IoT, Digital Twins and AI in Mining

IoT, Digital Twins and AI are creating significant efficiencies leading to major cost reductions in the Mining Sector.

Introduction/ Background

Mining as an industry drives the Australian economy. Iron ore and Coal are the #1 and #2 exports for Australia[1]. Yet the mining industry in general now faces a number of key challenges. The first is highly variable ore prices. With the drop of a few $ per ton in ore price a mine can become completely uneconomical. Mines need to take advantage of the higher ore prices now as an opportunity to invest and reduce operational costs through process optimisation and the implementation of predictive maintenance before the inevitable price drop. That way they will be in a better position to ensure they remain economical and avoid becoming a high profile casualty like we've seen in the past. In addition there are uncertainties regarding the Chinese governments strategy for sourcing steel and raw materials (Iron Ore and Coal) which could heavily impact Australian Mining. Australia is not their only supplier and variable relations between the two countries could inhibit trade in the future. Finally there is the potential for mergers and acquisitions to drive costs down in the mining industry as well. Those organisation that remain profitable due to lower operational costs are in a better position to be the acquirer as opposed to the acquired.

As a consequence mining companies need to consider all ways to drive their cost structure down in order to compete. These days the main tools for this are the IoT (Internet of Things), Big Data and the Digital Twins and AI that it enables which in turn provides for improved process optimisation and reduced downtime through predictive maintenance.

What is the Internet of Things (IoT)

This is the connection of the physical world to the virtual world through sensors, actuators and other forms of technology. Originally referred to as M2M (Machine to Machine) integration IoT is the modern term for the technology that connects your mine to its modern control systems.

But what is a Digital Twin?

A Digital Twin is a virtual representation of the physical world digitally. Unlike the old Programable Logic Controllers (PLCs), Distributed Control Systems (DCS) and Mining Execution Systems (MES), Digital Twins make use of modern User Interfaces (UI) and advanced visualisations to assist the operator in understanding what is going on in the mine. The data for Digital Twins comes from Internet of Things (IoT) based connectivity throughout your mining operation. Sensors collect data about real-time status, working conditions or position within a physical system. These sensors are connected to cloud-based systems often through technologies such as Edge Computing[2]. The cloud receives and processes all the data the sensors monitor with the input being analysed against business and contextual data. Opportunities for improvement are identified in the virtual world and then applied to the physical world.

1 *DFAT. (2018). Australia's Trade Statistics at a Glance Australian Governement - Department of Foreign Affairs and Trade Retrieved from https://dfat.gov.au/trade/resources/trade-at-a-glance/Pages/top-goods-services.aspx*

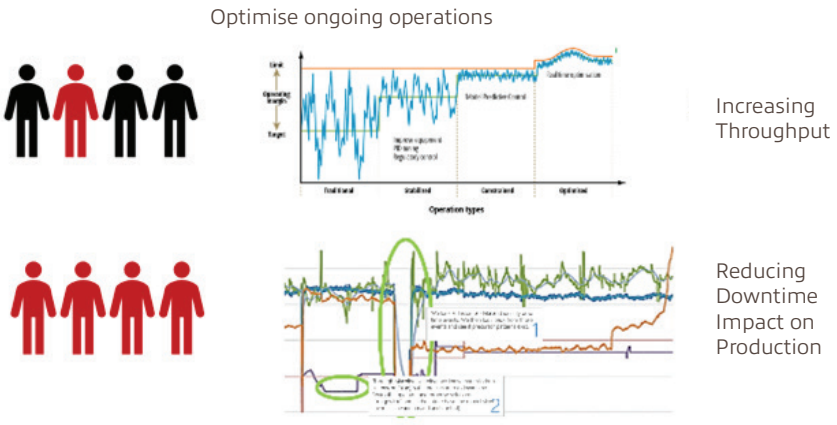
2 *https://en.wikipedia.org/wiki/Edge_computing*

And what is Artificial Intelligence?

AI is an evolution in the operation of a mine. The old PLCs, DCS and MES were designed to operate the mine to predefined setpoints determined by the operators. Through design but more so through experience the plant operators learnt the best setpoints for the operation of the mine to optimise efficiency and to minimise maintenance. The challenges with this model of operation are that operators can't respond that well to unforeseen conditions, not all operators are created equal in terms of process knowledge or capability and with the increased amount of complex data being presented to the plant operators, they often have trouble consuming that data to make the right decisions. Research has shown that when presented with large amounts of data, human beings often use heuristics[3] (mental short cuts) to make decisions. When presented with making the best decision versus making the easiest one, they often take the easiest one[4]. That in combination with 24-hour operation and taxing physical conditions, often means that the operator don't always make the best decisions for your mining operations or that the decisions they were making were largely reactive in nature.

Artificial Intelligence (or Machine Learning which is the type of AI most often used in Mining) makes use of the large volumes of data present in the mining environment to look for patterns in the data, thereby allowing the AI to forecast future events. In this way the AI is proactively defining the setpoints for the PLCs and DCS to improve and optimise operations and increase throughput. The AI can also proactively identify equipment failures, thereby minimising down time. In this way the use of AI improves costs. Your processes will still likely be supervised by humans. But by augmenting your operations team's decision making, AI make every operator your best operator.

- Your best operators often get very good at tuning machines so that they have less down time events, produce quality products and have high throughput. Their experience turns into artful instinct which is applied to everyday activities.
- Emerging data technologies such as machine learning (ML) and AI can use data to acquire that same knowledge. Proven scientific knowledge that can make every operator your best operator.



It is also important to understand that Artificial Intelligence is broadly split into three categories which includes ***Unsupervised Learning*** which looks for patterns in data, ***Supervised Learning*** where the engineer/ data scientist trains the AI to understand and optimise it's environment, and ***Reinforcement Learning*** where the AI trains itself on its environment. Broadly speaking *Supervised Learning* has found the biggest application in Mining but *Reinforcement Learning* is now finding increasing application because Data Scientists have found that AIs that teach themselves can outperform AIs that are trained by the engineers/ data scientist because they are better at learning their environment.

3 *https://en.wikipedia.org/wiki/Heuristic*

4 *https://www.jstor.org/stable/249534?seq=1#page_scan_tab_contents*

But why Now for IoT/ AI and Digital Twin Technology?

Process control, the cloud and Artificial Intelligence has been around for a while but under other names such as M2M. So why is it that people are talking so much about Digital Twins and Artificial Intelligence now? In short, because the capabilities of Digital Twins Technology and Artificial Intelligence have improved dramatically over the last few years. These advances include but are not limited to:

- Improved sensors and telemetry at ever reducing costs make the Internet of Things (IoT) and the data that IoT collects every more affordable and practical
- Massive parallel compute capabilities which allow organisations to manage large data lakes and apply AI across them very economically
- Improved mathematical, Machine Learning and AI techniques which means the AI is much better at prediction and prescription
- Newer AI techniques such as reinforcement learning (AI's which teach themselves) which is starting to find increasing application in the mining sector
- Edge technologies which allow mining organisations to utilise the benefits of the cloud whilst maintaining the availability which is critical for a mining operation

What does a typical Digital Twin/ AI Architecture look like?

The diagram below demonstrates a typical Digital Twins/ IoT/ AI (ML) architecture using Microsoft technologies. In terms of architecture, the way the data flows and the technical architecture is a function of its use and can follow three paths: Cold Path, Warm Path and Hot Path. The terminology references how quickly the data is transmitted and acted up.

In the Cold Path, data is sent non real-time to a data lake to allow analytics, reporting and modelling of mining operations along with training the AI (ML) models. Used to improve operations this structure is not used to run the mine per see but is used to afford Mining operations with a detailed historical view. Power BI is used to provide the operations teams insight into how the mine operations have been performing.

The next path is Warm Path. This is where the data is being used by plant operations staff to actively monitor and optimise currently ongoing plan operations. The data is presented in some form of operational dashboard and it is the plant operations staff which takes decisions on that data.

The next and final architectural path is referred to as the Hot path. This is where the data is used from plant operations in real-time by an AI/ ML system which takes real-time action (under operator supervision) to improve plant operations and to enact predictive maintenance routines. The AI (ML) may be configured to be predictive, prescriptive or full automated in nature. In late sections in this report, we talk about how organisations move through the IoT/ Digital Twins/ AI maturity curve and how they might deploy the technologies in this diagram.

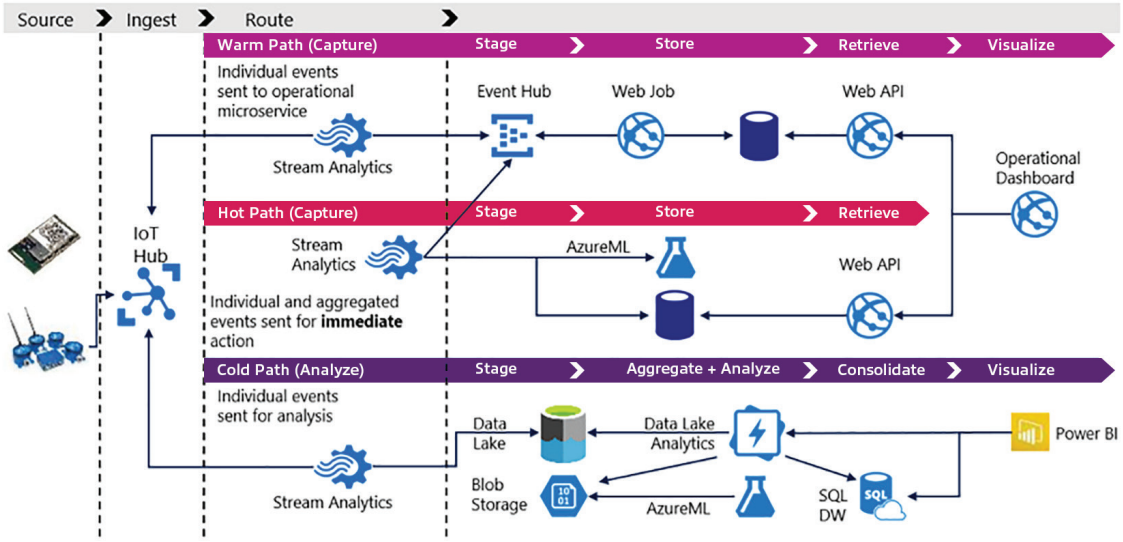


Figure 2: A Typical IoT/ Digital Twin/ AI Architecture

Examples of Digital Twins and AI in Use in Mining

Newcrest Mining is a typical example of how a mining operation can save millions of dollars through IoT, Digital Twins and Artificial Intelligence (AI). Newcrest was challenges with millions of dollars in costs from unnecessary downtime in certain parts of it's process. Digital Twins technology in combination with AI was used to show the operators how to more effectively run certain pieces of equipment to reduce downtime and unnecessary maintenance activities.

Figure 2: Crusher Operations at Newcrest Mining

5 *https://www.ignia.com.au/wp-content/uploads/2018/03/Case-Study-Newcrest-final-v1.pdf*

The IoT/ AI Maturity Curve

Most mining organisations go through a standard evolution in their IoT/ AI journey. Roughly speaking these steps are:

- First they are reactive: Simply looking at the current state of the mine and responding to it.
- Then they begin to collect historical data and look for trends which allows them to analyse what has happened and why, to make operational changes.
- That data collection begins to approach real-time which means their tools allow them to consider what is currently happening and be more responsive in their decision making.
- Then they begin to apply Artificial Intelligence/ Machine Learning to the data which allows them to be predictive in their analysis and more effective in their maintenance and operations.
- This then evolves to the solution being prescriptive in nature allowing recommendations as to how to run the mine and when to do maintenance, being made by the AI.
- Once operations feels comfortable they allow the AI to be prescriptive ,making the decisions directly under operations oversight. For some organisation and processes, this may evolve to fully autonomous solution.

Organisations face a choice in their IoT/ AI Digital Twin Journey in that they can decide to go broad and shallow at first focusing on bringing their entire operations up on the first step or two of the maturity curve together. Alternatively they may decide to focus on one part of the business bringing it quickly to the top of the maturity curve. It all depends on where the greatest business benefit is perceived to be.

Figure 3: The Mining IoT/ AI Maturity Curve

The Challenges with IoT, Digital Twins and AI in Mining

There are a number of challenges that Mining Operations and Engineering need to keep in mind when deploying their own Digital Twin and AI solutions:

- **Recognise that integration is always a challenge.** According to Gartner "through 2023, 75% of digital twins of OEM IoT-connected products will involve at least 5 different kinds of integration endpoints" W Roy Schulte, Benoit Lheureux and Alfona Velosa 4 Sept 2018
- **Picking the right technology platform.**
  - There are hundreds of commercially available platforms in this space. Future proofing may be a key issue as heavy market consolidation is expected.
  - Many DCS and MES providers will provide solutions which they present as offering Digital Twins and Artificial Intelligence. The challenge here is that those solutions usually don't work well in heterogenous environments where you may have a number of industrial technology vendors present. Also these vendors don't or can't invest as much in UI and AI development as the larger specialist software provider like Microsoft can. That said if you go after a specialty software provider in AI and UI then you will then need to integrate these tools back to your MES or DCS.
- **Develop a strong Business Case.** Understanding where the greatest business benefits are. It is important to understand and quantify the opportunity from installing Digital Twin/ AI technology
- **Understanding that AI requires time to train and optimise.** Most AI tools initially don't produce high degrees of accuracy in terms of modelling initially. But as more operational data is provided, the AI is continually optimised and will quickly outperform human operators in terms of control tasks.

How to Design and Deploy a Digital Twin/ AI Solution in Mining

The typical process for most mining operations in deploying a Digital Twin/ AI platform is to:

1) **Ideate** – Identify and quantify all the biggest opportunity within the mines and/or across your multiple mines. Define your preferred architectural strategy up front
2) **Define your Strategy (Go Broad or Go Deep)** – Understand whether it is better to bring up all your operations up the maturity curve at the same/ similar pace or whether it is better to focus on specific part of your operations
3) **Iterate** – Deploy your solution in small incremental chucks to minimise risk but to also drive benefits early. These benefits can support future projects in a self-funding program of works
4) **Support** - the overall process with project manager tools, structure, and systems to maximise success.

Conclusion

To reduce their costs structurally, mining companies need to look at technologies which can shift the dial in terms of operational cost reduction, process optimisation and predictive maintenance. IoT, Digital Twins and AI technologies have proven success in the Australian Mining Sector and are being adopted increasingly with close to half the industrial organisations in Australia taking on some form of technology initiatives around IoT, Digital Twins and AI[6]. Mining companies that are not currently deploying these technologies need to consider these technologies seriously otherwise they risk becoming another high profile casualty of fluctuating ore prices or changing Chinese sourcing strategies.

Why use Insight as your Partner?

Insight is a Fortune 500 global company that have operations across many countries in APAC and Europe with deep capability locally in Australia. Insight has proven ability deploying digital twins, data lakes and Artificial Intelligence/ Machine Learning at a number of different mining sites in Australia. We have proven experience stitching together large complex operations across multiple sites and we are experts in using Reinforcement Learning which is the most advanced form of Artificial Intelligence used in Mining scenarios.

To learn more, contact us today.

6 Gartner IoT Manufacturing Survey: conducted in May 2017 with 202 business and stakeholders from manufacturing enterprises in six leading industry nations in Europe, the US and Asia Pacific. The percentage mentioned refers to the survey question "Which of the following statements best describes your organisations adoption of IoT initiatives".