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Driving Open Autonomy and Innovation

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ABSTRACT

As the mining industry faces increased challenges with declining ore grades and harder to access deposits, operating mine sites in an environmentally responsible and economically viable manner will require innovations that improve efficiency in energy logistics, and automation.

Technological advancements in mining have been successful primarily because of the willingness and capability of these solutions to share information with one another, for example OEM payload systems sending information to Fleet Management Systems, and in turn Fleet Management Systems interfacing to ERP systems. To promote and facilitate the sharing of data, there has been a push towards open standards with initiatives led by organizations like ISO, ISA, EMESRT, and GMG. These efforts are aimed at creating a more collaborative and interoperable environment within the sector. However, when it comes to implementing autonomous solutions, a different trend dominates—closed-stack solutions.

These closed stack solutions not only prohibit a mine site from selecting best-of-breed solutions, by blocking the competition from entering the market, they also risk slowing innovation that could help overcome the challenges the mining industry faces.

Open Autonomy, an internationally published standard that allows any FMS to work with any Autonomous solution, breaks this closed-stack approach and invites competition from other industries. This competition comprises of autonomous suppliers from other industries and manufacturers of smaller, civil-sized haul trucks.

The availability and capabilities of these smaller-sized autonomous haul trucks will help tackle the challenges of responsibly and economically mining lower quality ore grades and mining harder to access deposits.

INTRODUCTION

Wenco provides a comprehensive suite of fleet management applications for surface mining operations of all sizes worldwide. Our current offerings include a scalable FMS that focuses on production management and operator

efficiency, an asset health system to minimize the impact of maintenance events on your operation and improve your equipment availability, an operator fatigue management system designed to avert fatigue-related incidents by identifying operators' ability to resist sleep, and a set of machine guidance applications to improve the precision, productivity and efficiency of a mine's drills, loading equipment, and dozers.

We work openly with other technology providers to actively accept their inputs into our system for reporting purposes, real-time event notifications, and making critical production and safety related decisions. With an open database and system APIs, we also share the operational, maintenance, and safety data that we collect with other systems in use at the mine.

The first autonomous haulage systems introduced into the open pit mining industry were developed and supplied by the major OEMs. These systems however required that the entire fleet was a certain make and model from that one OEM and that the fleet must be managed with that OEM's Fleet Management System. Wenco identified this as a threat to our business as a premier supplier of Fleet Management Systems. To combat this threat, Wenco's Martin Politick, Director of System Engineering and Architecture, introduced the idea of Open Autonomy, defining and creating standard-based interfaces for any FMS to connect and operate with any autonomous haulage system.

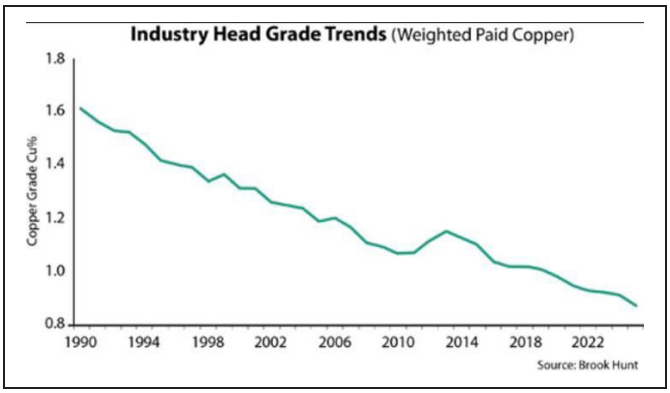
In 2018 Wenco submitted a proposal to ISO. Now ISO 23723: Autonomous System and Fleet Management System Interoperability has become a published and public standard with Martin as the convenor of that project to this date.

This initiative is much more than simply ensuring Wenco's viability as an FMS provider. This initiative helps advance the open standards strategy within the industry, encourages competition within industry, and ultimately helps the industry tackle some of the more significant challenges it now faces.

INDUSTRY CHALLENGES

Lower Quality, Harder to Access Deposits

The mining industry is currently grappling with a significant challenge: declining ore grades. This trend is observed globally in metallic mining. Though it is indicative of resource depletion or availability, the trend can also be attributed to various factors such as geological complexities, improvements in extractive technologies, and the extension of the lifespan of older mines. In the case of copper, the average copper ore grade is decreasing over time, while the energy consumption and the total material moved in the mine increases.



The average copper ore grade has decreased approximately by 25% in just ten years from 2006 to 2016.*

As high-grade deposits become increasingly scarce, mining operations are forced to extract lower-grade ores, which often require more intensive processing and yield less valuable output.

Another challenge is the increasing difficulty in reaching deposits. As easily accessible deposits are depleted, mining operations are compelled to venture into more remote and challenging environments. This not only raises operational costs but also poses additional logistical and environmental strains. As mining operations delve deeper and target lower-grade ores, the volume of waste material that needs to be moved and managed increases, escalating costs and exacerbating environmental impacts.

This combination of lower quality and harder to access deposits means that future deposit extraction will be conducted at greater depths and lower grades compared to current practices, and this tendency will have a significant impact on operating conditions and costs. As mines become deeper and stripping ratios increase because of that lower grade, more waste material needs to be extracted resulting in a corresponding growth in the necessary truck fleet.† Reducing the cost of truck haulage, which makes up about half of the operating expenses of a mining operation, is more essential now than ever.

Uneconomic Satellite Deposits

As mining operations progress over time, it's important to consider that the easily accessible and exploitable resources are typically the first to be developed or depleted.

* Decreasing Ore Grades in Global Metallic Mining: A Theoretical Issue or a Global Reality? MDPI Nov 2016

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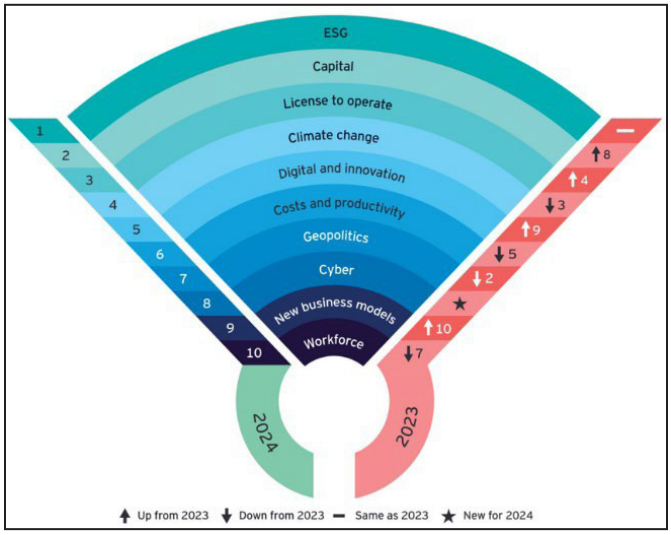
Consequently, the industry is forced to shift its focus towards smaller deposits that are located at greater distances from mining facilities. This shift in resource availability presents a set of unique challenges and considerations for mining companies.

The primary issue associated with mining smaller, more remote deposits is the inability to take full advantage of economies of scale. Large operations could spread fixed costs over a larger volume of resources to be extracted. However, with smaller and more distant deposits, achieving these economies of scale becomes even more challenging due to higher transportation costs, additional infrastructure, and an increased dependency on commodity prices.

The innovation and adoption of new technologies can therefore play a crucial role in making these smaller, remote deposits economically viable to mine.

Environmental Impact

ESG, the collection of corporate performance evaluation criteria that assess the robustness of a company's governance mechanisms and its ability to effectively manage its environmental and social impacts* is top of mind for mining companies.†



The issue of lower grades and harder access to deposits makes addressing these environmental challenges even more difficult.

As mentioned previously, the deeper the mine, the higher the stripping ratio. This results in a corresponding growth in the necessary truck fleet and each additional truck means a subsequent increase in diesel consumption. As grades decrease, more ore needs to be processed to achieve similar production. A decrease in copper ore grade between 0.2% to 0.4% requires seven times more energy than present-day operations.

The challenge of mining these low ore grades within hard to access deposits in an environmentally responsible and economically viable manner will require innovations in energy efficiency, logistics, and automation.

THE CLOSED-STACK PROBLEM

In the evolving landscape of the mining industry, there's a noticeable shift towards open standards, with initiatives led by organizations like ISO, ISA, EMESRT, and GMG. These efforts are aimed at creating a more collaborative and interoperable environment within the sector. However, when it comes to implementing autonomous solutions, a different trend emerges—closed-stack solutions.

Major Original Equipment Manufacturers (OEMs) offer autonomous solutions, but these solutions come with a significant limitation. They require mining operations to commit to their entire technology stack, from the equipment such as autonomous mining trucks to the Fleet Management System (FMS) and other software used to oversee site operations.

Currently, with these OEM autonomy systems all autonomous equipment within a mine must originate from their specific OEM, and only select equipment models are supported for autonomy. Transitioning to this singular make and model requirement is a significant financial hurdle for existing mining operations that maintain mixed fleets from various manufacturers.

The same is true with being forced to use their FMS. Fleet Management Systems vary in their capabilities and sophistication and are central to the efficient functioning of a mining operation. Monitoring and controlling real-time pit operations, FMS often evolve into a central hub sharing contextual information with various systems, such as Planning, Maintenance, HRIS and Finance Systems, Plant operations, and many more.

Replacing an FMS necessitates the severing and rebuilding of these integrations, resulting in extensive change management, training, and significant software development to rebuild the various upstream and downstream integrations.

A SOLUTION: OPEN AUTONOMY

The solution is Open Autonomy. Open Autonomy is essentially a universally recognized standard Application Programming Interface (API) that functions as a conduit

* www.gartner.com/en/finance/glossary/environmental-social-and-governance-esg-#

† MDPI Electrification Alternatives for Open Pit Mine Haulage January 2023

between the Fleet Management System (FMS) and the autonomy provider, allowing any FMS to operate with any autonomous system.

Wenco is driving this solution in the form of an ISO standard that clearly delineates the roles and responsibilities between FMS and autonomy allowing for a "best of breed" approach in selecting both the autonomous system and FMS.

ISO 23725 was first proposed by Wenco in 2018. The committee is convened by a Wenco executive and as of October 2023 has now reached the first ballot stage to achieve a status as a published standard.

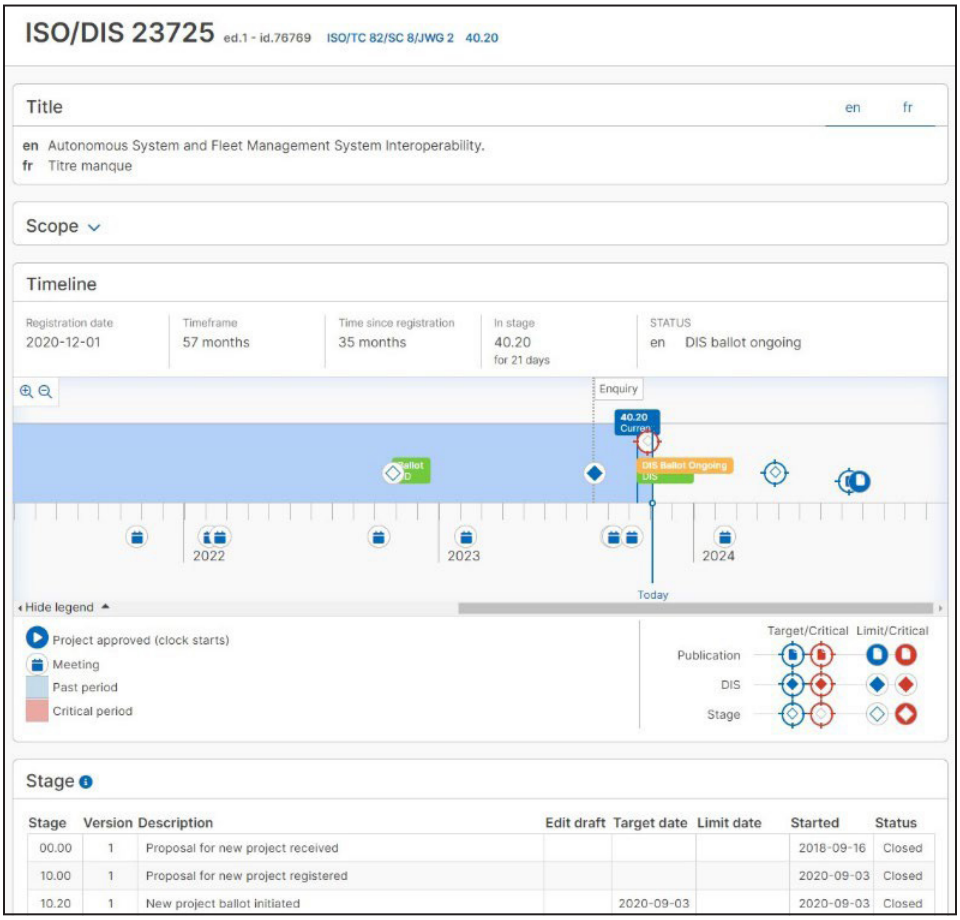
This standard is not exclusive to Wenco. It is designed for the benefit of the customer and enables them to combine any FMS to operate with any autonomous solution. For example, it will enable a CAT autonomous fleet to function with a Modular FMS, or a Komatsu autonomous fleet to function with Wenco FMS, or Cat FMS to work with Hitachi autonomous, or any combination of the above. Even though Wenco is owned by Hitachi Construction Machinery (HCM) who has their own autonomous haulage program, HCM is fully supportive of Wenco driving this initiative, reflecting Hitachi's commitment to fostering an Ecosystem of Partners.

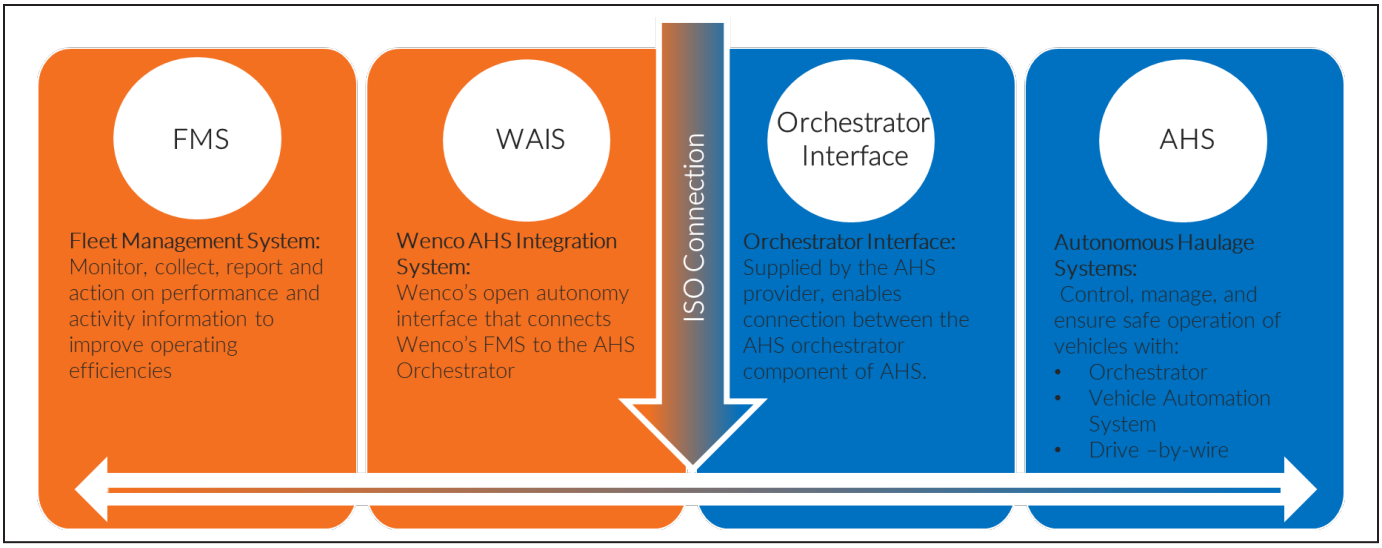
Open Autonomy requires a seamless communication between AHS and FMS. The AHS provider supplies the orchestrator interface which communicates with the FMS-AHS integration system and their Autonomous Haulage System. Wenco's Open Autonomy solution not only provides the fleet management system and the Wenco AHS Integration System (WAIS), which is the interface that enables other autonomous providers to communicate with the FMS, it implements the globally recognized ISO standard-based API, a crucial connection between WAIS and Orchestrator Interface.

OPEN AUTONOMY DRIVES INNOVATION

Open autonomy is so much more than being able to select your FMS of choice. Open autonomy is a gateway for companies previously uninvolved in the mining sector to penetrate the market.

Autonomous solutions that are in use in military, urban automotive, construction, or agriculture can now introduce their expertise into mining. They can automate the existing





equipment, providing an immediate benefit for mine sites who can now retain their existing mixed fleet of haul trucks from multiple manufacturers.

The competition with new entrants and their technology drives innovation in the mining industry which will in turn help overcome the previously identified challenges of responsibly and economically mining lower quality ores and reaching harder to access deposits.

This extended autonomy landscape enables long-haul road train autonomy and the use of smaller, more versatile trucks. There is also an increased diversity of companies manufacturing smaller trucks compared to traditional mining trucks. This heightened competition, featuring companies like Mercedes, Volvo, and Scania, can only benefit mine operators in the long run.

Accessing Hard to Reach Deposits

Wenco, as part of its autonomous initiative, is gearing up for trends like swarm mining, where deploying numerous smaller autonomous trucks may prove more efficient than traditional large mining trucks. A larger fleet minimizes the impact of equipment breakdowns on overall production.

Selective mining is a precision-oriented approach that focuses on extracting only the valuable ore, leaving the surrounding material undisturbed. Selective mining in open pits is made more effective with smaller, more maneuverable haul trucks and excavators. These smaller machines equipped with advanced sensing, mapping, and autonomous haulage technologies, and the accompanying smaller loading equipment, can access tight spaces and accurately target ore deposits, significantly reducing the stripping ratio. This starkly contrasts traditional mining methods, which involve large-scale excavation and displacement of material.

By reducing the amount of material that needs to be moved, mining operations can achieve significant cost savings. Less material movement means less energy consumption, lower carbon emissions, and reduced wear and tear on equipment, all of which contribute to lower operational costs. Moreover, advancements in selective mining can improve the efficiency of ore extraction. By precisely targeting the ore, miners can ensure that less of the valuable material is lost in the extraction process. This can lead to higher yields and improved profitability.

Reaching Satellite Deposits

To use smaller mining equipment, an increased fleet size of haul equipment will be required to effectively mine a given deposit, but labour costs would typically restrict this possibility. Open Autonomy makes this feasible by introducing a swarm of civil-sized autonomous haul trucks that can travel longer distances on smaller roads and civil roads to already established processing plants. This is particularly beneficial for mining operations targeting smaller, more remote deposits, where achieving economies of scale becomes challenging due to the increased operational costs and logistical complexities associated with these deposits. Satellite orebodies that were previously uneconomical are now economically viable.

Reducing Environmental Impact

As briefly noted above the use of smaller trucks can reduce the volume of material that needs to be moved. Less material movement means less energy expended. The smaller

trucks also exhibit superior payload-to-truck weight ratios, making them more efficient since more of the energy being expended is going towards moving material instead of driving the vehicle, resulting in lower carbon emissions. The higher payload-to-truck weight also makes the trucks better suited to electrification.

One of the major sources of greenhouse gas emissions in mining is fuel consumption during material haulage. To address this issue, the industry is moving towards electrification as a key strategy.* Many of the largest haul trucks in use today are designed as diesel-electric drives. In these vehicles, electric motors handle the task of propelling the equipment, with the diesel engine serving solely to generate electricity.

Trolley-assist operations, a well-established technology for diesel-electric equipment, have been in use for decades. Building upon this foundation, mining companies are exploring several feasible electrification technologies:

1. Battery-electric "converted" diesel-electric haul trucks: In cases where trolley-assist infrastructure is available, there is potential to convert diesel-electric haul truck designs to battery-electric systems. However, this transition presents certain technological challenges, such as energy recovery, charging speed, and battery weight. Currently, ultra-class haul truck manufacturers like Hitachi, Komatsu, Caterpillar, and Liebherr are actively pursuing this technology.
2. Smaller battery-electric haul trucks: When scaling up to larger battery-electric vehicles, the increased mass of the equipment requires higher voltages or significantly heavier cabling to manage the greater forces involved. With limitations on tire TKPH (tire load capacity) and battery voltage, super and ultra-class battery-electric equipment may be restricted to short-haul cycles with reduced flexibility. To address these limitations and regain some operational flexibility, mines are exploring the use of smaller battery-electric equipment.

THE CURRENT STATE OF OPEN AUTONOMY

Open Autonomy is no longer a vision, it is the present and it's continuously growing. Wenco is currently involved in two significant Open Autonomy projects, each with its unique goals and partnerships.

Roy Hill Iron Ore, an established customer of Wenco, is embarking on a journey toward automation. Their aim is clear: equip more than 75 mixed-fleet haul trucks with autonomous capabilities. To achieve this, they are collaborating with ASI, the creators of the Mobius command and control solution. This project focuses on Australia's Pilbara region, where a seamless integration of AHS-FMS messages between Wenco Mine and Mobius is vital. Mobius is tasked not only with managing the autonomous haul trucks but also with controlling all spotting and manned equipment. The end goal is to automate a production fleet that includes haul trucks ranging from 230 to 320 tons.

In another corner of Western Australia, Rio Tinto, in partnership with Scania, aims to automate a swarm of 80-ton Scania trucks. The integration is achieved by merging Wenco's fleet management system and high precision machine guidance application on the staffed loading equipment with Scania's autonomous haulage solution. The innovation here is evident in Scania's smart truck approach, allowing for greater autonomy with less reliance on real-time connectivity.

CONCLUSION

Openness is the key to innovation.

* thedriven.io/2023/06/23/bhp-says-battery-electric-cheaper-than-hydrogen-as-it-dumps-diesel-for-haul-trucks/

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Optimizing Froth Zone in Larger Flotation Cells Through Innovative Spider Crowder Upgrade

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ABSTRACT
Bigger flotation cells can result in larger froth surface areas and longer froth transport distances, this has been credited to impact froth recovery. Thanks to recent advancements, the newer flotation machines can be designed with different launder and crowder arrangements to enhance froth management. Nevertheless, lower head grades, complex ores and even larger mechanical flotation cells can lead to insufficient froth collection, even if the cell is equipped with the most recent flotation advancements like the center launder design. Aforementioned issue can become critical at the end of the flotation row. Increased crowding has been proven to be a solution to overcome inadequate froth recovery. However, scaling-up crowders for larger flotation cells can rise challenges, particularly in terms of structural limits and design for service. This paper presents the development journey for the Spider Crowder Upgrade, an advancement to improve froth collection in large flotation cells that are already equipped with center launders.

INTRODUCTION

Flotation is key mining operation to separate valuable materials from gangue to facilitate obtention of necessary metals that are highly demanded for current global needs, such as electrification and manufacturing. Consequently, this has surged the growth of concentrator plants to fulfill the aforementioned. This trend can be noticed at the flotation circuits, where cells have increased to volumes larger than 600 m^3.

Some benefits that these larger flotation machines have brough include the possibility to process higher throughputs, reduced installed footprint and energy consumption optimization. Nevertheless, they also have resulted in new challenges, like the need for newer maintenance strategies and difficult froth management.

Bigger cells have reported poor froth collection and low coarse particles recovery, thus hampering metallurgical performance. This effect has been attributed to its legacy design including suboptimal froth zone parameters, like large froth surface area and long transport distance.

Froth zone parameters relative to flotation tank volume growth has been plotted by Corona et al. (2021) in Figure 1 for Metso´s flotation cells installations. As detailed in the graph, there is a correlation between cell´s volume and froth transport parameters, such as Froth Surface Area (FSA), Froth Transport Distance (FTD) and Lip Length (LL). When these factors grew significantly, different arrangements of launder and crowders were trailed to mitigate this effect.

According to Mesa and Brito-Parada (Mesa and Brito-Parada, 2019b) it is highlighted that the available literature on the design of different inserts for froth control