

Horizon Scanning Series

The Effective and Ethical Development of Artificial Intelligence: An Opportunity to Improve Our Wellbeing

Mining

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Application of digital technologies in the mining industry

Table 1: Summary status of “digital technologies” in the mining industry

Technology	Status	Examples
Remote operations centres	Wide development and deployment amongst the majors, particularly where multiple operations are involved. The Pilbara is an excellent example.	<p>Rio Tinto – remote operations centre in Perth (iron ore) BHP – Integrated remote operations centre in Perth (iron ore) BHP – Integrated remote operations centre in Brisbane (coal) Roy Hill – remote operations centre in Perth (iron ore) Fortescue Metals Group – remote operations centre in Perth (iron ore)</p>
Advanced data analytics	Many METS and mining companies are reporting to use advanced analytic techniques. Impart, to cope with the “barrage” of new data from additional field sensors.	<p>Interlate - Remote real time data collection and advanced analytics Goldsmart/IBM – Use of IBM Watson to scan exploration data. Rio Tinto – advanced data analytics for predictive maintenance and operations. For example, the new Koodaideri mine touted as the “most advanced mine built” Komatsu/GE – providing a service to mining companies around big data analysis. Barrick/Cisco – partnership to digitally reinvent the business, using real time data and analytics. BHP data science applied to maintenance.</p>
Automation	Growing deployment, particularly of autonomous trucks. Application still mainly with the majors. (Good learning from the aluminium industry which is more advanced)	<p>Resolute – fully automated underground mine (in planning stage) Northparkes – fully automated underground mine Komatsu/Codelco - first known trial of autonomous trucks in 2005. Various - autonomous trucks (various suppliers e.g.: Komatsu, CAT, Hitachi, Volvo and users (Rio Tinto, BHP, FMG etc) Rio Tinto - autonomous trains in the Pilbara (Autohaul) Rio Tinto - autonomous drills</p>
Internet of things	Gathering pace. Most new equipment (mobile or fixed plant) now connected and with sensors capable of providing real time data.	<p>Interlate - Remote real time data collection and advanced analytics using the IoT.</p>

Technology	Status	Examples
Digital twins	Very early stage deployment of digital twins to date. Having said, the application of static mathematical models to simulate specific unit operations started in the late 1980's.	<p>PETRA/Newcrest – application of machine learning and digital twins to optimise mill performance at Lihir</p> <p>Anglo American – reports then use of digital twins to optimise its mining and haulage operations.</p> <p>Rio Tinto – using a digital twin to develop the Koodaideri iron mine in the Pilbara</p> <p>Siemens – the use digital simulation tools to design and operate belt conveyor systems</p> <p>Roy Hill – report the use of a digital twin to operate the Roy Hill iron ore mine</p>
Block chain	Emerging. Some initial interest by mining companies.	<p>Barrick - reducing the transaction cost of gold tracking and trading</p> <p>BHP - share information between vendors, contractors, geologists and shipping companies to track material movements of wellbore rock and fluid samples</p> <p>De Beers - ensuring all registered gems are conflict-free and natural, while also enhancing efficiency across the sector</p>
Machine learning	Emerging. Only a few specific examples, while most reports are around the potential of the technology	<p>PETRA/Newcrest – Application of machine learning and digital twins to optimising mill performance at Lihir</p> <p>Goldspot/IBM – machine learning to find new gold deposits</p> <p>Petra/Pan Aust – Machine learning algorithm to predict plant performance</p> <p>Anglo – using machine learning to improve plant performance</p> <p>BHP – machine learning to predict plant maintenance</p>
Artificial intelligence	Embryonic. Very few examples provided. Term tends to be used interchangeably with machine learning	<p>NVIDIA/ Komatsu – using AI to analyse construction sites.</p>
Value proposition	Generally stated/ expected that the value proposition is very strong.	<p>McKinsey – estimate the “value of digital” to be between \$40-80 billion for the Australian mining industry alone.</p> <p>Rio Tinto – indicate a cost saving of 15% for autonomous trucks in the Pilbara</p> <p>Anglo American – report that companies have generally seen a 30% business improvement, through cost savings and productivity improvement</p> <p>BHP - expect a saving of \$799M p.a. using data science applied to maintenance in coal mines in Queensland</p>

Table 2: Selection of examples, the application of digital technologies in the mining industry

Reference	Company	Description
https://www.techemergence.com/ai-in-mining-mineral-exploration-autonomous-drills/	Goldspot/IBM	<p>The company Goldspot Discoveries Inc. uses AI to try to improve mineral exploration. The company claims that the current practice of trying to find gold deposits is more of an art than a science, and they plan to change that with machine learning.</p> <p>In 2017 mining giant Goldcorp teamed up with IBM Watson to comb through a vast quantity of geological information to find better targets.</p>
	Tomra	TOMRA has developed smart sorting equipment for mining which uses colour-sorting, X-ray transmission or near-infrared sensors to examine every single piece of material moving through the equipment and is able to sort the material based whatever criteria the company wants.
	Petra/ Newcrest	PETRA Data Science first teamed up with Newcrest Mining in 2016 to solve a problem with the mills in Newcrest's gold mining operation in Lihir. In this case, PETRA used machine learning algorithms to predict and subsequently avoid overload events in the semi-autogenous grinding (SAG) mills, with the end goal of reducing mill downtime.
https://www.tribal-interactive.com/single-post/2018/03/02/How-Machine-Learning-is-Disrupting-the-Mining-Industry	Rio Tinto, BHP, Suncor, FMC	In a progression towards fully automated , intelligent mines, several companies (including Rio Tinto, BHP, Stanwell, Suncor, and Fortescue) have begun using autonomous haul trucks at their mines. Industrial vehicle manufacturers Komatsu, Caterpillar, and Hitachi have been developing these driverless haul trucks in close collaboration with mining operations, employing a combination of wireless communication, object-avoidance sensors, on-board computers, GPS systems, and artificial intelligence software that enable the trucks to operate autonomously.
	Rio Tinto/ Komatsu	Rio Tinto, who has employed a fleet of roughly 400 Komatsu haul trucks in its Pilbara mine, explains that the autonomous trucks have improved safety and cut costs by nearly 15 percent, partially due to the fact that the vehicles can be operated 24/7.
	Volvo	Volvo has also recently announced testing on a fully autonomous underground truck in the Kristineberg Mine. The new truck navigates the very narrow tunnels of the underground mine. This is especially innovative because GPS doesn't work underground as it does for autonomous trucks on surface mines. Volvo explains that these trucks increase productivity and safety: as they are driverless, they can work directly after blasting occurs, instead of having to wait as required by the current protocol.

Reference	Company	Description
<p>http://www.petradatascience.com/casestudy/newcrest-petra-collaboration-big-data-delivers-results/</p>	<p>Petra</p>	<p>At Lihir, our three mills had been experiencing multiple overload events each year, resulting in significant downtime. Over 360 million lines of data across 130 variables were collected, and by cross referencing this big data, the Petra team was able to identify causal factors and develop machine-learning algorithms which could predict future outages.”</p> <p>The Lihir mill FORESTALL® overload algorithms were developed using an engineered approach to data science. For example; in this case, engineering knowledge was used to create an additional 650 engineered signals from the original 143 raw signals for each SAG mill (about 800 signals per mill).</p> <p>At Future of Mining 2018, PETRA demonstrated the world’s first digital twin for mine value chain optimisation. Two years of historical data from PanAust’s Ban Houayxai mine was ingested into the MAXTA digital twin. (abstract submitted to Complex Orebodies, 2018).</p> <p>“The Ban Houayxai Gold-Silver Operation is a producing asset for Australian-based copper and gold producer, PanAust Limited. In 2018 a machine learning algorithm was installed at the Operation to predict future metallurgical characteristics based on previous process plant performance. The algorithm was enabled by the integration of two years of 3D geological with plant data to derive a formula that can be applied to block models, allowing both ‘backward’ reconciliation analysis and ‘forward’ predictions. Data from approximately 10 million tonnes of ore was integrated and analysed in 12 hour batches over a two-year period. Unlike conventional mine-to-mill studies based on samples and test work, or tracking batches of ore with markers, machine learning based value chain optimisation uses large amounts of historical data to predict future plant performance.</p> <p>Proprietary data integration software creates a digital twin of the value chain enabling machine learning algorithms to continuously ‘learn’ from the geology, and plant data to automatically update the prediction model ”.</p>

Reference	Company	Description
https://about.bnef.com/blog/anglo-using-digital-twins-robotics-boost-mining-qa/	Anglo American	<p>Anglo American Plc is using digital technology and machine automation to improve the productivity and safety of its mining operations. Companies that have digitized their technical equipment have “generally seen around a 30 percent improvement in their business – made up of about 15 percent in productivity and 15 percent in cost savings”, Tony O’Neill, technical director at the global mining company, told BNEF. The U.K.-based miner of commodities such as nickel, coal and precious metals is using “digital twins” to optimize its mining fleet, including applications to track the performance of haulage at its Los Bronces mining site in Chile and at a 500 km pipeline in Brazil.</p> <p>Due to declining quality of ore grades, energy consumption in mining has increased by 16 times since 1900, as more energy and water is used to produce the required amount of metal. Machine learning can help increase the efficiency of these operations by improving the precision of mining, so that less waste, water and energy get used, according to O’Neill.</p>
https://www.interlate.com/	Interlate	<p>Interlate is transforming the mining sector by creating predictable outcomes, reducing operating risk and increasing competitiveness. We do this by harnessing the power of the Industrial Internet of Things (IIoT), tightly integrated with expert human skills and world leading technical innovation. Interlate is a data business, it’s our food, it’s our source for everything. We use the historical data of a plant to inform us, we use the current data to deliver insights in real time back to the mining company.</p>
https://www.riotinto.com/documents/180514_Speech_Stephen_McIntosh_Breaking_from_tradition_The_Mine_of_the_Future.pdf	Rio Tinto	<p>Our Koodaideri project is an iron ore development being studied within our Pilbara business. It is planned to be our most advanced mine yet built. Through the use of digital design, advanced data analytics, machine learning, control loop optimisation and automation we will significantly improve how we operate and maintain this new mine. Through the use of digital twins, we will better interact and use the data we gather during design and operations. The digital twin will allow us to access real time data in the field to support our operators and maintainers. This will be our first fully paperless mine. Ultimately, Koodaideri will run as part of an integrated system, where we can integrate – in real time – the mine, process plant and rail system, including AutoHaul.</p>
https://goldspot.ca/	Goldspot	<p>GoldSpot Discoveries is revolutionizing the mineral exploration business by utilizing machine learning to target on a regional and localized scale. We are on a mission to enable future resource development by breaking down exploration barriers with data driven science, artificial intelligence and machine learning.</p>

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https://www.reuters.com/article/us-newmont-mining-results/newmont-mining-poised-for-growth-in-gold-sector-idUSKCN1G61GY	Newmont Blockchain	<p>And as the gold industry studies block chain technology as a way to confirm ethical and sustainable production, Newmont is interested in trialling it this year, he said.</p> <p>“We definitely want to be involved in it, we think it’s a good thing for the gold industry overall,” said Goldberg, adding that other miners may launch trials before year-end.</p>
https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Energy-and-Resources/gx-er-tracking-the-trends-2017.pdf	Komatsu/GE	<p>Komatsu, a global mining and construction equipment manufacturer, and General Electric announced plans to provide mining companies with big data analysis services using IoT technology to boost efficiency in mining operations. Applications include optimal truck routes and positioning, optimal speed and braking (based on site and terrain) with flow-on benefits in terms of reduced equipment downtime, better fuel efficiency and shipments between pit and port.</p>
https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Energy-and-Resources/gx-er-tracking-the-trends-2017.pdf	Barrick/Cisco	<p>In a move that likely heralds the wave of the future, Barrick Gold teamed up with Cisco to digitally reinvent its business. The aim is to digitize Barrick’s entire organization—from its mines to its head office. The company plans to improve decision making through the use of real-time data, analytics and predictive tools.</p>
https://nvidianews.nvidia.com/news/japans-komatsu-selects-nvidia-as-partner-for-deploying-ai-to-create-safer-more-efficient-construction-sites	NVIDIA/Komatsu	<p>Komatsu, one of the world’s largest manufacturers of construction and mining equipment, has selected NVIDIA as its partner to bring AI to jobsites, making them safer and more efficient, NVIDIA announced today. The partnership will focus on Komatsu using NVIDIA GPUs to visualize and analyze entire construction sites. The NVIDIA® Jetson™ AI platform will serve as the brain of heavy machinery deployed on these sites, enabling improved safety and productivity.</p>
https://www.pwc.com/au/publications/pdf/global-mine-2017.pdf	Rio Tinto	<p>A number of miners have announced or implemented digital innovations that are enhancing performance. Rio Tinto, for example, has built a remote monitoring and control facility that can connect with mines all over the world in real time.</p>
https://www.itnews.com.au/news/bhp-lifts-lid-on-major-data-science-project-478709	BHP	<p>BHP is applying data science to understand how it services machines located across its mines, in the hope of saving \$79 million this financial year alone. The miner revealed plans late last year to set up a maintenance centre of excellence (MCoE) based out of Brisbane. The MCoE will standardise maintenance systems and processes for BHP’s worldwide operations, replacing the previous model of having 40 different maintenance organisations globally, each with its own way</p>

Reference	Company	Description
		<p>of working. One of the keys to the MCoE model is its reliance on data science techniques, such as machine learning, to understand how maintenance is performed at each site and where improvements can be made.</p>
<p>https://www.siemens.com/global/en/home/markets/mining-industry/digitalization.html</p>	<p>Siemens</p>	<p>Optimizing conveyor belt systems: simulation and digital twin. With decreasing erection phases, there is no time to waste in the construction and design of open-pit mines – particularly when it comes to dimensioning belt conveyor systems. But to reveal the dynamic behaviour of the whole system and to explore and improve how the individual belt conveyor components work together, it needs more than the common calculation methods.</p> <p>That’s why we work with digital simulation tools to develop your new systems as well as to study the behaviour and interaction of the belt conveyor mechanics and drive solution in your existing systems: By means of simulation, it is possible to investigate changes, influences, and consequences in the system performance during modernization. We use the simulation results internally for planning and commissioning the drive solutions or provide them to potential operators or system builders. Simulation simplifies the selection of the suitable drive solution and controller in order to optimize the operational and productivity ratios.</p>
<p>https://www.itnews.com.au/news/roy-hill-shows-interior-of-its-remote-ops-centre-484841</p>	<p>Roy Hill</p>	<p>Iron ore miner Roy Hill has provided the first detailed look at the interior layout and design considerations of its remote operations centre in Perth. The miner appears in two videos by one of its technology partners, Schneider Electric, whose stack was revealed late last year to be powering a significant portion of monitoring, control and optimisation of the miner’s value chain.</p> <p>“In reality it means rather than operating in silos such as port or rail, we operate across the business. “It’s so important in automation and where we start to use technology, because you’re less reliant on structures like hierarchy but more reliant on how you collaborate with each other to get the job done.</p> <p>“Machine learning, AI, VR, augmented reality - the ‘digital twin’ - is what enables our people to focus on more value-added work rather than repetitive work.”</p>
<p>https://www.mckinsey.com/featured-insights/asia-pacific/digital-australia-seizing-opportunity-from-the-fourth-industrial-revolution</p>	<p>McKinsey</p>	<p>By better applying sensor technology, advanced analytics and process automation, the value of digital to the mining sector is between AU \$40 billion and AU \$80 billion in EBIT improvement. Capturing this opportunity requires end-to-end integration for real-time performance monitoring, optimization, and control.</p>

Reference	Company	Description
https://www.riotinto.com/ourcommitment/smar-ter-technology-24275.aspx	Rio Tinto	<p>We have the largest fleet of driverless trucks in the industry. The trucks are in action at our Pilbara iron ore operations, remotely controlled from our state-of-the-art Operations Centre in Perth, 1,500km away. At the end of 2017, we announced a more than 50 per cent expansion of our autonomous fleet, to more than 130 trucks by 2019. In February 2018, our autonomous trucks surpassed hauling one billion tonnes of ore.</p> <p>We're establishing the world's first fully-autonomous heavy haul, long distance rail network. In 2017, the AutoHaul® project passed its first major test – running 100km without a driver on board – as we progress towards full commissioning in late 2018.</p> <p>We were the first mining company to achieve fully automated hole pattern drilling without human intervention. Our Autonomous Drill System enables a single operator from a remote location to operate up to four autonomous drill rigs simultaneously. This technology is much safer for the operator and has improved both precision and equipment utilisation. Our Iron Ore business currently operates seven fully autonomous rigs for drilling production blast holes.</p>
https://www.riotinto.com/australia/pilbara/mine-of-the-future-9603.aspx	Rio Tinto	<p>Our Operations Centre in Perth is a state-of-the-art facility that enables all our mines, ports and rail systems to be operated from a single location, greatly increasing opportunities for shared experience and overall system improvement. It incorporates visualisation and collaboration tools to provide real-time information across our demand chain, and will allow us to optimise our mining, maintenance and logistic activities across the Pilbara in a way never before possible.</p>
https://thewest.com.au/news/wa/bhp-opens-remote-operations-centre-ng-ya-353099	BHP	<p>Mining giant BHP Billiton says its new remote operations centre and trial of driverless trucks will boost productivity without sacrificing jobs. The centre in Perth provides a real-time view of the company's entire Pilbara iron ore operations, including plants, trains and ports located thousands of kilometres away.</p>
https://www.australianmining.com.au/news/bhp-launch-coal-remote-operations-centre/	BHP	<p>BHP has launched an integrated remote operations centre (IROC) in Brisbane for its coal business.</p> <p>The miner aims to replicate the success it had with its IROC in Perth, which controls operations right across the Pilbara, covering more than 1500 kilometres of rail, stockyards, and two separate port facilities. Working with its joint venture partners Mitsubishi and Mitsui, the miner plans to provide real time coverage of its seven BMA mines in the Bowen Basin and the Hay Point Coal Terminal near Mackay, as well as its two BMC coal mines in the Bowen, and the Mt Arthur coal mine in the Hunter Valley.</p>

Reference	Company	Description
		According to BHP, the IROC will be a new, state-of-the-art facility located in Brisbane that will deliver an advanced control room which will operate continually, 24 hours a day, seven days a week.
https://www.afr.com/business/mining/iron-ore/inside-fortescues-next-frontier-the-control-centre-20161028-gsd3bl	Fortescue	From the company's Integrated Operations Centre (IOC) on the third floor of its Perth office, a rail operator remotely sends instructions to a screen on the dashboard of the first train, the driver slows or stops and the second train is allowed to go ahead. Meanwhile, the port operator coordinates the logistics for the incoming ship now assured of receiving the right product and moving quickly on its way.
http://www.abc.net.au/news/2018-08-09/worlds-first-fully-autonomous-underground-mine-in-africa/10090932	Resolute Mining	The Australian gold miner building the world's first fully autonomous underground mine is set to begin production in Africa, and experts say miners on home soil are watching closely. The rollout of driverless trucks, loaders and drills at the \$US223 million Syama gold mine in Mali should be complete before the end of the year. Perth-based Resolute Mining said the only jobs likely to go in the shake-up were highly paid foreign workers being flown in at great cost, with the 1,500-strong workforce including about 80 overseas professionals.
https://www.northparkes.com/improvement/worlds-most-automated-underground-mine	Northparkes	Our driver-less loaders, controlled from the surface, load ore from the draw point and transport it to the underground primary crusher where it is crushed, conveyed and hoisted to the surface. CMOC Executive Chairman, Steele Li said complete automation positions Northparkes as an outright industry leader, not only in Australia but globally. "Northparkes is a benchmark for others in the industry. Since acquiring the operation, CMOC has given the automation project our full support and it is wonderful to see it come to fruition."
https://www.mining-technology.com/digital-disruption/blockchain/blockchain-path-transparent-mining-supply-chain/	De Beers	In January, diamond giant DeBeers announced a blockchain initiative that it hopes will underpin confidence in diamonds and the industry at large by ensuring all registered gems are conflict-free and natural, while also enhancing efficiency across the sector. According to a company spokesperson, The Diamond Blockchain Initiative will: "Create a highly secure, decentralised, tamper-proof and permanent digital record for every diamond registered on the platform, as an added layer of assurance not been previously possible."
https://www.mining-technology.com/digital-disruption/blockchain/blockchain-path-transparent-mining-supply-chain/	Barrick	For example, a partnership has been made between Citibank, Scotiabank and Société Générale with Barrick Gold Corp and INTL FCStone to use the " blockchain " technology for a pilot study to reduce transaction costs of gold.

Reference	Company	Description
transparent-mining-supply-chain/		
https://www.mining-technology.com/digital-disruption/blockchain/blockchain-path-transparent-mining-supply-chain/	BHP	<p>Furthermore, returning to the supply chain use case, BHP Billiton is starting to use blockchain to share information between vendors, contractors, geologists and shipping companies to track and monitor movements of wellbore rock and fluid samples to secure real-time data and increase efficiency, as well as provide proof of provenance.</p>
https://www.highways.today/2018/03/12/komatsu-autonomous-haulage-plans-accelerate-mining-automation/	Komatsu/ Codelco/ Rio Tinto	<p>Komatsu is celebrating the tenth anniversary of the commercial deployment of their Autonomous Haulage System. More than 100 Autonomous Haulage System trucks now operate in Australia, North and South America. Based on the 10-year proven record of safety, productivity, environmental resistance and system flexibility in an array of mining environments, Komatsu now plans to accelerate the pace of Autonomous Haulage System deployment.</p> <p>In 2005, Komatsu began the Autonomous Haulage System trial at Codelco’s copper mine in Chile and succeeded in achieving the world’s first commercial deployment with Codelco in January 2008. A second successful deployment followed in late 2008 at Rio Tinto’s iron ore mine in Australia and Rio Tinto currently operates Komatsu Autonomous Haulage System trucks in four mines in the Pilbara region of Western Australia.</p>