribute the success here to capitalizing on improved operational and maintenance initiatives.

Prescriptive maintenance was first introduced to Evolution in 2019 through the data-enabled business improvement initiative (Project DEBI), where discussions occurred around available technology and how it could help the company's mining operations improve performance and productivity. Initially, the focus was on condition monitoring and leveraging collected data to improve efficiencies across the sites.

Previous maintenance programs studied for potential use involved working with previous iterations of automatic diagnostic programs based on vibration sensors. Using Aspen Mtell®, AspenTech's industry-leading prescriptive maintenance solution, provides Evolution technological advantages in asset performance management based on AI and ML, while adding measurable value to its maintenance programs. Rather than focusing on a single data point for an asset, such as vibration, Aspen Mtell can ingest as many data points and sensors as available, both upstream and downstream, to model failure probability curves.

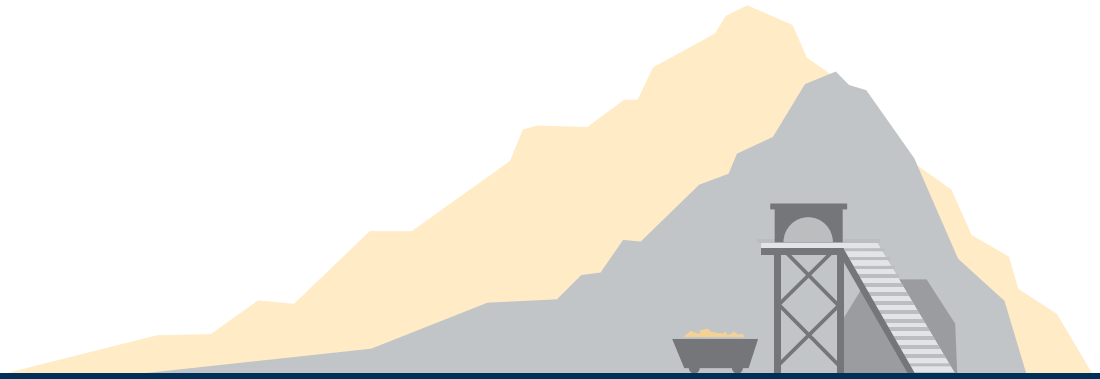


This all-encompassing data capture and analysis enables Evolution to make actionable decisions based on consolidated operational information, such as gearbox or motor bearings, rather than interpreting multiple standalone data points. Evolution saw the added value in looking upstream and downstream of an asset and using the additional sensor information available for a better operational view in making decisions. Aspen Mtell was selected for the pilot program to prove the effectiveness of prescriptive maintenance and get key stakeholder buy-in.

Before Aspen Mtell was implemented, Mungari had seen significant crushing circuit and mill failures. A prescriptive maintenance program was invaluable in predicting these failures and providing reliability improvement. In addition, being a relatively new operation with a solid distributed control system (DCS), the mine had the infrastructure to support innovative technology.

To successfully implement a prescriptive maintenance solution, there needs to be a good understanding and buy-in from team members tasked with deploying and maintaining the program. In evaluating the implementation and ongoing operation of this program, operators need to look at several factors related to personnel, as listed below:

1. Data management support
2. Program support, keeping in mind the team's other day-to-day tasks
3. Program champions need to present the entire value-added journey of a prescriptive maintenance solution to those involved so they can see the potential gains and not get caught up in the initial load of the setup



Equipment Monitored	Major Alerts During First Four Months of Implementation	Aspen Mtell Financial Impact
Tertiary Crusher	Adjustment Ring Failure Alert: Crusher found to be operating with narrower gap than recommended	$33,120 (AUD)
Concentrator	Motor Failure Alert: Build up inside bowl was found on inspection, reduced potential for lower production throughput	$77,649 (AUD)
Heat Exchanger	Heat Exchanger Failure Alert: Pin holes and small cracks found in the HT and LT plates, overhaul competed and inspection of secondary unit performed	$10,925 (AUD)
Primary Crusher	Pitman Anomaly Agent: Vibration dampers worn/cracked	$32,500 (AUD)
Primary Crusher	Jack Shaft Failure Alert: Imbalance/misalignment of the belt drive	$28,365 (AUD)
	Total	$182,559

Table 1. Equipment alerts from Aspen Mtell during first four months and financial impact.

Due to COVID-19 restrictions, the Aspen Mtell implementation occurred remotely, which benefitted Evolution Mining in a couple different ways. Because AspenTech did not need to visit the site in person, costs and safety risks associated with having contractors on site were avoided. Another advantage was the fast time to deploy and real-time support that was available to address any problems. Communication was key to the implementation process; daily, weekly and as-needed meetings were held internally with Evolution and AspenTech representatives.

Mungari selected three assets that were already being monitored and supplied three years of sensor data in addition to maintenance and failure records. This data was used to create the initial probability curves and failure agents. Aspen Mtell made failure predictions based on this historical information. The results, which showed that a successful prediction rate of 90% was achieved, were presented to Evolution.

One example of the successful predictions: Aspen Mtell detected major failures in the mill that had caused significant downtime three times during the two-year period prior to the pilot program's launching. Each period of downtime had associated production and revenue losses. Several major failure alerts were identified in the first four months (Table 1), supporting the decision to move forward with a larger scale implementation.

Based on the data collected and validated in the initial phase, the Mungari Operation moved forward with a larger implementation initially consisting of ten assets. Applying lessons learned in setting up the initial assets, the process to scale the program to other similar assets was rapid, with Evolution quickly scaling to monitor 30 assets with over 100 failure agents in use. The Mungari team worked on fine-tuning the agents based on equipment and operational changes while also strengthening the alert management workflow. On-site personnel reduced the average time to

acknowledge alerts from 5-10 days during the initial pilot to less than half a day, with process improvements and program training.

As part of the ongoing review process, identified failures were supported with operational review. This review had significant positive impact, over $700K AUD, during the first 15 months of the program (Table 2). In addition, the implementation resulted in better maintenance and downtime planning as well as reliability and safety improvements.

Prescriptive maintenance can also drive changes to maintenance inspections and schedules. As an example, Mungari was able to reduce the frequency of cleanings needed for the concentrator from every two weeks to every four weeks, as suggested by data analysis from Aspen Mtell. This is a notable example of how Aspen Mtell reduced unplanned downtime, which improved overall production with no changes to the process or equipment. The team also utilizes Aspen Mtell data to better understand how the facilities operate and can quickly confirm on-ground observations.

Time (Months)	Aspen Mtell Financial Impact (AUD)
0 - 3	$126,694
4 - 6	$60,865
7 - 9	$41,000
10 - 12	$200,837
13 - 15	$279,232
Total	**$708,628**

Table 2: Financial impact of the Aspen Mtell implementation (first 15 months).

Best Practices for a Succesful Implementation

As a result of the prescriptive maintenance implementation, the Mungari mine operates more efficiently, supporting the notion that prescriptive maintenance programs help organizations optimize asset performance and improve overall operational efficiency. While implementing a prescriptive maintenance solution can be challenging, the right preparation and mindset can lead to significant improvements and cost savings.

This section highlights some of the best practices that were followed throughout the prescriptive maintenance implementation.

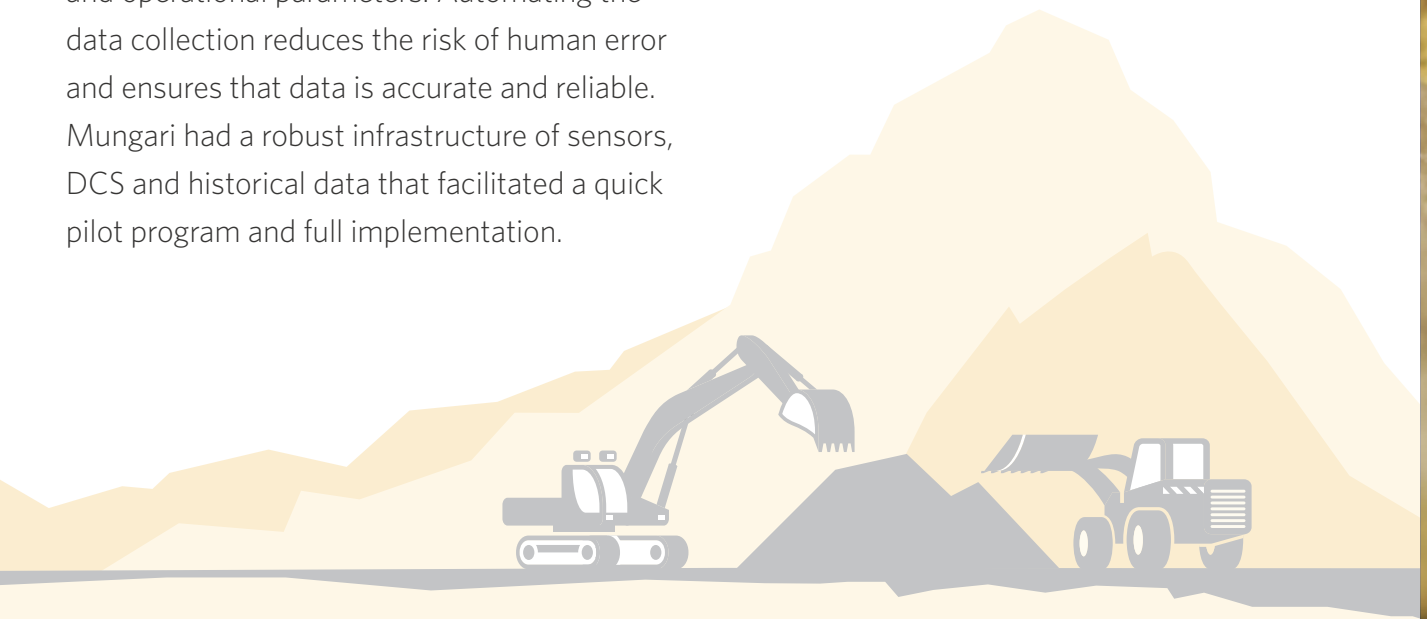
Strategic Planning and Preparation. Identify and prioritize which assets are most important to your operations, allowing you to focus on the areas with the biggest overall impact on production, safety and environment. Mungari initially identified three assets as critical components of the crushing and mill facilities based on previous asset failures in these areas. These assets already had multiple sensors available for both upstream and downstream, leading to the creation of failure agents and highly accurate probability curves.

Early planning is critical to get a clear understanding of the site level workload that will be needed in the initial stages and throughout the implementation, to set realistic expectations, to establish team member roles and to avoid inundating team members with additional responsibilities beyond the scope of their daily job function.

Operations have seen benefit by identifying and utilizing a team "Champion" during the implementation process. For the Aspen Mtell implementation, Matthew Anderson, Maintenance Superintendent, took on this role at Mungari. He was tasked with driving the project from an organizational level and helping all team members understand the value of the implementation. "Understanding the setup work and what the solution will deliver is critical to see the value and get the much-needed early buy-in from the team," says Matthew.

Data Collection. Assets must have sensors like Internet of Things (IoT) devices to collect key operational and usage data in real time. This could include monitoring vibration or temperature and other key indicators of asset health and operational parameters. Automating the data collection reduces the risk of human error and ensures that data is accurate and reliable. Mungari had a robust infrastructure of sensors, DCS and historical data that facilitated a quick pilot program and full implementation.

The Mungari team improved data collection based on the initial success of Aspen Mtell. The implementation presented key supporting data to acquire and install additional sensors and instrumentation to improve data capture and monitoring. "We really saw the potential of Aspen Mtell that went beyond just the pre-scriptive maintenance," added Matthew." Using consolidated data in a single probability curve enables users to perform quick analysis while simultaneously reviewing other critical detailed information. This capability has the potential to improve overall operational activity.



Communication. Communicate effectively with key stakeholders, including operations, maintenance teams, subject matter experts (SMEs), solution partners and senior management. Communication and collaboration enable transparency and quick, informed, actionable decision-making or program adjustments. During the initial pilot program and full-scale implementation at Mungari, SMEs with key knowledge of maintenance and operations made valuable contributions. The on-site team worked very closely with the AspenTech team to gather data, create agents, monitor alerts and validate results.

Maintaining the feedback loop from the on-site team was imperative in communicating the program's added value and ensuring the team had the right knowledge and understanding to build on early success. Daily meeting with team members were held (as needed) during the initial stages to help lay the foundation. Weekly meetings with AspenTech were also held to review alerts, make necessary adjustments and provide user feedback to improve the technology.

Training. Ensure that stakeholders are trained in the processes and workflows, and that they fully understand how to utilize that information in their decision-making and planning. Teams cannot make informed, actionable decisions without having a clear understanding of the available information. The Mungari team took the time upfront in the process to make sure the operational and maintenance teams had a good understanding of how Aspen Mtell worked, the data collection, agent creation and most importantly, the initial time and effort needed for setup. Setting a clear expectation of what that upfront process looks like is crucial to getting the site team and management to buy-in on moving forward with the solution.

Program Review and Validation. Implement a method for tracking prescriptive maintenance activities, alerts, actions taken and impacts on operations, costs and savings. Reporting on this information helps to validate that the program is meeting its goals and to identify further improvements. To accomplish this, Mungari implemented a standardized after-action reporting methodology for evaluating the impact of a failure alert. The team reviews all alerts triggered through Aspen Mtell. It applies a percentage value of contribution since alarms could potentially be raised through other means, such as human inspections or equipment/process thresholds. Utilizing this approach allows for a quantitative method of impact for the solution.

Example of the Impact of Implementing a Failure Alert

Asset: Tertiary Crusher
Failure Alert: Lube Oil
Estimated Production Loss Savings: $149,040 AUD
Estimated Parts Savings: $64,000 AUD
Maintenance Savings: $20,000 AUD
Total Financial Savings: $233,040 AUD
Total Savings Attributed to Aspen Mtell: $174,780 AUD
Aspen Mtell Contribution: 75%

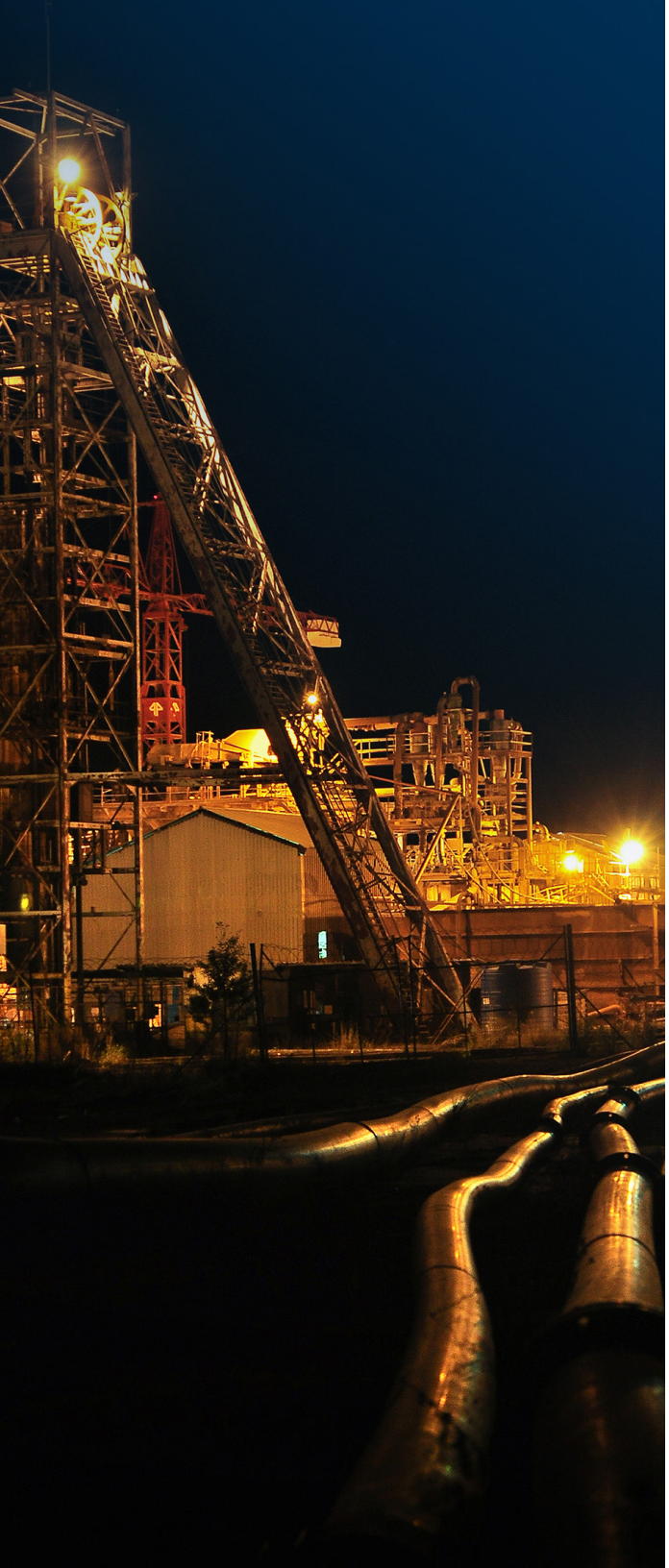
For example, in the case of the tertiary crusher, oil analysis confirmed the alert and also confirmed that the potential failure was imminent. The estimated Aspen Mtell contribution was set to 75% based on other inspection methods that could have identified the issue. With these after-action reviews, Evolution has shown an achieved value of approximately $700,000 AUD since the solution was put into full production. Outside of these monetary justifications, Mungari also sees value in the safety and environmental impacts of advanced failure warnings.

In addition to the safety risks associated with equipment failure, maintenance personnel may need to be sent into active areas to address the issue, which can further increase the risk of accidents. Implementing a prescriptive maintenance program provides early detection of equipment issues, which can be addressed during scheduled maintenance downtime rather than during production hours, reducing the need for maintenance personnel to enter active mining and processing areas.

Removing these additional human-machine interactions, operations can increase safety by minimizing risk from incidents.

Overall, the use of a prescriptive maintenance program helps Evolution Mining maintain a safer working environment for employees while also improving productivity and reducing the risk of costly downtime. One instance of this is having a failure agent monitoring an oil heater where a failure of the heat exchanger could have catastrophic safety implications, with hot oil vaporizing cold water, causing a rapid steam explosion. Having systems in place to minimize the risk of this occurring is of immense value and should be considered in evaluating such programs.

Monitor and Adjust. For a prescriptive maintenance program to continually add value, a consistent process for monitoring, evaluating and making necessary changes needs to be in place and followed. Regularly reviewing alerts and data is important to identify improvement areas and ensure that the program achieves desired goals and objectives. Mungari has created an efficient method for continuously improving its prescriptive maintenance solution. In addition to the meetings discussed previously, the on-site SMEs will consistently add new agents and adjust existing ones based on changes in operational parameters. Staying proactive in monitoring and fine-tuning the program will continuously add value to its operation.



Conclusion

As supported by the successful prescriptive maintenance implementation at Evolution Mining's Mungari Mine, adopting a prescriptive maintenance approach, like Aspen Mtell, can significantly improve operational efficiencies, operator productivity, asset performance and cost savings. By following the best practices outlined in this paper, organizations can more effectively implement their own program and take a proactive approach to improve reliability of their assets. It is important to have a strategic plan and clear understanding of assets, data and process, clear communication and collaboration across teams and consistent evaluations and adjustments to ensure program success and added value in the future. Mining organizations that commit to a prescriptive maintenance solution, such as Aspen Mtell, can expect rapid deployment and efficient incorporation with ongoing maintenance strategies, making it an excellent value add investment with an ROI measured in months.

Citations:

[1] Christiansen, B. (2018). Exploring biggest maintenance challenges in the mining industry. Mining.com.

About Aspen Technology

Aspen Technology, Inc. (NASDAQ: AZPN) is a global software leader helping industries at the forefront of the world's dual challenge meet the increasing demand for resources from a rapidly growing population in a profitable and sustainable manner. AspenTech solutions address complex environments where it is critical to optimize the asset design, operation and maintenance lifecycle. Through our unique combination of deep domain expertise and innovation, customers in capital intensive industries can run their assets safer, greener, longer and faster to improve their operational excellence.

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About Evolution Mining

Evolution Mining is a leading, globally relevant gold miner. Evolution operates five wholly-owned mines – Cowal in New South Wales, Ernest Henry and Mt Rawdon in Queensland, Mungari in Western Australia, and Red Lake in Ontario, Canada. Financial Year 2023 gold production guidance is approximately 660,000 ounces at an Allin Sustaining Cost of approximately $1,390 per ounce.

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