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Mining the data

An introduction by *Mining Journal*



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This is an exciting project; a Hitchhiker’s Guide to the new mining universe, with apologies to Douglas Adams.

The industry might have increasing problems with the dirt it’s mining – too deep, grades too low, metallurgically tricky – but many solutions can be found in the mountains of data now being produced. Rio Tinto is already talking in terabytes of data per minute being trafficked across its Pilbara mine network in Western Australia.

Too much data, too soon, for an industry still exploring the algorithms and expert systems that will shape truly powerful predictive analytics? Don’t panic!

While big data fatigue has no doubt already set in with a lot of mining industry executives, there can be no querying the profound changes promised by these high-powered analytical tools and systems for exploration, mining, processing, supply chain and enterprise planning and management.

Enterprise information management consulting partner with big business advisory firm Deloitte, Links Chithiray said operational intelligence was driving fundamental changes in the way information was exploited in mining. As connectivity to remote sites improved, a “landscape of reporting and analytic solutions is emerging that can enable greater transparency of operational performance in real time for operational staff, site management and executives of the organisation”.

“Mining is becoming an information technology industry,” said the head of National ICT Australia (NICTA), Hugh Durrant-Whyte, who has worked for Rio Tinto, extensively in mining research, and previously ran University of Sydney/ Rio’s Centre for Mine Automation Research. “It’s about acquisition, management and exploitation of information.”

Accenture’s North America mining boss Jose Suarez said digital technology was changing the game for 40 North American metals and mining companies surveyed this year when it came to improving operations, productivity and identifying growth opportunities. “I would say that as the major ERP transformations were completed in the last few years, the attention has been focused on digital ... [and specifically the] need to place more efforts on the integration



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“Big data analytics is clearly front-of-mind for many industry leaders, which makes this guide and its timing exciting”

of big data, with various new technologies that can improve productivity.”

And Anglo American group director, technical and sustainability, Tony O’Neill most recently described as “low-hanging fruit just within our grasp” the opportunities presented by big data and other key technologies. “For the first time in my 36-year career in mining, I feel we’re on the cusp of an explosion of game-changing technology,” he said.

A major industry survey completed by *Mining Journal* in the first half of 2014 put big data analytics at the top of a list of what mining companies (including 10 of the world’s top 20), contractors and engineering firms see as the game-changing technologies that will transform the industry in the next five to 10 years.

So the topic itself is clearly front-of-mind for many industry leaders, which makes this guide and its timing exciting.

No less a factor is the calibre of contributors to its content.

Thought-leaders from some of the top companies in the world working in this space have made incredibly valuable contributions to this guide, including Maptek’s Peter Johnson; Reflex’s Dave Lawie, Michelle Carey and James Cleverley; Hexagon Mining’s Haydn Roberts and Guilherme Bastos; Level 3 Communications and Telecom Liquid’s Teresa Cottam, Alison Marwick and David Eurin; and SAP’s Georg Gradl, Ruediger Schroedter, Daniel Stimson and Jennifer Scholze.

They are working closely with many significant mining and metals companies on the industry’s most advanced exploration, mining, infrastructure and enterprise big data projects, and they bring leading-edge insight here.

Richard Roberts
Editor-in-chief



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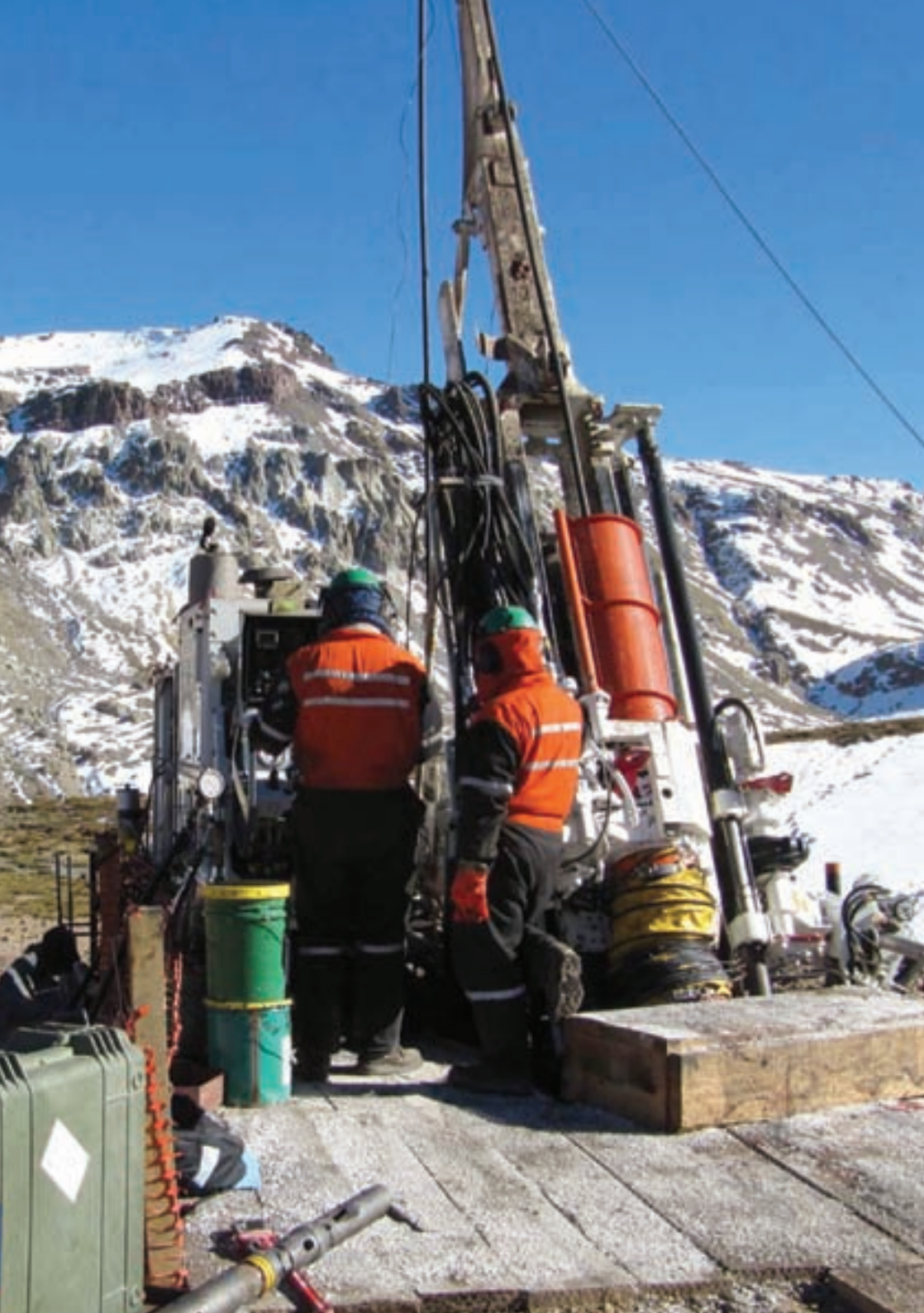
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The drill rig of the future

From borehole to boardroom

Reflex

Technology is driving rapid change in the way drilling data is collected, analysed and managed. And it is transforming the impact data has on decision making.

The concept of drills becoming mobile technology platforms is taking shape. Such 'mobile laboratories' will generate masses of data that must be validated at source, and analysed using advanced techniques both in the field and with the help of experts who can be located anywhere in the world, for near real-time decision making that can most cost-effectively direct the course of exploration programs.

While the drill rig of the future resembles a mobile surveying and sampling robot, operators today are already striving for greater accuracy, visibility and flexibility when collecting, accessing and analysing data. They must make informed decisions faster from any location and at any time without the time delays and inefficiencies that were typical in the past.

Resource, drilling and service companies are looking increasingly to technologies to reduce costs, enhance the efficiencies of their operations and remain competitive, and now for the first time in decades the drilling industry is witnessing fundamental operational changes that are gaining momentum.

REFLEX's HUB delivers a new, smarter way of operating for the drilling, exploration, production and mining services sectors. Three examples of this are discussed below, covering pXRF, survey data and mobile platforms.

Handheld X-ray Fluorescence (XRF) analysers have found widespread application across a range of industries, including mineral exploration. Software designed to control the XRF instrument decreases the likelihood of human error during data collection while aiding automated data management and delivery. This ensures data is transmitted directly from the field in a robust and streamlined manner using web-based services.

That is, geochemical data, including QA/QC data, are automatically transmitted from the digital instrumentation to a secure, central database.

QA/QC rules built into the data collection routine, combined with immediate feedback on any instrument values that are outside of accepted range on blanks, standards and duplicates, ensure data quality problems are rectified at the collection point rather than being discovered when it is too late.

Simplified workflows and access to instant geochemical analysis results reduce the cost and time associated with managing valuable and complex data sets.

"REFLEX's HUB delivers a new, smarter way of operating for the drilling, exploration, production and mining services sectors"

Exploring big data

10

REFLEX HUB
WORKFLOW

List of Drill Holes agreed between Client and Supervisor, automatically synchronised to the Driller's iPads.

Driller completes DDR, automatically sends to Supervisor's iPad.

Supervisor reviews DDR, automatically submits read-only copy to Client's iPad.

The Client approves the DDR and automatically submits it to REFLEX HUB.

REFLEX HUB automatically compiles and despatches Shift Report PDF's and throughput reports as appropriate.

PRODUCTIVITY GAIN

PREVIOUS
WORKFLOW

List of Holes agreed between Client and Supervisor, hardcopy provided to Drilling Supervisor.

Drives hard copy to rigs.

Provide hardcopy list to driller.

Driller hand writes shift information on hardcopy form.

Driller locates Supervisor and provides hardcopy report.

Supervisor reviews hardcopy and re-writes information on report.

Supervisor locates client to provide hard copy report.

Client emails approval to the Supervisor.

Supervisor despatches hard copies to Head Office.

Office staff clarify information they are unable to read.

Office staff manually compile and distribute reports to management.



REFLEX HUB delivers a new, smarter way of operating for the drilling, exploration, production and mining services sectors

Geologists no longer need to wait for weeks or months for off-site assay results to determine their next move. Decisions can be made without delay, based on facts, to better manage drilling programs and save costs.

Geologists view and approve survey records and then commit them for storage. The data can then be accessed through a web browser from any location world-wide.

The unique Reflex mobile paperless system makes collecting field operational, safety, drilling, maintenance and accreditation data easy and accurate using any iPad, Android or Windows Mobile device to digitally record and validate data as it is entered. Customised dashboards provide real time information and critical statistics for a single site or an entire business.

Supervisors, office staff and drilling managers have all reported significant productivity gains and other benefits after introducing REFLEX HUB, including:

- Time savings of more than 40% for drilling managers, and up to 80% for office personnel, in managing and processing drilling report data.
- Removal of obstacles to cut time between drilling activity and invoicing.
- Drilling managers had immediate visibility of key data across all operations, accessed via a web browser, in any location, enhance decision making.

Survey data is transferred from tool to a secure central database.

REFLEX HUB produces automated alerts, reports and dashboards for advanced analytics and easy and rapid decision making. It can act as an automated workflow engine, securely feeding verified data to existing systems, to enable some users to optionally maintain investments in legacy database systems as well as providing verified data for mining and GIS software packages.

Greenfields exploration

Advanced data management appears to have a major role to play in improving the industry's declining discovery rates.

Major new mineral resource discoveries – especially tier 1 deposits – are vital to maintaining the world's mineral resource inventory in the face of a continuing decline in average resource and mined grades of key mineral commodities. Such discoveries are becoming less common because many prospective, underexplored areas are obscured by deep, barren cover.

The world's demand for metals increased exponentially during the 20th century, for example, over the period 1910 to 2002 at an average of 3.3% per annum for copper (doubling about every 21 years) and 3.2% per annum for zinc (doubling approximately every 22 years), and is likely to continue to do so for the foreseeable future.

“Current Australian base and precious metal production is strongly concentrated in a relatively small number of maturing tier 1 deposits, most of which were discovered at least two decades ago”

Against this backdrop of exponentially increasing demand for metals are declining greenfield discovery rates of the host mineral deposits and declining grades of the deposits being mined. Australia's mature mining and exploration sector provides an acute representation of the emerging conundrum.

As highlighted by Guj and Schodde (2013), significant cost escalation over the past 10 years has seen a fourfold increase in exploration expenditure that has translated into a mere doubling of metres drilled. The focus of exploration and drilling shifted progressively from greenfields to brownfields activity. This, in

combination with increasing terrane maturity and deeper targets, has resulted in fewer and generally smaller discoveries at the expense of major greenfield discoveries critical to maintaining Australia's mineral inventory.

Current Australian base and precious metal production is strongly concentrated in a relatively small number of maturing tier 1 deposits, most of which were discovered at least two decades ago. Tier 1 deposits are large, long-life, and low-cost producers. They typically have a net present value (NPV) at the time of development of >AS\$1 billion, mine lives of >20 years, generate revenue of >AS\$300 million per annum, and are in the bottom 20% of the cost curve. Tier 1 deposits contribute disproportionately to global production. In the case of gold, for example, approximately 2% of deposits (those with >10 million ounces of contained gold) contribute approximately 50% of global production.

Progressively lower grade material has been mined from these deposits over time, such that over the past 30 or so years for gold and 20 years for copper,



average mined grades in Australia have approximately halved. This decline in grade has been driven by the relative paucity of major new greenfields discoveries over the past two decades, with reserves growth coming from known deposits which have already been high graded. The phenomenon of declining grades is not unique to Australia. The average grade of gold mined in the United States, Canada, Australia, and South Africa combined decreased from more than 10 grams per tonne in 1970 to about 7gpt in 1980, to below 3gpt in 2000 (Mudd, 2009).

Improving the rate of tier 1 discoveries in these environments demands a step change in mineral exploration techniques. A real key is the provision of enough information from the opening drill-hole in an exploration campaign, in near real-time, to build decision-making capacity to de-risk drill hole number two. This information will also boost vectoring, and/or help decisions to be made about the type of mineralised system being drilled.

At the leading edge of a move into the future is “prospecting drilling”, where extensive drilling activity is used to map mineral systems beneath cover, enabling geophysical and geochemical vectoring toward deposits.

“At the leading edge of a move into the future is “prospecting drilling”, where extensive drilling activity is used to map mineral systems beneath cover, enabling geophysical and geochemical vectoring toward deposits”



subsurface sampling needed, the technological platform for prospecting drilling revolves around low-cost drilling.

An optimum technology platform for prospecting drilling, under advanced development in Australia, borrows coiled tubing drilling from the oil industry, and complements it with downhole and top-of-hole sensing, providing real-time petrophysics, structure/rock fabric, geochemistry, and mineralogy.

The Deep Exploration Technologies Cooperative Research Centre (DET CRC), sponsored by some of the world's leading mining and drilling companies, has set itself the ambitious target of developing a greenfields mineral exploration coiled

Decision making with confidence

Resource companies around the world grapple daily with acquiring, accessing, managing and maintaining significant quantities of data derived from a range of sources.

Interpretation of these extensive quantities of data, to make effective decisions in a timely manner, is a seemingly insurmountable challenge that will only increase as even more data is generated through optimisation software and automation.

REFLEX HUB provides secure access to validated data, seamlessly transmitted from a range of survey and XRF data inputs protected through a validated chain of custody. These inputs are seamlessly transferred into your database or can be accessed, from any internet connection, anywhere, all in real time.

Accurate information, not just data

The rigorous and streamlined data validation function included in REFLEX HUB ensures that only data which can be transformed into valid, actionable information is accepted.

REFLEX HUB incorporates mobile form data collection (DDRs, safety, accreditation and pre-start check forms) to ensure the accurate capture of field data. Data is seamlessly transferred from the drill site to a secure, central database in REFLEX HUB where it can be accessed immediately, minimising the risk of delays in drilling.

Data validation includes:

- Validation at the point of collection for REFLEX pXRF and survey tools
- Survey sign-off
- Workflow control of key data fields such as drill-hole ID
- Assay batch QAQC reporting

Improved data reliability and a guaranteed chain of custody are possible through electronically captured, transmitted and stored field data.

tubing drilling rig, with the capability of drilling 500m holes at a cost of less than AUS\$50 a metre.

The world-first Lab-at-Rig® analytical platform will take rock powders from a solids recovery unit and deliver them via an automated sample handling system to XRF and XRD sensors. Additional sensors are expected to be added to this platform. Data collected from Lab-at-Rig® sensors will be uploaded from a remote drill site to a central data storage area (computing cloud) in real time, and from there will be accessible to a range of users and can be subjected to further analysis.

Trust your information

Transparency across multiple streams of data associated with a single drill hole, or an entire operation, allows managers to monitor activity to ensure the project remains within budget and on time.

With no paperwork required, associated errors and inefficiencies from the workflow are removed.

With access to survey data accessible in real time, decisions on drilling and surveying can be made while the rig remains operational on-site. With the significant costs associated with hiring and moving rigs, smart decisions made while the rig is on-site remove the risk of significant time and cost blowouts where rigs need to be recalled or have extended down time.

Resource managers can monitor their drilling programme with daily updates and results to ensure there are no unaccounted costs incurred, while drilling companies can access data for invoicing, inventories and payments, on demand, with an immediate impact on billing and cash flows. Little time is lost in implementation as REFLEX HUB is a Software-as-a-Service solution that does not require the installation of new software and needs minimal training.

To mine or not to mine

When you're making these types of decisions, the advanced analytics inherent in REFLEX HUB, with the automated alerts, reports and dashboards enable easy and rapid decision making. REFLEX HUB is available as an automated workflow engine securely feeding verified data to existing systems. This means geologists can receive the benefits of advanced workflows and analytics in REFLEX HUB, whilst optionally maintaining existing database systems.

REFLEX HUB is ideal for applications across the mining cycle, providing efficient drill hole and sample data management; from daily reporting requirements, including shift reports, pre-starts, safety reports, site inspections and employee accreditation, to geochemical, analysis and rig positioning and downhole survey information.

Near-realtime remote communication of the data opens the door to the type of cloud analytics seen in the oil and gas industry today. While the mining industry may never have 'big data' in the same sense as Google or Amazon, it is vital that interoperability and data integration lessons from these industries, and the oil and gas industry, are learned and that better outcomes follow.

“Data integration between data types, collected by multiple devices, will be critical in the new mineral exploration workflow”

Lab-at-Rig® data might be combined with downhole sensing data, measurement whilst drilling (MWD) data and logging whilst drilling data to improve the depth precision of geologic and geochemical data from cuttings, which in turn are used to inform the interpretation of petrophysical logging data.

Regardless of what happens on this front, data integration between data types, collected by multiple devices, will be critical in the new mineral exploration workflow. What is key to scalability is that the heavy lifting involved in this is moved from the user to the remote server system.

Initially, the Lab-at-Rig® system will be used with conventional diamond drilling rigs. Longer term the aim is to build a system that is compatible with the mineral





exploration coiled tubing drilling rig. Preliminary results have provided proof-of-concept that important components of the strategy, in particular depth fidelity and representativeness of samples, can be achieved.

Analysis of datasets and a work flow significantly different from that currently seen in mineral exploration will be required. This aspect of prospecting drilling presents an equally demanding challenge to that of developing the requisite drilling and sensing hardware. Fortunately the complementary information technology infrastructure and training required for successful implementation of prospecting drilling has already taken shape.

Surveying the future

Maptek

Peter Johnson, Maptek

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

18 “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 and chemistry”





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 in 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, with 3D resource modelling using computers evolving 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 that 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 fracturing 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.

A new way to measure up

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 (ancillary) measurement. 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 the data may be 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 pull-down pressure recorded on blasthole drills against geological models.

While the obvious primary purpose for measuring the hydraulic pull-down pressure is to monitor and diagnose the hydraulic system and drill performance, it

“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”

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 pull-down 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.

Connectivity the big enabler

It is increasingly common for sites, especially in the opencut 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 that 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 of 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 that 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 becomes 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.

“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’”

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 stages, 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 six-month to five-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.

Change drives further innovation

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 4km 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 2km 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 set-up 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 three hours, one person has created 100 million attributed 3D points, 1.4 billion RGB coloured pixels and all of 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 geo-located 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. Geo-technical 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 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

“In 15 minutes, surveyors can now create more data than they would have completed in a lifetime using the technology of 20 years ago”

high level of confidence about the activity, productivity and material movement in the operation.

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 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-and-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.

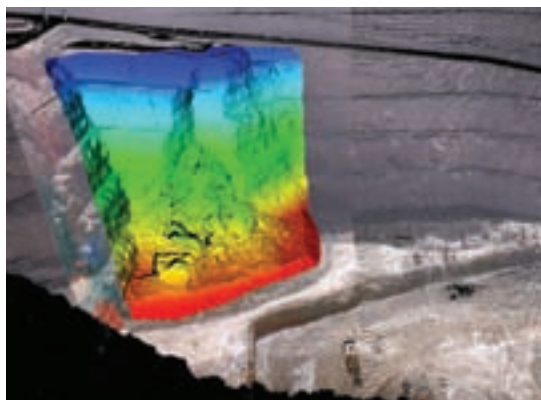
Delivering these results to the business takes less than 10 minutes. The surveyor has not yet left the scan location. Previously, there would be a lead time of at least a day to produce all this data, then prepare, publish and distribute reports and datasets. During that day, the surveyor would not be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

A real quantum leap

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 benefits 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 too late, or 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 measure 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 pull-down 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 sources 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 some-

“While systems like this may be referred to 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”

thing 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 high 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 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 RPAS 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 four-hour period. These were assembled photogrammetrically to create a digital terrain model with 3D measurements every 10cm 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. Certainly 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.

The digital mine of the future

Hexagon Mining

The digital mine of the future is closer than you think. Big Data might be a convenient hook upon which to hang that vision, but Hexagon Mining is built around connecting people; people faced with countless variables in an industry whose only constant is fluctuation.

Faced with rising energy costs, scarcer high-grade ores, declining commodity prices, and tighter profit margins, it has never been more important for a mine to make sense of its data. Productivity depends upon it; so, too, will the digital mine of the future.

Within that data is a smarter way to mine. By seamlessly integrating design, planning, and operations technologies, mines can be safer, and more productive. Central to the challenge of connecting people and making sense of their data is the need for one version of the truth.

Operational staff and managers are increasingly being overwhelmed with huge volumes of data from multiple sources, much of it in real time. As data is collected, and distributed to various systems at the mine, it is replicated and massaged before countless hours are then spent reconciling and rationalising this information.

The result is:

- Multiple versions of the truth;
- Silos of data and practice; and
- Spreadsheets dominate as a planning and execution tool.

By connecting people across a mine, we can connect intelligence and processes. Decisions can then be made that make sense and drive efficiency. All data, if



Optimisation and integration have never been more important for smart mines striving for productivity

managed and analysed correctly, can be important for understanding the performance of your project. Assembling all of this disparate data together and presenting it in a useful format is one of the largest challenges facing mining operations around the world today.

More and more data is collected via more automation and sensors. But not enough is being done with this data to make sense of it. Mine operators and mining executives are under tremendous pressure to meet profitability goals in an unfavourable market. Huge amounts of data are being collected from disparate sources every hour of every mining day. But neither operations, or mine management, or corporate executives can consolidate it, transform it, or analyse it on a timely basis.

Each day, data piles up and its value is lost as a tool to help mines do more, and do it better, faster, and more profitably. Add to that challenge the many variables and daily uncertainties inherent in the complex business of mining. Extreme environments, fickle weather, plus mechanical, geological, and engineering constraints are constants, as are fluctuations in the world economy.

Historically, mining has collected only the data necessary to operate. Some departments, such as maintenance and purchasing, do a much better job than operations in collecting and managing data. For productive mines seeking a competitive edge, this approach doesn't cut it anymore. Today, companies are under enormous cost pressure. Capital expenditures for projects have risen to billions of dollars. Operating expenses are extremely high due to wage competition in the past 10 years, along with increases in fuel and energy costs.

The need for a holistic view of the mine, one with clarity, accuracy, and timely reporting that everyone understands, is vital to move mining to its next level of productivity and financial performance. It will be the foundation of the digital mine of the future. Without that view, cost efficiency is not only lost, but escalating losses from under-informed decisions send ripples downstream costing millions of dollars from unintended consequences, money that could be going to the bottom line.

So what's the solution?

Cut costs by managing and using all data that affects the operation. How many drill bits used, how much fuel used, how many pounds of ANFO loaded? Those are all easy to measure, but how do you optimise them? You need to go back to the basics and look at the task at hand, which is building an accurate model of the mine, down to the level of geologic detail required to optimise engineering processes, while eliminating harm to staff and environment.

One of the key issues is collecting, filtering, and managing clean data in this realm. Because of the large amount of data being collected, it's essential to automate and manage in near or in real-time. The companies that make up Hexagon Mining have a long history of working closely with operational staff and providing accurate and robust solutions for daily work. As a result, we are uniquely positioned to not only collect the data, but provide the tools for analysing it.

The digital mine

Removing the impediments to efficiency, such as manual data collection, departmental silos, and Excel-driven reports is a quest all vendors are on. Mining companies are faced with an array of vendors who offer partial solutions. Smart mines need more than partial solutions. Optimisation and integration are essential for smart mines.



By focusing on business intelligence and business analytics, Hexagon Mining will help customers to identify lost time that's non-productive: breaks, crew stand-down times, lunches, and equipment breakdowns

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The combined experience, leadership, and expertise of Leica Geosystems Mining, MineSight, SAFEmine, and Devex Mining elevate Hexagon Mining to a unique position. Hexagon Mining is the only company to solve surface and underground challenges by uniting the world's leading software innovators. Together, they create an unprecedented spread of technologies within the mining vertical.

Central to efforts in mastering big data is our new Hexagon Mining Athena product. It's a unique solution based on the attractive synergies between our partner companies. Our goal is to understand the big problems, but provide practical, achievable, and scalable solutions in the short term.

HxM Athena imports, validates, analyses, and stores data from multiple input sources to a single data repository. It then presents the data in dashboard views that are easy to use and understand. The sources of data can be extremely varied, such as fleet management systems, (FMS) drill rigs, on-board fragment analysis cameras and general mine planning systems. In the future, dashboards for safety, and slope stability will be added.

Analysing and merging this data can answer questions like, "why are my shovels not meeting their production targets?" There could be several answers to this question, but one answer could be that the rock is not being fragmented efficiently, making it harder to dig.

It's a critical benefit for managers to be able to understand what is going on in

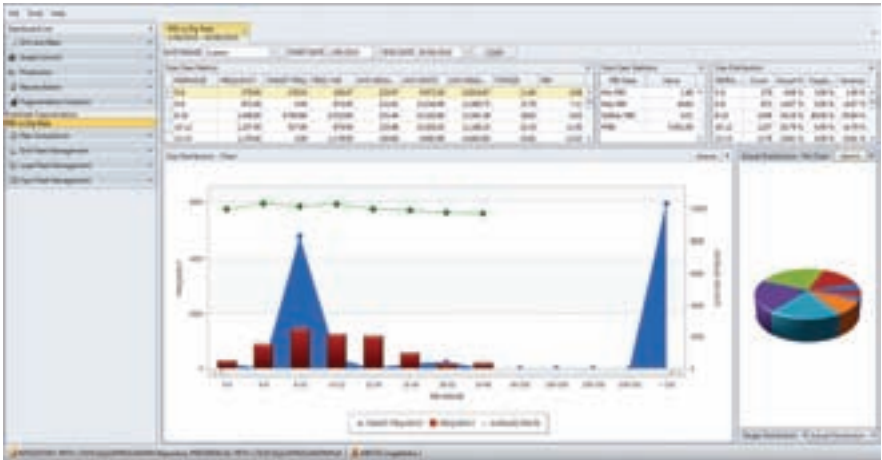


their operation across multiple areas of the mining value chain. Being able to track poor shovel performance back to a sub-optimal blasting process, for example, can give managers the confidence to change projects, improve practices, and track the results. This can be priceless information but it is easy to attach a value to this as well.

Tempted by technology such as laser scanners or HPGPS tracking, some companies are embracing data capture without the means to actually make good use of the data. HxM Athena is different because it offers both business intelligence and business analytics.

Athena allows data consumers to see their data on an attractive interface. For instance, being able to see the design and as-drilled blasthole locations and parameters together in one place can be hugely beneficial when you are trying to understand why a blast was good or bad. Better yet, Athena is mashing data from multiple sources, enabling you to understand why, as well as what.

The P80-versus-Dig-rate dashboard is a great example of this. It shows the



HxM Athena features dashboards showing the predicted fragmentation distribution curve versus the measured actual fragmentation curve, and compare them to the digrate of the excavators; a valuable tool for planning engineers

predicted fragmentation distribution curve against the measured actual fragmentation curve, and compares this with the dig-rate of the excavators. This is critical for planning engineers trying to understand why the mine plan objectives are being missed.

HxM Athena is central to plans for connecting with enterprise resource planning (ERP) systems. Athena’s interchange data structure will allow customers to not only connect ‘down’ and ‘over’ to data sources, such as FMS, but also to connect ‘up’

to ERPs, such as SAP. Athena will preside over all the data that flows in the operation of the mine, and will be the one source of information that everyone needs, including SAP.

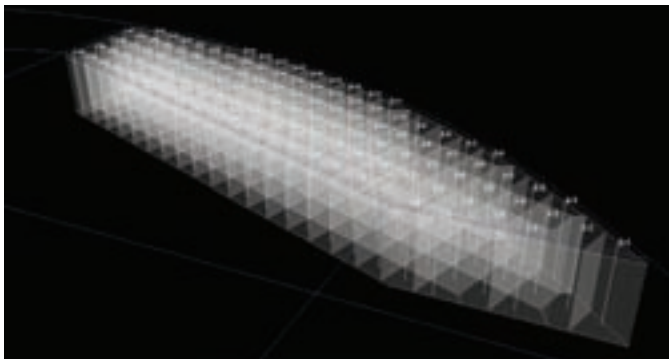
Understanding the problem is one thing, fixing it is another. Hexagon Mining is tackling this as well. MineSight's short-term scheduling product, Atlas, will soon be able to import actual FMS information automatically so that the mine plan is evolving. The obvious value to use here is the productivity rate of excavators. This is related to the rock hardness and the blast's effectiveness. So if productivity is falling behind plan, the Atlas schedule will be updated on the fly, allowing engineers to predict problems before they happen and hopefully solve them.

This cycle of plan, do, act, check is repeated through all our operational tools, such as MineSight Axis for grade control and the soon to be released MineSight Blast for drill and blast design management.

The drill and blast cycle is integral to Hexagon Mining's vision. MineSight Blast will bring precision and dependability to one of mining's most challenging steps. Incorporating a modern design interface, MineSight Blast will design and manage drill and blast patterns interactively on screen while storing all of the design (and actual) information in a SQL database. Drawing upon visualisation and automation software, together with MineSight's Axis product, Hexagon Mining will focus on tracking grade and rock fragmentation. This part of the mining cycle is too important to get wrong.

Poor fragmentation has major implications for crusher energy, refining and the whole mining process. Get crushing and grinding right the first time and mines really save energy costs and decrease the hit on the local energy grid. Hexagon Mining is looking to close that loop via Leica's drill fleet management machine guidance, and MineSight's drill and blast modules.

The wider technologies on offer from the Hexagon family will be invaluable, as



Viewing volume of influence solids and polygons will be among the compelling display features in MineSight Blast

Hexagon Mining cultivates other synergies to solve industry challenges. HxM Live Terrain, for example, integrates the disparate data from surveying and measure-



ment sources for a streamlined workflow. Those sources will include total stations, UAV, scanners, Lidar, and mobile mapping.

HxM Live Terrain assembles other technologies, from Leica equipment to Intergraph software, and combines it with data truthing and processing software, to build a database of all relevant data, ranked by fidelity.

Customers can select the area for which they need the latest terrain surface, and HxM Live Terrain will deliver it. This provides a much-needed tool for rationalizing a critical source of data for the mine – the topography surface as it is continually measured and mined. Hexagon Mining expects Live Terrain to be a huge benefit for a variety of users; from mine planning, to fleet management, to environmental, slope monitoring, reconciliation, autonomous mining, and regulatory. Better yet, Live Terrain can be a cloud-based solution.

Hexagon Mining is not the first company to build products that make sense of so much data, but it is the first mining vertical company to be doing this. The mining industry's need for a complete, life-of-mine solution – not partial solutions – demands nothing less. Hexagon sees a great opportunity for miners to use its technology to integrate and converge with other solutions for a smarter way to mine. By eliminating silos, and sharing an open platform, Hexagon Mining believes it will be an attractive proposition to the industry, no matter what mine planning or fleet management systems are being used.

Knowing Hexagon Mining's products will work with those of their competitors should be a bonus for companies looking for technologies that can be integrated, be they for safety, asset management, or asset optimisation.

With a 360° vision, Hexagon Mining, will offer the competitive edge needed by productive mines. Mine planning, design, fleet and production management, optimisation, fatigue monitoring, and collision avoidance software will be seamlessly linked for a comprehensive flow of data across all operations.

Fleet management, for instance, represents a huge opportunity for mines to minimise energy consumption, reduce carbon footprints, and save money. Leica Geosystems Mining's fleet management and optimisation expertise can deliver immediate relief for companies facing tough times with rising capital expenditure and operating costs. Companies like African Barrick Gold (ABG).

ABG contacted Leica Geosystems Mining to address these issues at ABG's North Mara mine in Tanzania. North Mara is a high-grade open pit gold mine with

“Mine planning, design, fleet and production management, optimisation, fatigue monitoring, and collision avoidance software will be seamlessly linked for a comprehensive flow of data across all operations”

The digital mine



Leica Jigsaw makes sense of the data deluge, helping mine staff to solve problems in near-realtime

a life-of-mine estimated at 10 years, and the potential to process 8,000 tonnes of ore per day.

In September 2010, North Mara implemented the Leica Jigsaw Mine Management Solution on 70% of its production fleet. The goal was clear: improve time management; increase production; reduce costs. The results surpassed ABG's expectations.

ABG installed the solution across North Mara's entire production fleet and by 2012, Leica Jigsaw was at work across all three of the mine's open pit deposits.

North Mara's scale and size presented several challenges. Production spans several large pits 15km apart. Supervisors couldn't be present to constantly monitor all fleet-related activities in all of the pits.

Leica Jigsaw's introduction reduced average collection time of the first load truck and shovel cycle times by a third. North Mara's hourly output of 2,000t was boosted by an additional 450t per day. The tools used to complete this analysis satisfied one of the major goals set by North Mara dispatch supervisors: to produce up-to-the-minute, end-of-shift reports and loading details.

Within six months of adopting the Leica Jigsaw Mine Management Solution, North Mara mine reported a marked improvement in equipment usage and efficiency.

ABG uses a variety of Leica Jigsaw's tools, including Joptimizer. Before North Mara mine could benefit from using Joptimizer, it was important for the mine to understand the variables affecting production. The system had to be configured to account for these variables. Vehicles had to be assigned to circuits, according to Joptimizer's results.

Previously, supervisors would appoint assignments to truck operators regardless of their route after unloading at the dumping location. Trucks would go to their respective dumping locations and return to where they had originally loaded the truck.

Using Joptimizer, trucks now dump loads at the dumping location; then receive

new assignments leading them to alternate loading units with shorter distances. Assignment routes are shorter and more efficient. With Joptimizer, only 13 trucks were needed to accomplish assignments, compared to 15 trucks that were previously necessary to complete the isolated circuits. Time is saved and productivity is increased.

Originally, consultants created the North Mara mine design and recommended routes to and from each location. In one project, the consultants relocated a stockpile with an estimated one million tons of sensitive material to a more adequate location. The original route assigned to move the material was labelled Old Route.

After implementing Leica Jigsaw, North Mara mining engineers ran a simulation using Leica Joptimizer tools. The findings presented the Proposed New Route, as the shortest path that yielded the best output.

Operators began using the Old Route and recorded an average 21-minute travel time between points A and B. Joptimizer's Proposed New Route cut that time by a third. The optimised route meant increased truck productivity and significantly more output tons.

It costs US\$236 per hour to operate a dump truck at North Mara mine; about \$814 per hour to operate a Terex 170 shovel. Over 25 days using the Old Route, ABG would have spent \$965,345. Using Leica Jigsaw, and specifically Joptimizer, ABG actually spent \$663,068, saving more than \$300,000.



One product respecting underground essentials such as process control logic, data communication challenges, safety standards, and environmental issues, is now a reality thanks to Devex's SmartMine I UG package

Underground, Hexagon Mining is also taking great strides thanks to Devex Mining. This month, Devex and AngloGold Ashanti Brazil wrote a new chapter in underground mine operations. After four years of collaboration, SmartMineUG will be unveiled at the Lamego Mine, in Minas Gerais, Brazil.

SmartMineUG is the world's most comprehensive system for managing

underground mine processes. Its creation began in 2010 when solutions for managing underground mines were mere adaptations of open pit mine systems.

Devex decided it was time to develop a product for underground operations; a product that respected underground essentials, such as process control logic, data communication challenges, safety standards, environmental issues, and other factors.

In mid-2010, Devex embarked on developing SmartMinelUG, the first system for managing underground mine process automation. Much of Devex's development team was mobilised to the project and a laboratory was established to test the modules being developed for the new product.

Devex recognised early on that the goals of the SmartMinelUG project converged with the needs of AngloGold Ashanti Brazil, a client with a history of joint development in customized solutions.

Six months of talks lay the foundations of a commercial partnership for the joint development of SmartMinelUG in Lamego. It was agreed that Devex would use Lamego's underground mine as a test platform for the system's development.

This would allow Devex to incorporate the experience and expertise of AngloGold Ashanti's mining professionals, and other customers could visit and see the progress at Lamego. The agreement established price advantages for AngloGold Ashanti in the final acquisition of all hardware, software, communication tools and services.

In 2011, work officially started on the SmartMinelUG project at Lamego, 26km from Belo Horizonte, home of Devex's headquarters. Devex developers worked tirelessly on this project, whose modules were developed with the support

of Lamego's teams. Experts in each area of the mining process participated and explained their needs. They guided, tested and used each of the modules developed in partnership with Devex, considering not only the specifics of cargo and transportation, but all processes in an underground mine.

About 70 Lamego employees, from all hierarchical levels, contributed to SmartMinelUG, which was completed this month, becoming the world's most complete system for underground mine automation.

Pivotal to Hexagon Mining's vision of smart change is safety. SAFEmine is the global benchmark for solutions that prevent mining accidents. Today, more than 20,000 mining vehicles in 45 mines worldwide are equipped with SAFEmine's Collision Avoidance Systems (CAS).

About 70 Lamego employees, from all hierarchical levels, contributed to SmartMinelUG, which was completed this month, becoming the world's most complete system for underground mine automation"



FatigueMonitor is an innovative solution that integrates data from fatigue detection and collision avoidance to minimise accidents involving mining vehicles

Now the Switzerland-based company has launched FatigueMonitor, which is integrated with CAS.

About two thirds of traffic accidents in surface mines are because of driver fatigue or exhaustion, according to industry statistics for open-pit mining. FatigueMonitor is an innovative solution that integrates data from fatigue detection and collision avoidance to minimise accidents involving mining vehicles.

It's mining's first multi-technology, fatigue detection system for monitoring driver alertness. It enhances SAFEmine's impressive suite of traffic safety solutions.

CAS protects vehicle operators from collisions in the constrained mining environment. SAFEmine's data shows that a lot of mining accidents happen due to fatigue. FatigueMonitor smartly fuses CAS data with PerClos and body clock inputs that can detect early signs of fatigue and prevent this type of accident.

In addition to the CAS and fatigue monitoring solutions, SAFEmine's versatile safety package includes SafetyCentre and ShovelAssist. SafetyCentre is made for haul trucks, displaying all relevant safety information via cameras and radar, and other sensors, such as tire pressure. ShovelAssist is a solution to avoid damaging light vehicles and clean-up equipment around shovels.

Hexagon Mining can make any mine safer and more productive today. The future is even more promising. With its commitment to shape smart change, Hexagon Mining does not just imagine bridging the gap between short term planning and operations, or connecting fleet operations with mine planning, or making analytics and business intelligence holistic and universal; it is working to make these solutions a reality.

While fluctuations in mining are guaranteed, Hexagon Mining aims to be the industry's other constant, the dependable foundation on which mines can build productive futures. Integration and automation across the entire mining chain is the goal. Representing more than 100 years of innovation and experience, the company has all the ingredients necessary to realise that goal.

And with it, the digital mine of the future.

The future is now

10 big data use cases for transforming mining

SAP

Big data is the decisive ally in tackling and ultimately solving the high-profile problems facing mining companies. Despite the virtual goldmine of big data in mining, underinvestment in technology puts mining behind other industries with respect to their ability to unlock its value. Currently, companies in natural resource industries spend just 1% on information technology compared with 5-7% for most industries. This underinvestment means that mining companies collect data but have a limited understanding of how it can inform and improve their businesses.

Big data is driving numerous use cases that have the power to transform mining. The key, as in any mining operation, is to find the most valuable data, determine where it can be most impactful, and then use it for competitive advantage.

There are now tools and technologies on the market that allow mining enterprises to use data to transform every aspect of their operations, and according to a recent survey, some 61% have started applying big data in particular use cases (see Figure 1). This article explores 10 use cases where mining companies are undergoing transformation with the help of big data technology and describes the tremendous benefits they're realising as a result of their efforts.

1. The connected mining enterprise – the internet of things

We are no longer living in a world where mines have to remain dark. With embedded software available with virtually every asset, companies can achieve a real-time view and understanding of all their machinery. Imagine being able to gather information from every piece of equipment and every worker, so that you could better schedule maintenance and technicians – or have full visibility into operations that allows you to better understand which truck, which shovel, and which mine are performing better than the rest and why.

There's no reason to just imagine this. Instead of asking "why?" ask yourself "why not?" when it comes to collecting and analysing as much information as



Figure 1. The value of big data in energy and natural resources

Source: Survey of mill product and mining industry executives at SAPPHIRE NOW 2014



possible about your operations. Now more than ever with the convergence of smart devices, advanced connectivity, and platforms to manage the collaboration, you can “mine” not only iron ore, diamonds, and silver – but data as well.

The technology to create this symphony, in which every item a company owns or operates is providing data on itself and its interactions with other things, is called the Internet of Things (IoT). The IoT is the foundation for a fully connected mining enterprise, in which companies fully realise connected asset management, operational monitoring, and business process transformation.

What does a connected mining enterprise look like in reality? Data is being constantly generated from sensors measuring gas and oil pressure, temperature, weight, and performance of every asset a company owns and operates, supporting real-time telemetry. With the IoT, mining companies gain detailed visibility into their operations and processes. It's like a patient living in the Middle Ages suddenly arriving in 2014 and receiving an MRI and the best healthcare available. Reactions are no longer predicated on guesswork or information from last week but rather on up to the minute real-time feeds of machine data that provide a complete picture of mining activities, processed in-memory to support in the moment decision-making.

Many asset intensive industries, including suppliers to the mining industry, are making use of insights from IoT data for remote service management. By monitoring devices remotely, service managers can dispatch technicians based on up-to-date and detailed information for performance-based service. What's more, they can detect worn equipment, such as a drill bit becoming dull, and automatically order a replacement bit to minimise equipment downtime. These new processes improve responsiveness, minimise service and support delivery costs, and increase service revenue.

The most dramatic vision of the connected mining enterprise comes from mines that are remotely operated, using driverless trucks and robotics. Rio Tinto, a respected international mining company, with products spanning resources such as coal, aluminum, gold, and uranium, has mining operations around the globe. Rio Tinto's Pilbara mine (*below right*) in Western Australia is controlled from a remote operations centre 1500km away in Perth. Driverless trains carry iron ore across 1500km of track. The mine features a driverless intelligent truck fleet and remote control intelligent drills.

The Pilbara mine is a vivid example with its remote operations centre. The more important takeaway is that given machine interfaces and the IoT, all companies have an opportunity to make their mines part of the connected mining enterprise. With the aid of big data analytics, companies can generate data-driven intelligence from connected things, devices, and people to optimise business processes and automate operations.



2. Mining for millions – procurement

It may not be the sexiest big data use case, but procurement processes are ripe for considerable cost savings. Procurement is especially costly for mining companies because they must coordinate services for businesses that operate in remote places, across the globe.

A key issue in mining procurement is spare parts. In many cases, due to the specialised nature of the parts and the vast number of machines involved, many at international sites, mining companies deal with several thousand different suppliers and hundreds of thousands of different parts.

When companies are forced to deal with that type of volume without data-driven systems, costly errors are almost inevitable. Companies need to ensure that they have a seamless flow of information about their needs, both current and future, as well as real-time inventory, to ensure that they can avoid part shortages and unplanned downtime.

Take, for instance, the Ariba Network, the ultimate global supplier network with over 1.5 million connected companies, including many major mining enterprises and their suppliers. Ariba is the Amazon.com of the energy and natural

resources industries – everything that any company could want, all in one place.

ThyssenKrupp, a premier international industrial and engineering firm, recently joined the Ariba Network with the explicit purpose to automate the document flow between its suppliers and ThyssenKrupp. This will be a big step forward to build best-in-class processes.

ThyssenKrupp realised that a great benefit of joining would be the ability to drive efficiency

across the entire procure-to-pay process and to improve collaboration with its huge number of international suppliers. Using the network enables ThyssenKrupp to improve procure-to-pay process efficiency through purchase order and invoice automation and started in a pilot project.

In general, companies can use the network as leverage in negotiations for volume purchasing, driving down costs and increasing consistency across work-sites. The tools also offer insight in terms of the cost benefits of volume buying, allowing the business to purchase similar parts in one place, rather than relying on piecemeal purchasing. The result is cost savings that can easily run into the millions. ThyssenKrupp is actually discussing how to benefit from these opportunities of the Ariba Network.

An important point about the use of big data in procurement is that companies view this as a continuous improvement process. Even more important is the ease with which this approach can empower managers and decision makers throughout the organisation and foster a culture of continuous improvement.

"An important point about the use of big data in procurement is that companies view this as a continuous improvement process"



3. No more surprises – predictive maintenance

A company is only as successful as its equipment. When a drill goes down or an excavator is out of commission, lost sales build up quickly. An out-of-commission excavator can cost a company US\$5 million a day, while the loss of a haul truck can reach \$1.8 million per day. Something as simple as suboptimal tyre pressure decreases the lifespan of truck tyres, which are among a truck's most expensive replacement parts; one tyre costs as much as a passenger car.

With the right technology, mining enterprises can exert control over maintenance processes. Almost all machinery is already equipped with interfaces or sensors that produce reliable information about its condition. By listening to real-time sensor data, companies can be alerted immediately when a machine or part is in need of repair. Even more importantly, companies can project, using historical data, forward forecasts, and advanced algorithms, when assets are likely to break or need service and can perform preventative maintenance, typically at a fraction of the cost. For example in a production plan, companies can predict different maintenance needed for areas of the mine that have different environmental characteristics and that create different wear rates on machines.

In addition to savings from reductions in unplanned outages, companies also reap the windfall of being able to better coordinate maintenance in the most efficient way. For companies operating in remote locations, this is invaluable, as they're better able to plan to get specialists to these locations and get the correct part there the first time. A recent ARC survey showed that 75% of respondents indicated strong interest in predictive maintenance service offerings either now or within the next two years

Just how much of a difference can using data for predictive

maintenance make? Companies that have adopted solutions of this kind have experienced an increase in first-time fix rates of 22%, leading to a 28% reduction in repair times. The biggest benefits come from full integration with the entire business process, which gives access to previously unlinked sources as well as the ability to take immediate action.

A leading global equipment manufacturer is revolutionising the maintenance of



its machines and equipment using alerts captured with telematics technology combined with warranty claims information using the in-memory database platform, SAP HANA (see side bar “In-Memory Technology Drives Instant Big Data Insights” for details). The manufacturer loads “hundreds of millions of data points into SAP HANA. These included machine alerts we capture through the telematics technology running on our machines, warranty claims from our global SAP system, and contextual information from our dealers,” said a company representative.

“Our team also developed a simple user interface that let our engineers work into the data, and slice and dice it in multiple different ways, to get to the information they need. This provided insights never before available. We got massive amounts of data we’d never seen before in seconds.”

The resulting visibility enables the manufacturer to recognise issues two to three months faster than before, resulting in fewer problems and happier customers.

Another important trend is collaborative maintenance, which allows a company’s premiere expert to help with maintenance remotely. Using videoconferencing, as well as 3D visual design tools embedded in individual parts and machines, a group of experts can be brought together to make a fix. It’s as if the products themselves have become smarter, coming with their own experts who can guide staff onsite.

Combined, these tools give mining companies more sophisticated and effective asset management and reduced downtime. Repair and maintenance schedules become key data points that companies can analyse to determine root causes across their organisations. What if a certain truck part fails at different sites? Or what if trucks with a particular type of oil in the transmission operate more reliably? With this type of information, companies can dig into the performance of their equipment and ascertain which tools are most cost-effective and perform root cause analysis. Leveraging big data for predictive and collaborative maintenance puts an end to living at the whim of one’s equipment – mining companies can put maintenance on their schedule and their budget.

4. Smarter vehicles, greater savings

A wave of fear sets in when teens first get behind the wheel. Will they be responsible? Who else will be in the car with them? Will they be distracted while driving? Many parents wish there was an app that allowed them to track their kids’ movements, to know the who, what, and why when curfew was missed before the kid even walks in the door.

Mining companies often want to know just as much about their vehicles as fretful parents. Fortunately, for mining enterprises, they can. Companies can track their vehicles precisely. Systems can recognise if a truck is slowing down and can send alerts to the control center or following trucks and suggest actions to avoid incidents. And in the most dramatic cases such as an accident, they can pinpoint



In-memory technology drives instant big data insights

In-memory computing technology has been shown to help organisations better manage and analyse huge amounts of information. The good news is that substantial progress in the development of hardware and software now makes it possible to analyse such data volumes from different sources in real time and at affordable cost. The SAP HANA® platform is a flexible, in-memory data platform that is data-source agnostic and allows you to analyse large volumes of data in real time. Unlike traditional approaches to data management, SAP HANA consolidates two landscapes – online analytical processing (OLAP) and online transaction processing (OLTP) – on a single platform. This enables you to process both transactional and analytical workloads fully in memory. The result is a rapid acceleration in business insight and dramatically lower total cost of ownership (TCO). Whereas traditional data warehousing technology requires a lag time of hours or days, SAP HANA gives you what you need, when you need it – in real time. All of this represents a quantum leap in data processing capabilities, enabling your organisation to do what it does faster and with greater accuracy than ever before.

With virtually instantaneous response times, companies can speed analytics, aggregate and evaluate sentiment data, and crunch volumes of internal and external data to identify trends and make better predictions, improving business performance. SAP HANA can be deployed on premise or in the cloud. The on-premise option combines software and hardware on a single appliance for a comprehensive solution. Cloud options – including the SAP HANA Enterprise Cloud service and the SAP HANA One service – combine fast time to value in a managed or public cloud context with mission-critical performance. In addition, SAP HANA can be extended to a mobile workforce – empowering employees and partners to access data and functionality from any device at any time and make smarter decisions on the go.

ArcelorMittal Mining uses the SAP HANA platform to improve its visibility into key performance indicators and to speed reporting. With data coming in from all mines globally, ArcelorMittal produces massive quantities of data that can easily be handled by SAP HANA, ensuring that all analytics draw on up-to-date and accurate data. Common and automated processes across all mines has led to increased data integrity and quality for one version of the truth, simpler management and lower cost of the IT landscape and opportunities to grow profit and revenue through enhanced insight and rapid decision making. That means greater insight for faster, more informed decisions, supporting ArcelorMittal Mining's business priorities. "I am very convinced about SAP HANA as our common platform for any kind of data – SAP, non-SAP, reporting – and becoming our One Point of Truth not only for reporting, but also for predictive analysis and proactive review of data," says Hervé Legrand, CIO, ArcelorMittal Mining.

where in the mine their vehicles are and who is operating them.

Yet, better safety isn't the only advantage that big data vehicle tracking offers to mining enterprises. Just as GPS has revolutionised the way we all drive, essentially allowing us to avoid getting lost, embedding GPS and other sensors in all vehicles allows companies to optimise the use of their fleets.

UPS is well known for doing this in the package delivery business (route analysis showed that having UPS trucks only make right turns saves both time and fuel), but the same rules apply for mining companies. Companies can track the routes of their vehicles to judge efficiency. Sensors can provide data on the weight of a truck, how it was loaded, its condition, its fuel usage, and its tyre pressure. Fuel leaks can be immediately detected. Half-loaded trucks are repacked before ever leaving the site.

All this data can drive immense insights. In one case, a mining company used SAP technology to monitor its truckloads and found that its trucks were leaving the mine at 85% capacity. This meant more trips, more gas, more time driving, and more maintenance and repairs. Using this information, the company changed its practices to ensure vehicles were loaded as close to 100% as possible, resulting in significant savings and a reduction in the time needed to bring targeted quantities of resources to market.

Essar Steel has been an early adopter of applying big data to vehicle management. The company brought its entire 3700 vehicle fleet online with GPS and RFID technology to monitor equipment movement as well as fuel levels and usage. RFID tags were placed on every diesel tank with sensors placed inside tanks to ensure accuracy. Essar Steel has achieved 5% annual savings on maintenance and 10% on fuel just by using this technology. The company even performs systematic refueling because of the diagnostics at its fingertips.

5. Benchmarking to stay ahead of the curve

Imagine an Olympics in which the time of every runner, every swimmer, was recorded in isolation, without reference to one another or the performances of past Olympians. This is mining without benchmarking. Without data, from all sites, across the entire company, as well as from partners, businesses cannot know what defines normal, exceptional, or abysmal performance. Data is essential for helping to set standards and baselines so that companies know where they are and where they should aim to go. Benchmarking allows mining companies to continuously monitor and change strategies and behavior in a regular improvement cycle that uses real data to support the continuous advancement of operational performance.

This is why cross-site and cross-company benchmarking is key. By comparing one's own operations to those of partners and competitors, mining companies can get a good sense of whether operations are inefficient or on target. For example, companies that have benchmarked against open data provided by the US government in its Energy Star Performance tool, which provides benchmarking data on energy usage across industries, have achieved savings of 9 to 18% in electricity costs.

Benchmarking technology provides real-time information on all aspects of the business, from orders to equipment status to product quality, and compares them to industry benchmarks as well as to multiple sites or mines within the same parent company. Companies gain instant visibility into how their sites are performing against each other – and their competitors. If a particular site is lagging in productivity, companies need to know this so they can make the necessary changes to correct the issue.

Benchmarking has other applications as well. In joint production efforts, in which multiple companies are collaborating on a particular site, a mining enterprise can directly compare its performance to its partner to know whether productivity is where it should be. Benchmarking tools also improve asset and product performance, as companies can know how well any given asset is performing in real time compared to industry standards. Thus, if a particular brand of drill is comparatively ineffectual, it can be taken out of commission immediately.

One of Latin America's leading steel and mining companies used benchmarking tools to reform its environmental, health, and safety management. Previously, it relied on a mismatched collection of legacy products. Obviously, this led to problems, as regulations vary greatly from country to country and trying to know what standards have to be met in all of these locations required tremendous effort. But now, the company is able to know whether they're on top of safety at every instant. The results have been dramatic: an 80% reduction in the time to complete accident investigations and reports; a 50% increase effectiveness of environment, health, and safety action plans; and a 40% reduction in occupational health exam costs. The data the company generated using benchmarking has empowered the company to set standards that all business units have to meet and to implement uniform best practices. Benchmarking has improved production and revenues, but it has also led to a more cohesive and safe environment for all employees, which helps make them an attractive place to work and builds goodwill in the communities where it operates.

6. Taking the work out of workforce management

Typically more than half of the workers in a mining company are contractors. In order to comply with regulations and ensure that a site has personnel with sufficient technical expertise as well as the appropriate tools for a given job, mining companies need a centralised way to track all the data relating to the certification and skill levels of their entire workforce.

Deploying total workforce management software enables mining companies to plan their needs at an individual site, ensuring that the entire team, whether full-time employees or subcontractors, have the skills to manage the job. But even more importantly, this technology enables companies to integrate the backgrounds of their full-time employees with the temporary workers hired at any given site to get a complete picture of who is on the payroll and their skillsets.

Additionally, multi-resource scheduling software helps companies schedule the right talent with the right tools for any given job. These approaches make it easier to comply with regulations about hiring practices, handle payment of workers, and attract talent – all with optimum efficiency.

Total workforce management shares many similarities with procurement applications. Mining companies can use a procurement network to find the contingent workers they need, relying on the feedback of other companies and suppliers to verify the quality of the newly hired workers. This takes away much of the screening process that can consume so much time and money. Additionally a total workforce management solution confirms that the requested work can be performed, has been performed and the resulting invoicing and payments are automated with a high degree of accuracy, thus eliminating the manual invoice verification processes.

To manage its combined global workforce of employees and contractors, a large mining company implemented SAP's Fieldglass Vendor Management System. Previously, the mining company relied on numerous labor suppliers to provide temporary, statement of work contractors to meet its workforce demands in locations across the globe. With so many disparate companies involved in labor procurement, the business had to pay special attention to ensuring that all employees received complete health, safety, and environmental training. Using Fieldglass, and integrating it with the company's ERP system, the mining company was able to ensure compliance while increasing transparency about its workforce, verifying proper classification of all workers (whether statement of work or permanent), and improving efficiency by automating procurement processes.

7. Safety in numbers



Like many other high-risk professions, such as police work and oil and gas exploration, mining generally only makes the news when something goes wrong. The thousands of times an operation is running smoothly and is compliant with all environmental, health, and safety (EHS) standards receive no publicity, but the one protocol breach or incident grabs headlines.

The brand integrity and identity of mining companies are bound up with their success in mitigating risk, both to the environment and their employees. More and more frequently, mining companies find that being diligent about meeting the highest standards for environment, health, and safety is also a recruiting tool, as potential employees want to work for and be associated with such companies.

In order for a company to minimise incidents and keep workers safe, it's not enough to be reactionary when problems arise. Companies must also track near misses, such as a tyre going flat on a truck entering a mine, a slippery surface where someone nearly tripped, or a structural issue after workers left a shaft. They



catalog these incidents in order to adopt preventive measures in the future. Companies often fail to recognise the risks they run without such monitoring.

Deploying EHS software enables companies to track every incident, and near incident, that occurs, regardless of location. And incidents are tracked from detection to resolution, meaning that companies do not leave problems to fester. Additionally, companies improve their environmental performance by being able to measure their sustainability and consumption. Operating sustainably means operating efficiently and cost-effectively, so monitoring fuel levels and power consumption can be another focus. These tools empower companies to track their emissions, which eases their ability to comply with regulations that can vary from country to country.

MMG Ltd, a global resources company, has strong internal processes supported by EHS software to continuously improve its environment, health, and safety processes and outcomes by analysing hazards, incidents, near misses, and safety observations. The company says that its ability to collect valid data to learn from incidents has helped it identify and share best practices across sites and reduce risks, prevent incidents, and drive continuous improvement.

Dubai-based SK Solutions has an innovative big data solution driving safety in mining and many other industries. Their Asteroid platform uses sensors on machinery to capture and analyse data, dramatically boosting safety and efficiency across some of the most complex industry landscapes. A network of sensors located on machinery throughout each customer site monitors contextual details about every activity in real-time. These encompass the machinery's position, movement, weight, and inertia along with wind speed and direction, temperature, and more. Potential collisions are detected before they occur. An autopilot kicks in to make immediate adjustments, eliminating operator errors. The information is delivered on dashboards and mobile devices, visualised with live 3D images with customisable views.

8. Geospatial, 3D, and Google Glass – transforming the user experience

Imagine the difference between navigating by the stars to find the New World versus winning the America's Cup with the aid of technology on the ship and big data crunchers on shore. That's the kind of quantum leap you see when you can enrich business data with geographical context, visualising its shape and form and presenting it in real time using interactive technologies.

Geographical information systems (GIS) have replaced old map analysis processes, traditional drawing tools, and drafting and database technologies. GIS has natural connections to mining – from exploring and identifying new assets to planning and development, scheduling, and reclamation. GIS, especially when integrated with systems of record like ERP, offers a way to visualise mines and their activities in a new way.



GIS provides accurate information about the surface and subsurface of a mine, so companies know the precise location of every truck, drill, and excavator, even if it is thousands of feet underground. This makes maintenance easier to perform and monitor, and in the cases of dangerous incidents, can also be used to accurately track the whereabouts of staff and make sure that everyone is out of the area in question. In addition, mining companies are using GIS to evaluate mining conditions, improve facility management, handle mining tenements and lease management, and plan reclamation activities. For example, with solutions that use geographical data, mining organisations can better manage costs associated with land, leases, construction and so on.

Mining equipment is enormous. It's difficult to photograph, let alone train people on. 3D visualisation tools are transforming training to make it easier to see how equipment works and how to operate it. Joy Global, a leading international manufacturer of mining equipment, has benefited greatly from adopting 3D visualisation technology for just these purposes. The company has improved the safety of its equipment and augmented its training of new and current employees by being able to present trainees with visualisations that bring the training to life in a way no 2D schematic could. Employees see during training what they'll see in the field, depicted with precise accuracy. This leads to less retraining and fewer on the job mistakes. Joy Global now spends far less on training because it is able to reuse engineering schematics to feed its 3D visualisation tool while at the same time providing better quality training on its products – a true win-win.

The ability to have help while you're in the mine, whether with training or through a videoconference, is changing the way mining and maintenance are done. Most tablets, however, are not well suited to conditions in the mines. Wearable technology such as Google Glass holds promise for such applications, though at this writing it is unclear whether it is yet being used in the field.

GIS, 3D visualisations, and wearable tech are also perfect technologies with which to use gamification techniques in mining to accelerate attracting, hiring, and training the next generation of miners. With these tools, the mining industry has greater visibility into the mines than ever before, and workers in the mine have better access to information that can help them right at their point of need.

9. Social media and crowdsourcing

Social media and crowdsourcing might not seem like likely topics for mining companies, but they hold important keys both in terms of reputation and in terms of encouraging participation in innovation and funding.

Public perception of mining companies is ever more important as brand identity can have dramatic effects on corporate reputation, profits, and shareholder value. Just as companies need to be able to track their inventory, they must monitor and analyse public sentiment about their company. They want to avoid being blindsided by an issue relating to their company that is being discussed in social media.



This sentiment analysis can help prevent or mitigate negative headlines or negative sentiments towards expansions in the local community. Mining companies operate in so many nations at a given time that perception about the business, also referred to as “social license to operate,” can vary widely by location. Companies can use social media monitoring to keep abreast of whether individuals in a given location will be ready and willing to work for them and whether the community as a whole is receptive to the company’s presence or expansion. Monitoring social media provides insight on public sentiment and early warning of possible reputational issues.

While Google has no difficulty attracting top talent – about 300 people apply for each opening – manufacturing and mining have had a more difficult time. Crowdsourcing is no replacement for recruitment, but it can help bring attention and expertise to bear on difficult problems. Canadian mining company Goldcorp used crowdsourcing to help the company decide what to do about its 50-year-old Red Lake Ontario mine, which was deemed to be tapped out. Goldcorp conducted a contest to get feedback on the best sites to drill within its holdings. Virtual prospectors from around the world, hoping to gain part of the US\$575,000 prize, crunched data Goldcorp made available on its website. They pinpointed more than 110 targets likely to contain gold. Some 80% of those yielded substantial quantities, which resulted in over \$3 billion in extracted gold.

10. Big data analytics: making everyone more productive

The invention of the printing press was monumental because it democratised information. Everyone could buy books, not just the wealthy. Putting knowledge into the hands of the many brought Western Civilisation out of the dark ages, and productivity spiked. Big data analytics holds the same promise.

Instead of just a few analysts with the keys to a company’s BI tools, new technology has democratised the ability to use data, getting role-based analytics and dashboards into the hands of employees to help guide their daily work. While in 2012 about 10% of employees used analytics in their day-to-day work, some 75% will do so by 2020, according to Analysts (see Figure 2).

Advanced analytics and algorithms are leading to breakthroughs in efficiency. A

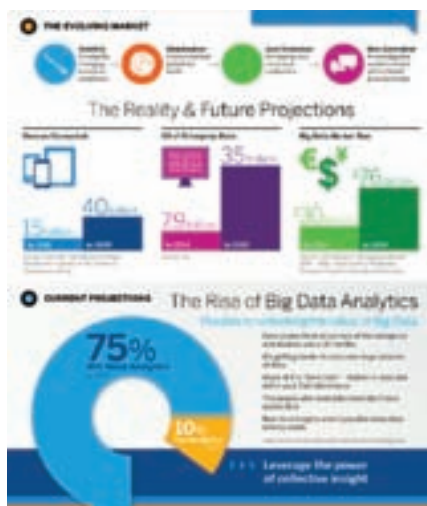


Figure 2: Some 75% of employees will use analytics in their work by 2020

Source: Nucleus Research, Gartner, Fortune Magazine

recent McKinsey report noted that “powerful data-driven analytics also can help to solve previously unsolvable (and even unknown) problems that undermine efficiency in complex environments: hidden bottlenecks, operational rigidities, and areas of excessive variability.” The report notes that mining, metals, and similar industries are using advanced analytics to find improvements in their production areas and, as a result, are seeing an additional 2-3 percentage points of margin.

Adopting quality analytic platforms and dashboards also helps users visualise data to better grasp it. No matter the size, speed, and structure of the data, premiere systems can process the data and present it to users ready for analysis. Companies gain a competitive advantage by having unparalleled visibility into real-time operations. Pairing this visibility with predictive algorithms enables employees to predict how operations will be running versus always looking backward at historical data to make management decisions.

Analytics techniques that have been applied in other sectors are gaining popularity in mining as well. Monte Carlo simulations, often used in biology, finance, and insurance, help model different outcomes. A mining company used this technique to challenge a project’s capital assumptions, in part by deploying historical data on various disruptions – for example, rainfall patterns – to model the effect of floods and other natural events on the company’s mines. This effort helped the mining company to optimise handling and storage capacity across its whole network of facilities, thus reducing related capital expenditures by 20%.

A recent survey showed that companies that use real-time monitoring of production and parametric data about processes, materials, and operations show a 10% higher capacity utilisation. Taking action on the newfound visibility and insight from big data is only possible when the company’s analytical and transactional systems are both running on a single platform that can handle the complexity, volume and disparate sources. An in-memory database is increasingly seen as the best option for such a platform.

Connecting strategy to execution is also critical to the success of big data analytics. Companies that communicate their analysis and strategies and work with their employees to achieve results see a significant uptick in employee engagement and further direct benefits.

By engaging employees across the lines of business in helping to use data to address important business problems, the mining division of a global chemical company was able to move quickly to address key problem areas and drive a feeling of greater ownership. Wrench time, a measure of how much time skilled workers spend doing the task they are trained for (versus in meetings or in transit), increased from 22% to 45%. Productivity rose by 50% over a two-year period, generating additional profits of US\$350 million. Costs fell sharply, with annual run-rate savings of approximately US\$180 million. All of this happened as a result of engaging employees with data and giving them both accountability for their targets and a voice in how objectives were achieved.

Where should you start?

For mining companies looking to integrate big data solutions into their operations, the logical first question is: where should we start? Here are some recommendations to consider.

- **Recognise the opportunity:** Understand how becoming a data-driven enterprise can increase productivity and operations at all levels, as well giving you an edge over competitors.
- **Analyse needs:** After getting a grasp on the types of tools that are available, engage in self-analysis to determine the biggest challenges and how better data could assist in providing a solution.
- **Adopt KPIs:** Don't wait until after you've adopted big data technology to track key performance indicators (KPIs). KPIs are the basis for judging the effectiveness of any business initiative, offering a view of whether you're achieving your objectives.
- **Standardise KPIs across the enterprise:** Once you've put KPIs in place, ensure that KPIs are consistent across the entire organisation so that operators in New Zealand are working towards the same goals as those in Mexico.

Once data enters the bloodline of an organisation, you are left wondering how you ever lived without it. Results can be experienced immediately, as you are able to connect strategy to execution in real-time. You can run comparisons across locations to find which locations are performing well and which are not and make changes accordingly. Once you set an objective, whether improved mine safety or less fuel usage, data can reveal whether new standards are being met and how to change current practices to augment productivity.

Conclusion

For mining companies, being able to use and analyse big data will be the difference between success and failure in the future. With the type of wrap-around technology available for big data, companies should never again be in the dark about their assets and should realise dramatic efficiency and cost improvements through better scheduling of maintenance and oversight of equipment. Mining may be one of the oldest enterprises in human history, but it can now be at the cutting edge of technology.

To learn more:

Internet of Things: <http://www.sap.com/pc/tech/internet-of-things.html>

Procurement: <http://www.ariba.com/solutions/the-ariba-network>

SAP Community Network: <http://scn.sap.com/community/mining-and-mill-products>

Connecting the mines of the future

Level 3 Communications and Liquid Telecom

As is clear from the contents of this guide, there is a wide range of ways in which mining is being, and will continue to be, transformed by new technological solutions. While we're undoubtedly on the cusp of a new era in mining, the industry is currently considerably behind other heavy industries – even its peers in oil and gas – when it comes to utilising technology to transform its performance.

Until fairly recently, the mining industry had not been under sufficient pressure to stimulate change. So compelling as new methods and technologies are, miners would likely have continued to lag behind other industries if it had not been for a fundamental shift in the market – a shift that is largely attributable to changes in supply and demand, how these factors have affected the economics of mining and, in turn, how they have affected the operational imperatives of miners.

The recent change in fortunes of the global mining industry has compelled companies to take a hard look at new ways of operating, and at effective methods pioneered in other industries to improve their commercial performance.

Miners have looked to other heavy and manufacturing industries for inspiration, and some have brought in managers with different skillsets from outside the industry. By employing managers from the retail and consumer goods market, for example, natural resource companies gain key supply chain management skills. This has revealed new processes and technological approaches that promise to yield significantly better results for miners.

There is certainly huge scope within mining to use technology to transform 'rock factories' into smart mines and smart enterprises. Lean manufacturing processes, based on real-time data, integrated and optimised supply chains, and the concept of remote operations – managed out of integrated remote operations centres (IROCs) – all contribute to more efficient mining and improved results.

Critical to the effectiveness of all of this technology is interconnectedness.

The smart mine is a connected mine and the smart enterprise behind it is a connected enterprise, fuelled by accurate real-time data that enables it to make better and smarter decisions. Staff and contractors can also work smarter, to compensate for higher labour costs and a limited labour pool, if mines enable new working scenarios supported by sufficient connectivity.

Connectivity is the key enabler for the collection, transfer, dissemination and communication of data; it is also the enabler of the analysis, comparison and reporting of that data. Chris Holmes of IDC Manufacturing Insights says: "A fundamental rethink is happening on the way [mining companies] are run. There is a focus on productivity and efficiency that leads to a discussion on technology,



including project management and supply chain solutions to complex communication and simulation tools.”

Mining companies are already rolling out more connectivity and more technology to transform their operations. A study conducted by Accenture in spring 2014 reveals, for example, that one-quarter of North American mining executives said their overall digital investment had more than doubled in the past three years. Ninety-three per cent of companies said that they were satisfied with the results achieved from their digital investments, and 96% intend to increase their investments again over the next three years (33% say they will increase their investment significantly).

“What this shows is that, in effect, connectivity has become the arterial network of the mining body – ensuring safe and efficient operations, and informing better commercial decisions”

What this shows is that, in effect, connectivity has become the arterial network of the mining body – ensuring safe and efficient operations, and informing better commercial decisions. It has become such a fundamental tool of the industry that it requires companies to carefully consider how they deliver the right kind of connectivity, matched to business requirements, at the right time and cost. While connecting up mines and deploying more technology to create smarter mines might be a no-brainer, getting the connectivity piece of the jigsaw right can make the difference between a mine being viable or not, and therefore a mining company flourishing or floundering.

The transition from rock factory to smart mine

The ‘digitisation’ of the mine is part of an evolutionary process that transitions the mine from being a rock factory to being a smart mine. As can be seen in Figure 1, each stage of this process adds new capabilities to the mix, as connectivity grows and becomes more widely available.

At the ‘rock factory’ stage there is little application of digital technology, and a very siloed approach is taken to any technology that is deployed. At the next stage of maturity, increased connectivity and more digital technology is used to improve

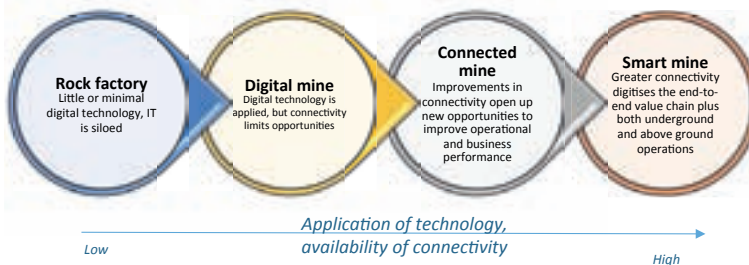


Figure 1:
From
rock
factory
to smart
mine

operational efficiency, safety and commercial performance. As the connectivity bottleneck opens up further, a connected mine can utilise realtime data to get a more granular and instant view of what is going on, enabled by more cost-effective and higher bandwidth connectivity. At this stage the mine can automate its processes and equipment more, can deploy increased numbers of sensors that can, in turn, be remotely monitored as the mine begins to become part of the Internet of Things (IoT), and miners can collect, disseminate and communicate results using mobile devices connected to cellular or WiFi networks. This enables them to utilise data more effectively while working and to collaborate more effectively. Or, as Maptek's Peter Johnson explains, they can now work "in the data".

In the final stage of maturity, smarter mines extend connectivity underground and enable even more benefits to be gained by digitising whole supply chains to squeeze out the maximum operational efficiency achievable. At this stage, novel applications of technology puts the tools into the hands of staff to take decision-making to the next level, create much safer working environments, and to re-use knowledge gained historically to take more intelligent decisions in the future. A smarter mine is more automated, and delivers a level of operational efficiency that makes marginal assets viable to exploit, thereby increasing the number of economically viable assets and boosting a company's commercial performance.

The right network choices for smarter mining

The concept of the 'digital mine', and its successors the 'connected mine' and the 'smart mine', is thus achieved by using information, collaboration, automation and communication to enhance operations by enabling miners to unify all their processes and the data they produce into an integrated data set. Managing, processing and utilising this complex data, and delivering the tools to exploit the insight it delivers, requires access to effective connectivity solutions

These solutions must be resilient, robust, reliable, available and secure – even in remote or harsh environments. The remote nature of much of today's mining activities has meant that even though data demands are growing at an exponential rate, the chief challenges are not technical requirements such as huge bandwidth or very low latency, but the availability of sufficient bandwidth at a low enough cost so as not to impede the take up of new data-intensive applications.

That said, no single connectivity approach delivers against all the needs of miners all of the time, because the best approach will depend upon the locality, the stage of the mining lifecycle, as well as a range of other factors.

This brings us to the crux of the matter. While connectivity is required to drive efficiency and better commercial outcomes, how do mining companies decide which network strategy to utilise?

As Figure 2 shows, the stage of the mining lifecycle determines how long the asset lifecycle is, how mobile or flexible the solution needs to be, as well as how much data is likely to be generated which, in turn, affects the connectivity choices.

Connectivity's role during design and construction

During this phase more staff, and more companies, are going to be onsite than at any other time.

Connectivity helps collaboration between different contractors, while monitoring applications help keep contractors safe while delivering the insight required to ensure the mine is delivered on time. At this stage the mining company may build in fibre, if appropriate, because it will serve to deliver against the company's needs at both this and the next two stages. In many sites digging a fibre link will be a fairly trivial cost compared to the total capital cost of developing the mine.

Some companies will achieve this by delivering fibre along with the electricity cabling, potentially reducing costs further. At others, the sheer remoteness means fibre may not be an option and satellite remains the preferred strategy. But even here, not all satellite providers are equal in terms of reach, cost, reliability and bandwidth..

Generally, as asset lifecycles lengthen, so longer-term solutions become more viable. This means that where the locality and environment permit, an investment in fibre can pay long-term dividends in terms of reliability, performance and cost.

A key consideration at this early stage may not be just the requirements of the operational and commercial issues during production, but the mining company's wider obligations such as Corporate Social Responsibility (CSR) programmes and social licences to operate (SLOs). Both of these have a direct impact on the economic viability of mining identified reserves, and are increasingly key to gaining permission to exploit reserves. Firms face raised costs to implement against these goals; but also are likely to face disruptions to production from disgruntled locals if they do not.

These wider obligations, and how they can be addressed in the digital age, are a material consideration when selecting network strategy. Network availability is one way of providing the required benefit to the local community. Utilising some of the



Figure 2: Connectivity requirements across the mining lifecycle

network capacity for delivering social benefits can fulfil mining companies' obligations but this can be self-serving - for example, by using the network to deliver educational programmes that help educate the next generation of workers.

The role of connectivity in the production and operation stage

Once the mine is connected, the cost of operations can be driven down further through the introduction of cost-saving technologies and better utilisation of key and expensive assets and staff. New ways to save money will stem from the

**"The race
to smart
mine status
has begun"**

reduction of waste and rework – resulting from better decision-making – improved asset efficiency and, ultimately, much improved supply chain management. Data will help mining companies more accurately identify and monitor their cost drivers, as well as deliver a much safer working environment.

To maintain their competitive edge though, mining companies need to look at new innovations that promise to boost their operational performance even further: the race to smart mine status has begun.

Rio Tinto and BHP Billiton are now both using autonomous trucks in their Australian iron ore mines, for example, and Rio is using driverless trains. Small unmanned drones are starting to be deployed to monitor processing plants and measure ore stockpiles. All of these scenarios require connectivity to operate equipment remotely and transfer data between equipment and integrated remote operations centres (IROCs).

One of the key innovations that can be found in smarter mines is the ability to deploy technology not just above ground but also underground. As the head of the University of the Witwatersrand Mining Engineering School Fred Cawood says: "A smart mine means you can understand in realtime on the surface what is happening underground, and the ability to communicate in two ways. We can now save costs by warning a worker underground that he or she should not proceed in a particular direction. ...Alternatively, it enables you to understand production flow and, where losses occur, to know in realtime where the losses occurred and then to do the remedial action using the instructions from the control room."

As Cawood notes, by extending surface technologies and connectivity to the underground environment, mining companies can take better care of workers by keeping them away from high-risk areas. He believes this will not only save lives but also add enormous economic value to mining companies. This is achieved by utilising monitoring to identify underground risk and then combining this insight with data from wearable devices, for example, to identify the location of workers. Connectivity enables the two datasets to be collected and compared in realtime to create instant, actionable insight, and provides two-way communications to advise workers on the best course of action.

Dundee Precious Metals has built an underground WiFi network by installing 45km of fibre optic cable in its Chelopech mine in Bulgaria. Among other uses,



this enables miners to use tablets underground to feed data between the face and a control room on the surface. Explaining the benefits of this approach, Nikolay Hristov, the general manager of the Chelopech mine explains: "It is the next generation of underground mining ... it let us go to the next level of planning and scheduling and drilling activities that needs to happen – and the next level of progress and monitoring those tasks. It is like taking the lid off the mine and having a complete look at what is going on."

Mines have utilised video surveillance for security purposes for a long time, but increased connectivity and advancements in video surveillance technology mean that a range of new services can be utilised to increase mine production and protection. Miners are increasingly using cameras connected to equipment control systems to monitor conveyor belts, for example, which means that if a conveyor belt is broken, miners will be quickly alerted and the operation can be halted.

Video motion detection can be used to monitor primed blast sites for safety purposes, or to keep an eye on valuable equipment or product. When monitors detect movement, changes in pressure or temperature, cameras can be switched on for remote technicians to check, diagnose and take any necessary actions. Data from a wide range of systems can be combined to deliver an accurate and timely picture of events, and 'data overload' is avoided using a 'black-screen' approach whereby screens are only lit up if something anomalous is detected by systems that use complex algorithms and rules to filter results.

Alerts, alarms and triggers make the smart mine hyper-responsive to changes and challenges. The information gathered in realtime from the mine, combined with historic data, enables miners not just to react to the situation, but to predict and plan for the future – thereby staying in control.

Closure and post-closure

Since the 1970s, mining companies have become increasingly financially liable for reclamation and safety post-closure. Sometimes these programmes have been adopted by companies voluntarily as part of their code of corporate responsibility; but at other times they are required to take more responsibility post-closure because of mining regulations passed to ensure abandoned mines remain safe and the cost of dealing with them is not transferred to the taxpayer. Such programmes are now frequently incorporated into the environmental impact assessment and are now an ongoing consideration throughout the mine's lifecycle, both from a financial and technical perspective.

Monitoring programmes may be required for many years – typical ranges are two to 10 years - to meet environmental and safety objectives for temporary and permanent closures. Costs can be minimised by connecting sensors and cameras to the internet, so that data can be centrally and remotely monitored over long periods - a classic Internet of Things (IoT) use case. This enables the effectiveness of reclamation measures to be monitored and any corrective actions to be

identified and taken. Using this type of approach, a smaller number of staff can monitor a large number of mine and ex-mine sites remotely both during and after production.

All of these use cases though are enabled by adequate and reliable communications infrastructure both above and below ground.

The enterprise of the future

When it comes to optimising mining performances, we have to look beyond the mine itself across the entire mining enterprise and into the extended supply chain. In addition, mining companies often have wider social obligations that need to be fulfilled, and have to meet the needs of staff in terms of making mining an industry that younger generations want to work in.

To enable the smart mining enterprise to deliver optimal business results, mining companies have to use technology to make better realtime business decisions, to utilise key staff more effectively, and to ensure safety, security and compliance.

In terms of better realtime business decisions, the future mining enterprise will become a global, seamless enterprise, stitched together by connectivity and highly available, accurate data. This vision requires not only faster access to better data, but also improved analytics to enable the business to respond more effectively to demand to deliver better short-term and long-term business results.

In the future, mining companies will not base decisions on simple, initial business cases, but will require the ability to continually make accurate decisions tuned to market demands, the mining firm's needs and the conditions in the mine. Through better data, smart mining companies will be able to plan more effectively about production in a volatile market – enabling them to decide when to bring on new capacity versus when to step up production in existing capacity, and helping them meet their shareholder obligations. This moves them up the hierarchy of understanding from having readily available data to being able to utilise knowledge to gain wisdom (see Figure 3), all of which drives better outcomes. The ability to connect and use data more effectively though is entirely dependent, on reliable and usable connectivity.

We have heard how connectivity enables a level of automation that transforms

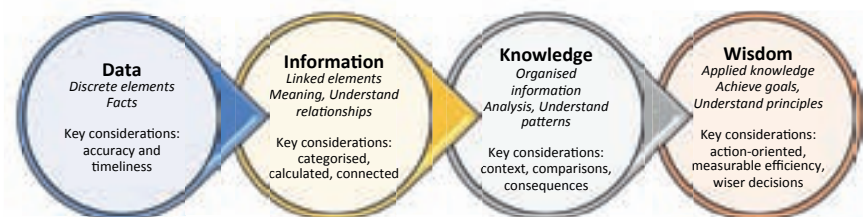


Figure 3: From data to wisdom – how connectivity combines data sets with human insight to deliver better outcomes



the economics of mines, and how connected devices and sensors can deliver enhanced safety, operational and commercial performance. But connecting people remains a key challenge that should not be overlooked, as a smart mine will deliver not just Internet of Things (IoT) scenarios, but Internet of Everything (IoE) scenarios. IoE combines IoT with the Internet of People to deliver new possibilities and even greater efficiency. As Accenture's Rachel Bartels notes: "It is not just having automated trucks, it is about the degree to which you are creating a connected worker and a connected asset." In other words, data from increasingly connected things needs to be combined and then recombined with human knowledge to deliver the level of insight that maximises outcomes.

Connecting people to the smart mines and smart enterprises enables mining companies to better utilise their expertise; delivers new, safer and more efficient modes of working; and accommodates the connected world requirements of the next generation of workers.

This presents an opportunity to enable greater mobility of workers by taking data out of back offices which was previously only accessible via PCs and laptops, and putting it into the hands of workers via tablets so that it's available to them as they do their jobs. This makes miners more effective and more productive but it also increases the value and usefulness of the data itself. Although the scenarios here are mobile, and utilise mobile devices, the connectivity to these devices does not necessarily have to be cellular. Increasingly, mobile devices of all kinds are WiFi-enabled and there is an opportunity to deliver a mobile-like experience using WiFi as the access technology rather than cellular. Neither does this have to be restricted to data services: new technologies such as VoWiFi (voice-over-WiFi) extend the core capabilities of mobile networks and mobile applications to handsets and devices attached to WiFi.

The availability of WiFi also delivers against the welfare needs of workers to stay in contact with their family and to be able to remain part of the connected world. These needs are becoming increasingly important due to the scarcity of skilled staff in certain parts of the mining industry.

This recruitment crisis is partly because fewer young people have trained as geophysicists and mining engineers in the last 20 years – leading to an aging workforce. But also because there is considerable competition for those young people who are trained.

The scale of this problem was highlighted by the US Bureau of Labor Statistics which calculates that the US has only produced an average of 1,700 geophysicists per year since 1995 – of which three-quarters have gone into the oil and gas industry. According to The American Geoscience Institute this means that about half of US geoscientists are now less than 15 years from retirement.

Neither is the problem just an American one: the UK, Canada, South Africa and Australia all face similar issues. Forty per cent of Canada's skilled mining workforce, for example, are over 50, and a third of workers are eligible for retirement by 2015.

Case study: How Level 3 powers FQML's growing business

First Quantum Minerals Ltd (FQML) produces mainly copper, nickel, zinc, gold and platinum group elements. It has a geographically diversified portfolio of seven mines, several development projects and administrative offices. It's poised to become one of the top five copper producers in the world, with a strategic plan to deliver 1.3Mt/y of copper production within five years.

FQML required a new communications infrastructure to power its growth, as its legacy communications infrastructure was neither sufficiently flexible nor scalable enough to keep up with the growing demands of its business.

FQML therefore selected a MPLS/IP VPN and Managed Network Service from Level 3 Communications. "Level 3's MPLS/IP VPN has virtually eliminated all the bottlenecks and outage issues we were dealing with by providing CoS for voice, financial reporting and email. For the first time we have a service level agreement and guaranteed uptime, which is incredibly valuable for a business like ours," comments Ben Rodgers, group network manager at FQML.

"It was always a huge challenge trying to figure out how to link up sites in places like Mauritania, Zambia and rural parts of Turkey with our offices in Australia and Europe," continues Rodgers. He adds that Level 3's global reach, which includes fibre networks anchored on three continents, undersea cables, and seamless integration with satellite services, is one of the service's biggest benefits. "Level 3's global infrastructure helps us provide mission-critical services such as secure file uploads, video communication and reliable email to the most remote locations on the planet."

FQML now has a highly available and reliable connection wherever it does business, with the Level 3 network providing more efficient delivery, multiple quality of service (QoS) levels, plus the ability to prioritise traffic and manage bandwidth for optimal performance.

By selecting the Level 3 Managed Network Service (MNS), FQML was able to accelerate the launch of its upgraded network by passing many of the time-consuming and resource-intensive tasks to Level 3. For example, it has outsourced WAN administration, configuration of managed routers and failover policies, help desk operations and even data encryption.

"Now we get to concentrate on what we do best, because we know they're doing what they do best," says Rodgers. At the ICT level this means that FQML has a single point of contact for troubleshooting and network planning, as well as the peace of mind that comes with being backed by a highly responsive team of experts. All of this translates into significant business benefits. For example, the company has saved as much as USD10,000 per month just from long-distance calling, according to Rodgers, thanks to the upgraded VoIP system supported by the Level 3 MPLS/IP VPN.



This creates a competitive marketplace for existing skilled staff, who can dictate terms and refuse contracts where the conditions are not to their liking. Staff are moving to both countries and companies that offer the best terms and conditions, and the market is skewed in their favour. By offering a better network experience at remote sites, mining companies can compete more effectively for staff by providing better communication and network-delivered entertainment services to improve their quality of life while on assignment.

In addition, mining companies can use connectivity to deal with skilled staff shortages in another way. By centralising their scarce human capital, they can utilise expert staff better, allowing them to do their work remotely by providing them with real-time feeds of data, collaboration and videoconferencing facilities so they can diagnose, advise and liaise with colleagues on the ground. Centralising key staff means that mining companies can keep them safe and secure, rather than exposing them to unstable or potentially dangerous environments.

Security issues in general are becoming ever-more important, both for mining companies themselves, as well as for their staff. Changes in working practices – such as the use of mobile devices and more connected mines – deliver both risks and opportunities to mining companies. Firms now have to worry about contractors who might be accessing and stealing valuable data via mobile devices, or who introduce risk due to unsecured applications on devices that are also used for personal purposes.

Industrial espionage and intellectual property theft may not be new, but connecting increasing numbers of devices and sensors to the network opens mines up to cyber-attacks such as those already seen in the oil and gas industry. For example, in 2012, Saudi Aramco and Qatar's Rasgas were attacked by a computer virus which aimed to stop production. And in August 2014, 300 oil and energy companies in Norway were targeted in a huge hacking campaign. The attackers used 'spear phishing' attacks to trick companies' executives into opening malicious attachments.

"They [the hackers] have done research beforehand and gone after key functions and key personnel in the various companies...The goal is to plant a Trojan or a virus on the machine...Then the attacker can sit outside and download damaging code," said Hans Christian Pretorius, director of the operative division of Norway's National Security Authority (NSM). The goal, he said, was to syphon off sensitive information from the organisations.

Although attacks may not yet have reached this scale in the mining industry, more connectedness introduces more risk, and Ernst & Young have highlighted cyber hacking and information system security as one of the top ten risks facing the mining and metals sector. Ernst & Young found in their 2013 Global Informal Security Survey that 41% of mining and metal respondents reported a rise in external threats over the previous year. Twenty-eight per cent reported an increase in internal vulnerabilities. Likewise Symantec has stated that one in every

Liquid Telecom: Providing advanced telecomms to mines in Africa

Mining in Africa places severe demands on all stakeholders, more so perhaps than in other continents. Many of these challenges arise from the isolation that results from poor local infrastructure including roads, hospitals and centres of commerce. Communications are an essential tool for mines to manage their infrastructure, assist centralised decision-making and support the life of local staff.

Liquid Telecom's dedicated bandwidth solutions use satellite-based communication systems for fixed locations that require high-speed, secure, reliable connectivity between mines and central offices. Using Ku-band satellite frequencies and advanced coding and modulation techniques means the system operates flawlessly, even during rainy weather conditions. When possible and economically feasible, a fibre optic cable is installed between the mine and the closest network node. Highly efficient transmission technologies and optimisation methods provide the most responsive satellite solution available.

The ability to capture and continuously update ore reserve models can help reducing business risk and inform management decisions. These would typically be based on modern technologies that generate 3D images of the deposits using magnetic and gravitation measurements as well as ground penetrating radar. Also the ability to apply expert mining skills remotely can reduce the requirement for experts to be on site permanently or transit time between sites, thus optimising staff costs and reducing travel discomfort. These technologies and remote processes generate large volumes of data, which can be a challenge to transmit to central offices. To answer this requirement, broadband communication links are usually necessary. They provide a vast amount of bandwidth at a lower cost than satellite-based solutions.

Other areas for improving efficiency would include management of the dump trucks and the transport fleet through GPS technology. This can enable the management of maintenance, which represents a high cost item in mining. Shared bandwidth solutions are ideally suited for such monitoring with low to moderate bandwidth demands, requiring a low-cost but reliable connectivity service. Multiple contention ratio options, balancing minimum performance against cost, are available and enable management of communications costs.

Increased efficiency from the use of telecommunication tools can also be expected to arise from general process improvements such as the optimisation of the movement of machinery and materials and the remote supervision of plant condition. Some mining operations such as diamond mines require continuous secure video surveillance from a security centre, sometimes shared by multiple mines, to prevent theft of valuable minerals. This can be accomplished with site-to-site, secure broadband communications. This requirement can be met using virtual private networks (VPN) with Multi Protocol Label



Switching (MPLS) over satellite or fibre cables (if installed to several mines). Liquid Telecom's Newtec satellite platform integrates support for VLAN switching to address the requirement of building scalable VPNs. Combining connectivity via satellite and fibre cables. It is also possible to implement IEEE 802.1Q protocol extensions.

The health and safety of the mining staff are key success factors in a mining operation. These can be enabled or enhanced with broadband, for example supporting clinic visits and resolution of trauma cases with remote medical expertise including test results and tele-consultations. Liquid Telecom's Newtec VSAT platform is a satellite access service that is optimised to provide a two-way communication circuit using Ku-Band satellite E7B. The platform is engineered for broadband and supports real-time applications such as VoIP and video-conferencing.

Whereas in the past mines were often constrained to operate using telecommunications services at 1Mbps or at best 2Mbps satellite links, it is now possible through Liquid Telecom's satellite and optic fibre technology to increase this bandwidth to between 10Mbps and 1000Mbps (both upload and download), and enable a wide range of advanced communications services.

2.7 mining firms were subject to email-based attacks or 'spear phishing' in 2013.

This is where the network increases risk as well as opportunity. As more business functions are centralised, and with the convergence of IT and operations technology (OT), cyber hackers now have an access path to operational systems from the Internet. Many legacy systems are inherently less secure than current systems, because when they were deployed the emerging risks due to increased connectedness did not exist.

Process control networks (PCNs), for example, which are used to monitor and control industrial infrastructure and processes, were historically considered relatively low risk from a cybersecurity perspective, because they were isolated from enterprise networks and could only be accessed onsite by mining staff. This is no longer the case, as systems used to monitor, control and manage a range of environmental controls (such as air flow and circulation, detection of flammable or harmful gases and machine temperatures) are now online. If any one of these systems were targeted, it could lead to an increased risk of injury, or site and machinery damage.

While a range of strategies need to be implemented to avert impending 'Cybergeddon', the solution again begins with the network. This is another example of where not all networks are equal. Not only does Level 3 have one of the world's biggest fibre networks, but it also works hard to both connect its customers and protect them. We take a range of measures to do this and while our aim is to stop attacks before they start, we also employ a variety of controls and countermeasures on our network (both proactive and reactive). We're continually innovating and engaging with industry stakeholders to ensure a better performing and safer network for everyone.

Hexagon Mining

Faced with rising energy costs and tighter profit margins, companies are turning to Hexagon Mining for solutions.

Hexagon Mining unites the innovative technologies of Devex Mining, Leica Geosystems Mining, MineSight and SAFEmine. It seamlessly links mine planning, design, fleet and production management, optimisation, fatigue monitoring, and collision avoidance software for a comprehensive flow of data across all operations.

Hexagon Mining will focus on business intelligence and business analytics, (BI/BA) identifying non-productive time. By analysing such information and feeding it back into MineSight's planning and operational programs, customers can plan and schedule around real-time information coming from their mine.

Essential to Hexagon Mining's solutions is safety. SAFEmine is the global benchmark for solutions that prevent mining accidents. More than 20,000 mining vehicles in 45 mines worldwide are equipped with SAFEmine's Collision Avoidance Systems (CAS). Now SAFEmine has launched FatigueMonitor, which is integrated with CAS.

By shaping smart change, Hexagon Mining is not just imagining closing the loop connecting short-term planning and operations, or linking fleet operations with mine planning, or making analytics and business intelligence holistic and universal; it is making these solutions a reality.

Website: hexagonmining.com

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Guilherme is an Electrical Engineer with a Master's Degree in Automation Engineering (CPDEE, 1997) and a Doctorate Degree in Computer Science (UFMG, 2005). He is the cofounder of Devex Mining, and was the company's CEO between 2008 and April 2014.



**HEXAGON
MINING**

Level 3 Communications and Liquid Telecom

Level 3 Communications is a global communications provider headquartered in Broomfield, Colorado, that provides communications services to enterprise, government and carrier customers in more than 60 countries around the world. Liquid Telecom is a leading independent data, voice and IP provider in Africa that provides fibre-optic, satellite and international carrier services to Africa's largest mobile network operators, ISPs and businesses of all sizes. The chapter has also been authored by Telesperience, a global communications and media analyst firm.

Websites: www.level3.com / www.telesperience.com
www.liquidtelecom.com

Teresa Cottam

Chief Strategist for Telesperience

Teresa has more than 20 years' experience in the industry and was previously an Associate Principal Analyst with UK-based telecoms consultancy Analysys Mason. Before that she was Research & Publications Director at Chorleywood Consulting, a specialist BSSOSS consultancy which was acquired by Informa Telecoms & Media.



Alison Marwick

Director for Natural Resources business in EMEA, Level 3

Alison Marwick has over 18 years of sales experience in IT & Telecommunications. She joined the company in 2013 to set up the Natural Resources business having previously worked for Internet for Business and BT Global Services as Sales Manager focusing on the Oil & Gas and Mining industries. She is the Level 3 representative for Oil & Gas UK's Contractor Council.



David Eurin

Group Chief Strategy Officer, Liquid Telecom

David Eurin joined Liquid Telecom in 2013. In his role as Group Chief Strategy Officer, he is responsible for leading the formulation of the commercial strategy. Before joining Liquid Telecom, he was a Partner and Head of Africa at Analysys Mason, a management consultancy specialising in TMT. David has extensive experience in the fixed and mobile telecommunications industry, gained in Europe, North Africa, the Middle East and sub-Saharan Africa, where he advised senior management teams on strategic, regulatory, financial and commercial issues.



Maptek

Maptek™ is the leading provider of innovative software, hardware and services for the global mining industry. With more than 30 years of commitment to mine technology research and development, it offers an extensive range of products backed by unparalleled customer service and support.

Website: www.maptek.com

Peter Johnson

General Manager – Australia



Peter Johnson is a Mechanical Engineer with 16 years of experience in designing and delivering technology innovations for the global mining industry. In 1999, Peter began developing long-range 3-D laser scanners and applying this new technology to the mining industry. Following the award of a federal government R&D grant to promote commercial outcomes, he established and led the team which developed the first Maptek I-Site Laser Scanning products. These were released to market in 2004.

It was a natural step for Peter to assume the role of Global Product Manager for Maptek I-Site hardware and software. Under his leadership, the team was awarded the Institute of Engineers Australia Engineering Excellence Award and the Electronics Industry Association Gold Cup Award. Today, I-Site products are manufactured in Australia and sold to mining operations worldwide. They are proven to add significant operational accuracy and efficiency in a wide range of mine survey tasks.

In 2006 Peter was appointed General Manager of Maptek, Australia, where he is responsible for the delivery of all Maptek solutions and services to Australasian markets. In this role, Peter has overseen design, delivery and commercialisation of several new software and technical solutions and the successful introduction of these to the industry.

He remains active in developing new technical capabilities for the mining industry, as well as the provision of services that support business critical technical systems. Peter is also responsible for the commercial and operational management of Maptek Pty Ltd, working with approximately 170 staff in five locations around Australia.



Reflex

In today's environment, immediate access to reliable, secure information is important for timely decision making. Whether your exploration or mining project is located locally or remotely, important project metrics are available for you in real time, wherever you are. **Website: www.reflexnow.com**

Dr Michelle Carey

Global Product Manager – Data Solutions

Michelle has over 15 years' industry experience in an array of geochemical specialist and senior management roles working for companies including WMC Resources and BHP Billiton. Michelle has worked on numerous commodities, focusing on nickel and gold exploration from strategy development to project execution. She has expertise in diverse geochemical techniques specialising in deep cover exploration approaches such as hydrogeochemistry.



Dr David Lawie

Global Product Manager – Geosciences

Dave is a graduate of the University of New England and has held global positions in Exploration Geochemistry and R&D with both Pasminco and Anglo American before joining ioGlobal as Managing Director in 2004. In late 2012 ioGlobal was sold to Imdex and is now part of the REFLEX Division. As Global Product Manager – Geosciences, Dave's role now involves rolling out these services through a global network and moving REFLEX into real-time, at rig geoanalysis technologies.



Dr James Cleverley

Principal Geochemist

James has 16 years' experience in mineral exploration and mining-related research and development following a Masters degree in Mineral Exploration and PhD in hydrothermal geochemistry from University of Leeds in 2001. He has experience in a wide range of techniques and technologies including application of new technologies in helping the characterisation and delineation of ore systems including portable XRF, software tools such as Leapfrog, advanced x-ray techniques and data analytics.



SAP

As market leader in enterprise application software, SAP (NYSE: SAP) helps companies of all sizes and industries run better. From back office to boardroom, warehouse to storefront, desktop to mobile device – SAP applications and services enable more than 263,000 customers to operate profitably, adapt continuously, and grow sustainably.

Website: www.sap.com

Georg Gradl, Director

SAP for Mining & Metals, SAP



Georg heads a global team of solution managers responsible for SAP's solutions for the Mining and Metals industries. Georg has more than 25 years of business experience in the IT industry including industry solution management in various industries with a strong focus on logistics, manufacturing and operations.

Ruediger Schroedter

Global Lead for Mining, SAP



Ruediger is responsible for solution management globally for SAP solutions for the mining industry. He has spent more than 15 years in the Mill Products and Mining industries and before that had extensive experience implementing SAP solutions for customers in these industries.

Daniel Stimson

Director, IBU Mill Products and Mining, SAP



Dan is a member of industry solution management team responsible for SAP solutions supporting the mill products and mining industries. Areas of focus are the SAP business analytics portfolio and SAP HANA In-memory solutions. Dan has been with SAP for 18 years.

Jennifer Scholze

Senior Director, Global Industry Cloud Content, SAP



Jennifer is responsible for thought leadership and content to support SAP's work with Mill Products and Mining industries globally. Jennifer has spent more than 20 years in the IT industry in various roles including venture capital, solutions and industry marketing, and strategic and field marketing and communications.





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