Surveying the Future

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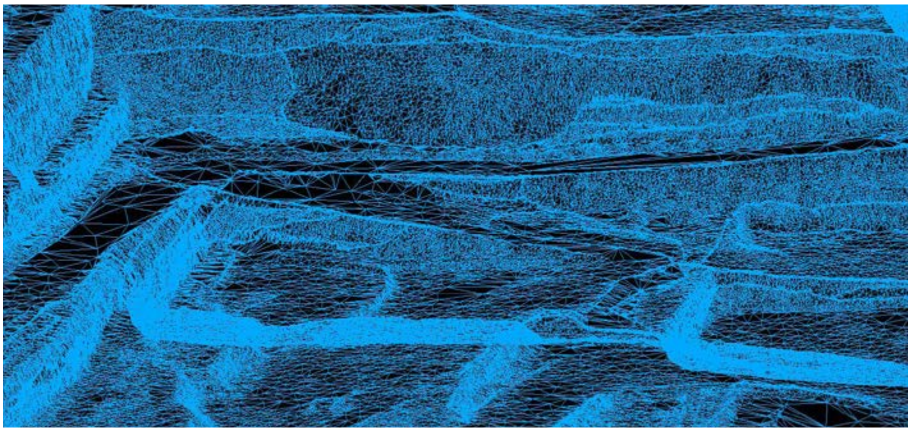
In the past 20 years the application of engineering knowledge and techniques, technology and data analysis in the mining industry has come an astoundingly long way. It is now common for a mining operation to be described as being analogous to a large, outdoor production facility - a rock factory. This analogy can be applied simply as a way of describing the fundamental 'value add' processing of some material in such a way as any factory can be described. In mining this is the beneficiation and extraction from the earth of an ore that can be refined, smelted or shipped. That sounds like a rock factory.

However, it is when the rock factory analogy is applied literally and practically to the planning, operation, management and evaluation of a mine that the similarities are truly demonstrated. It is then proven not only to be accurate, but to also be a technically rigorous way to run a mining operation.

The goals of delivering long term business outcomes and a high level of confidence in large capital and time investments, safety, quality and efficiency, and minimising impact on the environment can then be realised. Anyone who has experience in production engineering in a more traditional factory environment will be well aware of the supreme importance of measuring, recording, reporting, comparing and acting upon data. The success and economic viability of the business supported by the factory is a delicate balance. It can live or die based on the accurate execution of the various processes within that factory - some of which can be as simple as repetitively punching a single hole in a metal panel in the correct place. If the hole is in the wrong place, or is not punched, then the product is defective, and



the process has failed. To assure the outcome, measurement is required. Did the hole get punched? Is it in the right place? Is it the right size? Is there only one hole? Even a simple process such as this example will be measured and tracked against impact on downstream processes to a level of detail such as to give the operators of that factory confidence that there will be no defective product outcomes as a result of one faulty execution.

However, the mining industry presents a number of unique challenges in applying these concepts. This is a factory which is not only processing rock, it is also made of rock, and that rock is all of variable structure, quality, value, hardness, density, stability, chemistry, and so on. What's more, most of these characteristics are only represented to engineers operating the mine via a statistical 3D model made up from relatively sparse drilling samples collected prior to mining. Finally, the whole factory operates either outside, in the weather, or underground, in the dark. As with most production processes, the plant and processing tools (such as crushers and drills) will only work optimally with a certain quality or type of feedstock. Mining engineers are continually challenged to blend materials in order to meet quality targets for grade, hardness, chemistry etc. So a huge number of variables affect a mining operation, and many of them are only understood well enough prior to commencing mining to merely indicate the feasibility of a mine and a long term mine plan.

The techniques and models for proving the feasibility of an orebody are quite well established, and 3D resource modelling using computers has evolved to an advanced state in the past 40 years. This capability alone, however, is similar to engineers at a car manufacturing plant saying that they are quite certain that they have found all the necessary components to make a car. Actually then building it at an economically viable cost is another, completely different challenge - this is the same for the rock factory. Throughout history, there have been plenty of mining companies with great resources which have failed to make any money.

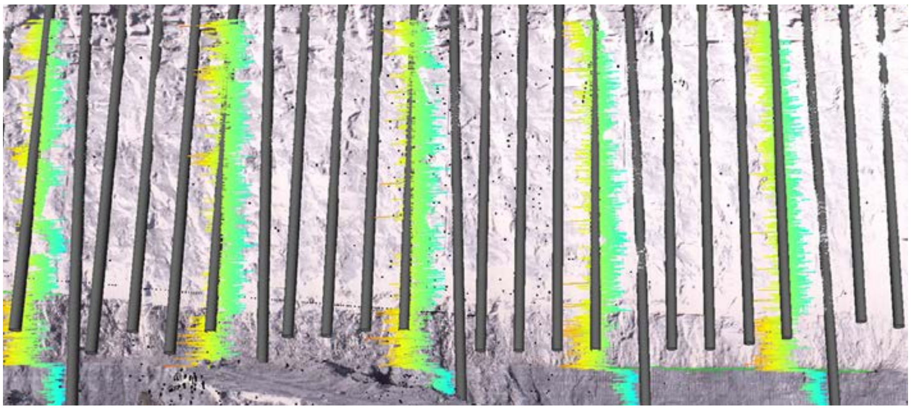
Measurement of each stage of the mining process is key to the successful delivery of a mine plan in the medium or long term. This measurement should be approached in the same way as any process control problem. The range of acceptable variance or error in each process should be understood. The processes or machine capabilities must be understood. The various measurement techniques employed to measure performance of these processes and machines must be designed to provide accurate, reliable, timely and unambiguous data to inform decision making. Only then will mine operators be able to take action during the process, before significant variance is experienced and it is too late. In a quality management sense, this is the classic 'plan - do - check - act' cycle. Knowing how to 'act' (or react) in response to changes and variability in an operation or process requires validated data collected at the 'check' stage. The collection of this data is now possible at an impressive scale, and across almost all sections of the mining value chain.

The very nature of the products and environment involved in mining means that a large proportion of the information being measured and analysed is spatial information. The core business process in mining is the removal of overburden and extraction of ore in an economical manner. Very large volumes of material are moved by trucks, shovels, dozers and draglines, all of which require mammoth capital investment to obtain and huge operating costs to maintain. The processing techniques used in mining are dramatic and irreversible. Explosive blasting and downstream comminution of material is a one-way process, and is applied to large volumes of material at a time. Even minor variances from the target outcomes for any factor involved in these processes can have a dramatic impact on costs and performance. As a consequence, detailed measurement and analysis of a large number of parameters is now recognised as a key success factor for the operation and crucial to delivery of a quality, successful mine.

Communications, networking, database and sensor technology have evolved in the past 20 years or so to a point where it is now quite possible to measure, record, track, analyse and make improved decisions based on operational data from within a large number of mining processes. At the most fundamental level, measurement of the 3D surface of a mining operation can now be conducted very quickly and in great detail using 3D laser scanners. These instruments allow miners to reconcile material movement and surface positions in 3D against plans and designs for pit shapes, stopes or cavities, stockpile volumes, roads and more. Surveyors have become orders of magnitude more productive and have proportionally increased the value they deliver to a mining operation through survey measurement. It is not uncommon for a mine or stockpile surface to now be updated on a daily basis, rather than monthly using conventional survey methods. This higher frequency of measurement will, quite simply, reduce the variance shown in the mining performance from the plan - by enabling better decisions to be made earlier. These laser scanning instruments are now commonly vehicle mounted or automated and can produce millions of 3D data points in a matter of minutes.

Innovation in this area is driving the combination and comparison of spatial and other data to enable a new standard in quality management through the various processes making up the mining value chain. There is a thirst for more data, and more combinations of data, and the technology to enable its exploitation is being applied in the mining industry in new ways thanks to increased connectivity and data analysis and visualisation capabilities. A mining operation is always changing, so the measurement needs to be repeated frequently and continually during the life of the mine. Astounding quantities of data are being measured by an increasing number of data sources.

Data sources can be broadly described as either direct measurement sources, or indirect (or ancillary) measurement sources. Direct measurement sources are those deliberate, dedicated measurement systems applied to particular parameters within a mine. Conventional geodetic survey and GPS, 3D laser scanning, photography and photogrammetry, airborne mapping, radar, spectrography, seismic, gravity, electromagnetic, chemical assay and many more techniques are applied at various stages of mining. Ancillary, or indirect measurement sources can be described as the primary systems, processes and operations within a mine that collect data which may be equally as relevant to the success of a mining operation, but where maybe the data is collected as a by-product of some other primary purpose for the system.



Examples include machine telemetry data, fleet movement and human resource data, PLC or SCADA data, energy use and plant performance data, as well as environmental monitoring data and more.

Secondary data sources can also be included; here the data is created or collected for one purpose but is useful for other purposes. A virtually limitless number of combinations and comparisons can conceivably be made between data types which can deliver some extremely valuable information. One simple example which is well known and widely used these days is to compare the hydraulic pulldown pressure recorded on blasthole drills against geological models. While the obvious primary purpose for measuring the hydraulic pulldown pressure is to monitor and diagnose the hydraulic system and drill performance, it is known that there are very reliable changes in hydraulic pressure as the drill bit passes from one geological unit to another (generally due to the hardness of the material).

So this hydraulic pressure sensing can be used to correlate, confirm and validate the geological setting for a particular blasthole, and for an entire pattern. This enables great increases in accuracy of the placement of charge in a blast, resulting in lower ore dilution, better fragmentation and overall lower cost and better recovery. The drill control systems are sensing and recording that hydraulic pressure anyway, and so the only enhancement required to achieve this greater accuracy is to combine that data with the existing knowledge about the geology and blast pattern design. This is not high tech - it is just a clever way to use the data that is available.

There is also a natural tendency towards speed and automation for any measurement techniques used in mining, and the developers and vendors of the technical systems deployed in mines are driven to create solutions which can deliver automated, accurate data with as little latency as possible. The objective in this drive is to enable confidence in decision making and lower process variance without adding excessive costs. This means improved reaction to variances in a process and contributes directly to the productivity of a mine. Therefore, it is also common for mining equipment to be equipped with GPS for both tool positioning and location tracking. The blasthole drill in the earlier example can then automatically correlate the GPS position with hydraulic pulldown pressure. If it is then connected to a site network, a database can be automatically populated with accurate spatial measurement detailing the geology of the ground being prepared. All of this additional detail, without any additional effort or time during the process, can be made available to blasting engineers to refine every pattern design and blast executed. An immediate increase in quality and productivity is realised.

It is increasingly common for sites, especially in the open cut environment, to be connected and well covered with wifi or 3G/4G networks. While it can still be quite expensive, this connectivity is a huge enabler not only for the collection of data from various primary and secondary data sources, but also for the transfer, dissemination and communication of the results of whatever analysis, comparison or reporting is created from the data. When this is coupled with the increasing technical capability for mobile computing on tablets, phones and other devices, another advance becomes possible. Miners are able to conduct various types of work on the data, actually during some of the processes that may be either collecting or using the data, so people can now be said to be working 'in the data'. Workflows, tools and systems are immersed in data now - it is everywhere.

If you allow the Google app to access all the information on your smartphone, you will see this in action. Instantly, all your relevant data is collected, sorted, analysed and presented to you in the context of your normal day - you have been placed into your own data! Another new concept kicked around is that of the 'Internet of Things' - this is the idea that all devices are smart and connectivity is ubiquitous, allowing everything to effectively talk to everything else in a contextually relevant way. This is exactly where mining is heading.

Automated data sharing between systems and equipment is now possible, and can deliver productivity outcomes as a result of the accuracy, speed and precision that automation creates. At this juncture, the concept of data having a source or origin, which is then followed by some process or other, and an end point - usually a report or database entry - starts to become blurred. The path of data use is not simple, and multiple, different uses may be enabled for a certain data type.

At the core of a mine's operational technical data is the block model. This is a mathematical, statistical model splitting the resource into 3D geometrical and attributed shapes of various sizes so as to accurately represent the geology, geochemistry, structure, shape, location and size of the resource. An accurate block model makes a successful mine, and a massive amount of data and effort goes into creating, maintaining and updating the block models for a mine. Block models can comprise millions of blocks, with each block containing several hundred attributes. The block model will initially be created by exploration and project development geologists. Drilling, assays and downhole geochemistry data will all contribute to the creation of a block model, which may prove a resource of economic viability which will eventually become a mine.

However, it is during the mine's operation that the block model is able to deliver its greatest value, and also benefits significantly from the addition and combination of a vastly greater amount of information as it become available. To refer back to the rock factory analogy - a mine is a factory that starts operating without 100% certainty of what material will be used in the production processes. No other factory operates like this! So a huge amount of effort is now applied to increasing confidence and understanding during the mining process, and optimising the design and production processes to suit. In this way, mining is an iterative, cyclical and continuous improvement process. An optimised plan is made, then executed. As that mining execution progresses, data is measured from many sources and more is learned about the resource or the mine design. At regular points, a new plan is created, and this is again optimised to take consideration of the new information that has been added to the plan - and so on.

Short term plans are revised in timeframes as short as weeks. Medium and long term plans may cycle on 6 month to 5 year timeframes, and anywhere in between. The consistent factor is that while the plan is being executed, more and more information is being gathered that can contribute to the improvement of the plan. A mine is a business; if a better plan to deliver greater business outcomes can be shown to have value, then it will be adopted. Given the huge investment and scale of the resources being considered in the mining industry, even a very small fraction of a percentage increase in productivity can be worth millions of dollars. So a lot of money is invested in gathering, recording, understanding, analysing and reporting more and more data from virtually any data source that can be thought of.

This also drives innovation in technology and technique. Mining presents some of the most demanding conditions for measurement systems anywhere in the world. Mining is a dangerous business as well, and any measurement task must always be a second priority after the safety of people. Underground mines are hot, wet and noisy with limited data connectivity, no light, no GPS, limited line of sight for measurement and tight spaces that see fragile measurement equipment regularly destroyed by vehicle interaction. At the other end of the spectrum are the ultra large open cut mines in places like Northern Chile, where a pit may be 4 km across; it is hot and dusty, access is limited and the ground condition is hazardous. In both cases, conventional measurement does not easily satisfy the needs of miners for data collection. If a mining operation requires some parameter measured to improve the understanding of a mine plan, it needs to not impact or risk the existing plan, and it must deliver value in a timeframe which makes it relevant. It is pointless to learn of the errors in the positioning accuracy of a blasthole drill after the pattern has been blasted - that is far too late!

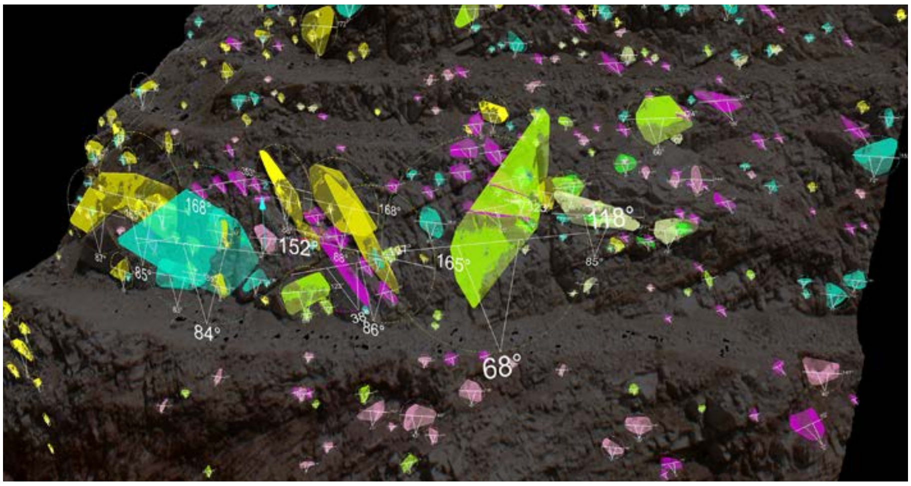
Mining specific technologies have been developed which have made a vast difference to the performance of mines globally. Consider 3D Laser Scanning - while less than 20 years old as a capability in any industry, it was applied in mining, by Maptek, as early as 1997. Mining has arguably driven the development of the state of the art for this equipment since then. Laser scanners used in mining are now significantly more durable, safer and easier to use than those in other industries where the technology is used. They also measure longer ranges with equal or better precision, and are combined with colour image sensors, GPS, survey capability and specific software for managing and processing the vast amounts of data collected by these machines faster and more efficiently than any other industry I am aware of.

To illustrate the scale of the data collected from this source alone, on an average day one surveyor using a 3D laser scanner would probably generate about 20 scans (it is possible to do much more, but unrealistic in day to day operations on a mine given the various other tasks a surveyor is responsible for).

Each of those 20 scans will measure up to 2 km from the scanner, and could contain around 5 million 3D measurement points which are also coded with the intensity of laser reflected from each point - the reflectivity of the surface. The metadata about the setup location, operator, time and temperature are also recorded, as is a panoramic, 70 megapixel colour image which is automatically mapped to the 3D surface that the scanner has created. Each scan takes around 15 minutes to conduct. So in less than 3 hours, one person has created 100 million attributed 3D points, 1.4 billion RGB coloured pixels and all the necessary metadata to make this information immediately useful.

The software collecting the scans knows where each scan location is in the mine, because it has wirelessly connected to the GPS antenna, as well as how the scan datasets all fit together. Seconds after connecting the scanner to this software, the 20 new scans and photos are all geolocated and ready for use in analysis of the mine surfaces. Where a site has adequate connectivity, this can happen in the pit, straight after data collection. In 15 minutes, surveyors can now create more data than they would have completed in a lifetime using the technology of 20 years ago.

Once this data is on the network, it can be shared among any number of users. Stockpile reconciliation reports can be created based on volumes measured. Pit wall condition reports can be made based on wall profile measurements. Geotechnical risk can be analysed based on the very high detail in the scan data. Geological mapping can be done based on the exposed rock face and compared with the geology model or other data such as seismic or electromagnetic. Production progress can be calculated by measuring progressive material movement in the working areas. It is possible for all these tasks to be completed and the results provided to the business within the same day as the data was measured. It is now possible



for this level of detail and precision in measurement to be conducted at frequencies as often as daily in operating mines, giving a very high level of confidence about the activity, productivity and material movement in the operations.

Adaptation of these types of measurement advances now see laser scanners mounted on vehicles or fixed infrastructure, and protruded into inaccessible stopes and other voids to provide measurement outcomes that have always been very difficult and in some cases dangerous to achieve. Wireless control and automated operation of the scanners and software provides remote data acquisition and consistent, reliable analysis and reporting, allowing an even wider range of tasks - such as stability monitoring and stock reconciliation, to be completed. However, it is in innovation through integration where some great advances are now being made, and where the competitive advantages of the truly large, complex mining operations have been built. Particularly in the case where multiple mining sites are contributing to a single mill feed, ROM or ore stock, the measurement, tracking and understanding of the geology and operations at each of those sites and how they combine to create a production outcome is critical. A number of mining companies are now operating these large, complex operations, and the level of automation, measurement and connectivity they employ is always in direct proportion to the success and profitability of those operations.

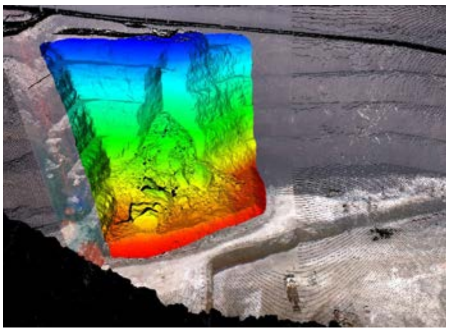
Consider again our surveyor with the 3D laser scanner surveying the open pit mine. If there is wifi or 3G/4G coverage it is now possible for the same software operating the scanner to understand which part of the mine is being measured and go to the site network server to find the relevant design surfaces for that particular area. Once that is found, the new measurement information is compared with the design and automatically analysed according to construction tolerances; progress schedules for the delivery of the plan, and cut / fill volumes are then calculated for each region of significant departure from design. Cross-section views and annotations can be added by the surveyor with one click, and a condition report on the progress and accuracy of delivery of the design can be produced. This report is published to the cloud where the surveyor's colleagues can see, interrogate and understand the data. It is also compiled as a report in a corporate template for distribution to production crews, engineers and managers.

Delivering these results to the business takes less than an extra 10 minutes - the surveyor has not yet left the scan location. Previously, there would be a lead time of at least a day to produce all this data, then prepare, publish and distribute reports and datasets.

During that day, the surveyor would not be available to work on anything else - depriving the mine of valuable measurement capability. The real value in the speed and richness of delivery of this data is, however, not in the dramatic increase in productivity of the surveyor.

Rather, it is in the ability to deliver valuable data in near real time to the equipment, locations or people where it is needed. Now the data is all available, and it can be connected in smart ways to bring huge benefit to the mining operation. Allowing machines and plant equipment to communicate and transfer data in a meaningful, yet ad-hoc way between themselves is now starting to become possible, enabling Machine to Machine (M2M) applications in mining to squeeze even more value out of more data.

The most immediate impact of this is cost reduction. Consider a pit wall which is constructed according to a particular design. When it is complete, the shovels, excavators and dozers are all relocated to work on some other task. Following this relocation, surveyors would have, in the past, measured the pit wall, usually in some detail.

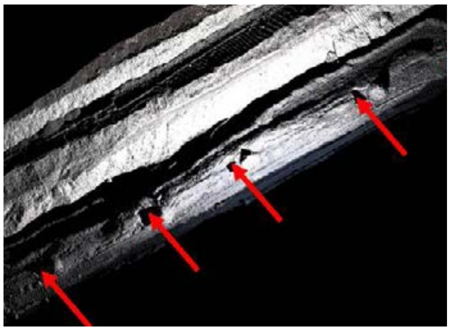


If there was any nonconformity (possibly a geotech hazard such as an overhang, or significant deviation from the design surface or batter angle) it was either a) too late, or b) time consuming and costly to return dozers and excavators to the location to rectify the error, which in turn causes delays in the short term mine plan, and additional operating costs.

It is now possible to measure, analyse and report on pit wall conformance in real time, and have the shovel operator, production shift crew supervisor and anyone else who is interested view conformance reports, volumes and sections within minutes of the surface being created. Errors can be rectified immediately. This type of integration leads to great leaps forward in precision and productivity.

Soon, we will see the lines between planning and design, and execution and construction blur, or even disappear. This will happen as the level of integration and online data analysis and communication increases so as to cause the mine design, planning and execution value chain to become a complex closed loop feedback system. Here the overall objectives of a long term plan are targeted by a self correcting, and self governing set of systems and equipment working in concert to achieve those goals. This is not too far in the future now.

It has been possible for some time for a bulldozer or grader to make a new map by pushing dirt around. GPS sensors on the blade are used to guide the operator for blade position, as well as work to measure the position of the blade, and record this as a reasonably accurate measurement of the new terrain which the dozer itself has just created.



Much the same as the hydraulic pulldown pressure in the blasthole rig being used to verify geological boundaries, there is now greater motivation and more viable capability to collect and use data sourcs in integrated and connected systems throughout the mining value chain.

We are now enabling integration between design and execution for processes such as drill and blast and explosive loading. Equipment such as blasthole drills and explosive loading trucks are becoming more connected via GPS and wifi, as well as becoming more able to sense and record information about themselves, their performance and their surroundings. Designing and executing a blast will soon be more like printing a document on the office printer than blowing something up. The exact shape of the bench will be known, the exact location and extent of each blasthole will be known, the quantity of each product to be used will be modelled and reconciled against stock, and the drilling, loading, initiation and timing of the blast will all be largely automated. Electronic initiation systems will be programmed directly from the design environment and there will be very little left to chance.

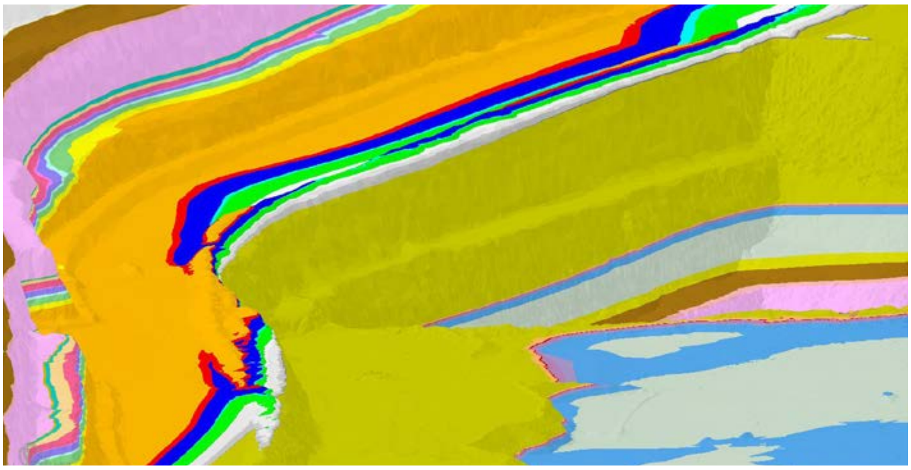
This is not such a stretch to consider. It is only possible because of the quantity of relevant data available and the ability to leverage and communicate that information between the drill and blast engineer and the mining production crews and equipment and even the consumable blasting products at the right points in the process and in the right context.

While systems like this may be referred to sometimes as ‘expert systems’, that is a falsehood - these systems are just as dumb as ever.

The great advances are in the types and quality of data being made available, and the ability to connect and automate the various factors within the system to the correct points in the data model.

Planning processes have for a long time used input data such as the minimum turning circles or rimpull curves for haul trucks as design parameters. The time will soon come when most types of equipment become aware not only of where they are in the mine and what they are doing (thanks to their own telemetry, load scales or strain gauges, engine and fleet management systems), but will also become geologically aware, or resource aware. All the data is available for this now - it is only the connectedness that needs to be enabled. A face shovel at a bench can know with good accuracy where (in mine grid coordinates) its shovel teeth are at any time. It can also communicate with, and have knowledge of the assigned destination for each of the haul trucks that arrive for loading. This is not a new capability, and it is augmented by collision avoidance, light vehicle and human interaction avoidance, load scales and many other advanced systems installed on these big shovels.

It is now also feasible that this shovel can know with very high precision where its design target surface is in comparison with the as-built surface it is working on. To make this shovel really spatially aware, it should know what the block model predicts is in the face ahead of it, as well as what head grade is being fed at the mill, stockpile volumes for the various ore types, rail transport capacity and timetables, and even customer order pipelines. If a shovel such as this was equipped with the right data, it should be able to selectively mine a face for both ore grade and production volume targets,



delivering optimised short term product flow in concert with a fleet management system delivering results around long to medium term plans (such as overall fleet availability, haul cycle times or crew fatigue management). This starts to look like a factory operating along principles of total quality management, just in time delivery and continual improvement. The techniques are the same as any other factory would use to achieve this, but the quantity of data involved in mining is significantly larger, and the environment is far more complex and less predictable.

Apart from the inherent economic and safety risks of mining, the chances of operating a mine badly increase dramatically when the geology is poorly understood, and the geological knowledge is not paid due attention during planning and execution. Mining equipment can become resource aware as described above, enabling a type of real time grade control by either selective digging, or selective routing of trucks to a number of sources to target a particular blending goal. The ability for detailed structural information to be made available in near real time can also contribute to a successful outcome.

Structural and geotechnical analysis can now be conducted on laser scanned working surfaces to provide up to date detail on joint planes, faults and any geotechnical hazards to machine operators.

At the same time, it may simply update the geological model that the machine is referring to. This leads to improved safety outcomes due to the reduced chance of wall collapses, and less risk of production delays. Similarly, repetitive sampling of the shape and position of a wall can identify geotechnical stability hazards as deformation and creep characteristics are analysed. Integrating this information with fleet management and dispatch systems can automate the predefined exclusion zones for vehicles when certain risk alarm levels have been reached.

By better understanding and monitoring the structural stability and performance of the mine walls, engineers can design with more confidence and precision. In an open cut environment this may mean the ability to design steeper batter angles while retaining geotechnical stability. Steeper batter angles can add significant value to a resource by reducing overburden removal and enabling access to a greater proportion of an orebody. In an underground environment, better understanding and precision in the measurement of surface and structural features may enable stope construction with higher precision and confidence - again possibly increasing resource recovery without compromising safety.

Structural joints mapped from laser scan data can be plotted onto rose diagrams, along with joint persistence and spacing. This data can be used by drill and blast engineers in blast designs to optimise the initiation direction for minimising in situ wall damage. Laser scan data can be modelled to optimise pattern spacing and burden to achieve the desired fragmentation, as well as to guide charge design for energy distribution and propagation.

Demonstrating the concept that most mining data will be used multiple times for different purposes, this high resolution laser scan data which carries so much information about geotechnical structures can be used to build an accurate geotechnical database. Analysis of this data over time is useful in defining structural boundaries between primary and secondary mineralisation, allowing geologists to accurately update and validate the geological model as the working face advances.

Remote Piloted Aircraft Systems (RPAS - also known as UAVs or drones) are now providing a fast and accurate way of adding more data to the picture by mapping and monitoring change across the mine landscape and its infrastructure. An RPAS equipped with a mapping payload can gather vast quantities of detailed data across a mine site and its surrounds.

These systems are quickly evolving to the point where they are are safe and reliable to operate, and easily deployed by end users. Dedicated software designs and manages the flight plan and autopilot programming to collect high resolution aerial photography of superior quality. The dynamic stabilised platform embedded in the drone payload allows precise aerial photography. With dynamic GPS control it is possible to achieve an accuracy of 20mm in both the horizontal and vertical axes. In a recent test on a site of about 400 hectares, 3000 air photos were taken over a 4 hour period. These were assembled photogrammetrically to create a digital terrain model with 3D measurements every 10 cm across the ground over the entire area. This exercise can be repeated as often as needed to update terrain models or detect changes in equipment, landform or vegetation. Any repetitive process is well suited to these mine mapping RPAS.

Merging the terrain data from mapping RPAS with the oblique data from the 3D laser scanner creates dense surface models that are photorealistic, accurate and provide a reliable platform for overall site management. These detailed models can be combined with any other mining data. It is certain that the development of RPAS measurement and data collection systems is still in its very early days.

This is an exciting area, and one that really demonstrates the big ongoing demand by the mining industry for more data, more often.

Within another few years, the technical systems landscape at most mines will be far more connected, efficient and integrated than it is today. Volumes of data, an order of magnitude above what we see today will cover every aspect of these operations. All technical systems, plant and equipment will have access to any of that data to help better meet target performance and contribute to successful delivery of the mine plan. Long term mine planning is unlikely to change significantly, other than the expected increase in productivity and accuracy, while short term planning will be able to evolve such that it will be done in a mostly automated fashion, and on a planning cycle that may be less than one hour.

This level of agility and flexibility is the goal of most businesses - react to changes in conditions, stay on target and understand the impacts of plan deviations quickly. It is certainly a good approach to total quality management in the rock factory. Exploitation of the vast amounts of technical, operational, resource and spatial information available, and the ability to quickly measure, record, analyse, understand and communicate all of the new data required to track each facet of an operation is the key enabler to operating successfully. Successful miners of the next 10 years will be set apart from those who fail to properly use, or ignore, the data they have access to. This game changing paradigm shift is a result of collaboration between innovators in measurement technology and their counterparts in the rock factory.

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