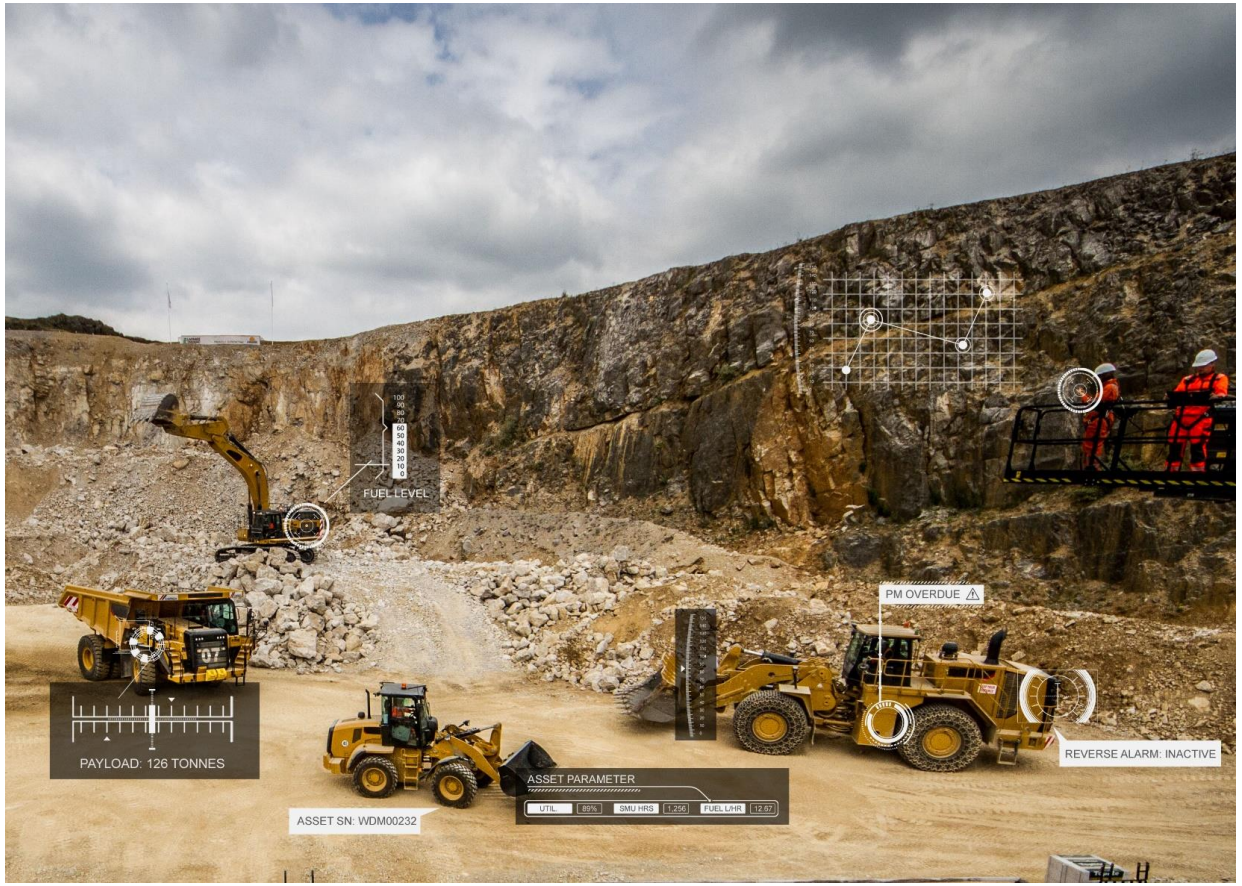
Mining goes Digital –

What have we learned and what are the trends?



What is Digital Mining? Is it all about radical, new technology…

Digital Twins

Mines of the Future ™ (Rio Tinto)

Machine Learning

… or about making better decisions faster (or automatically)

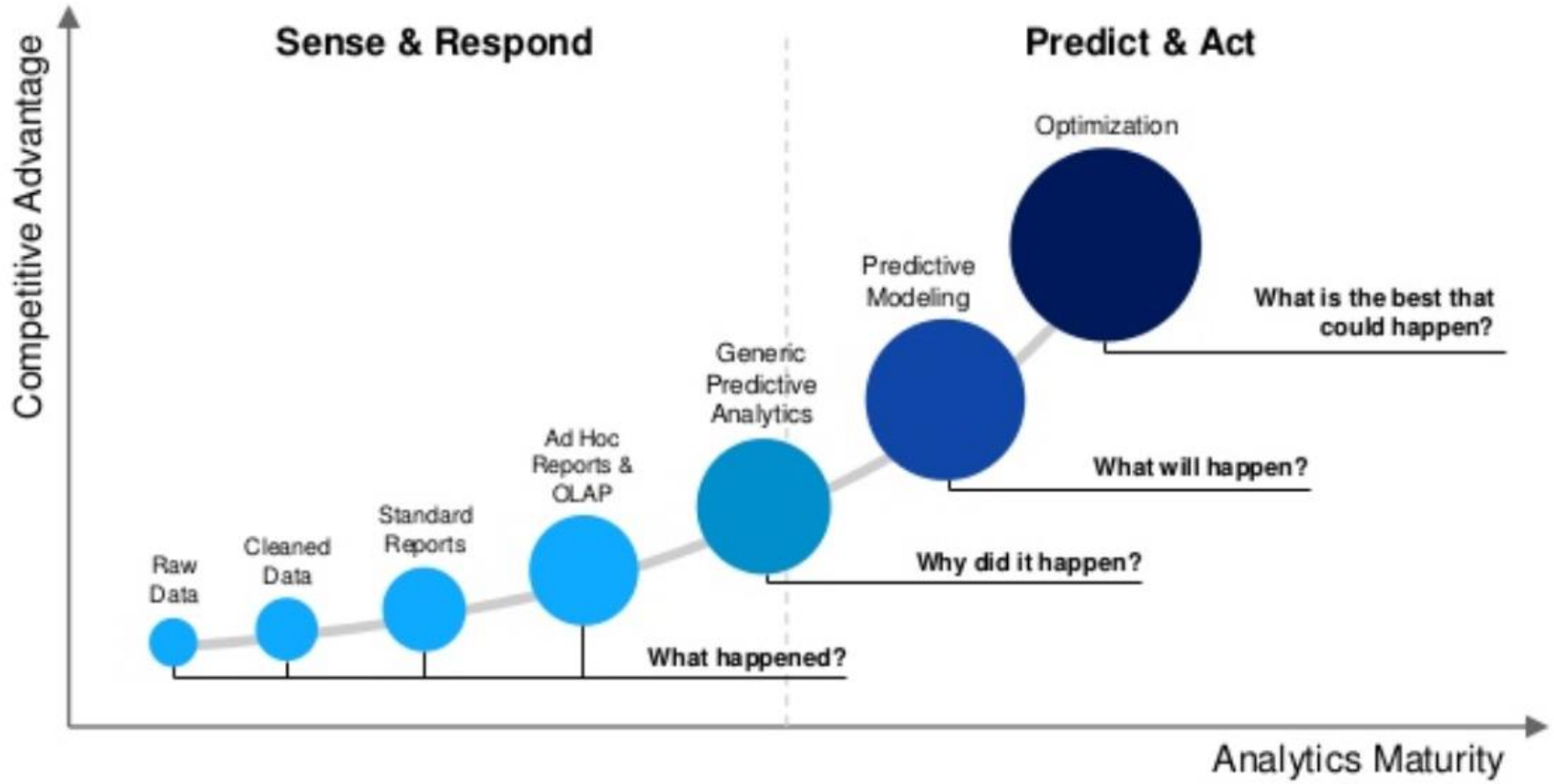
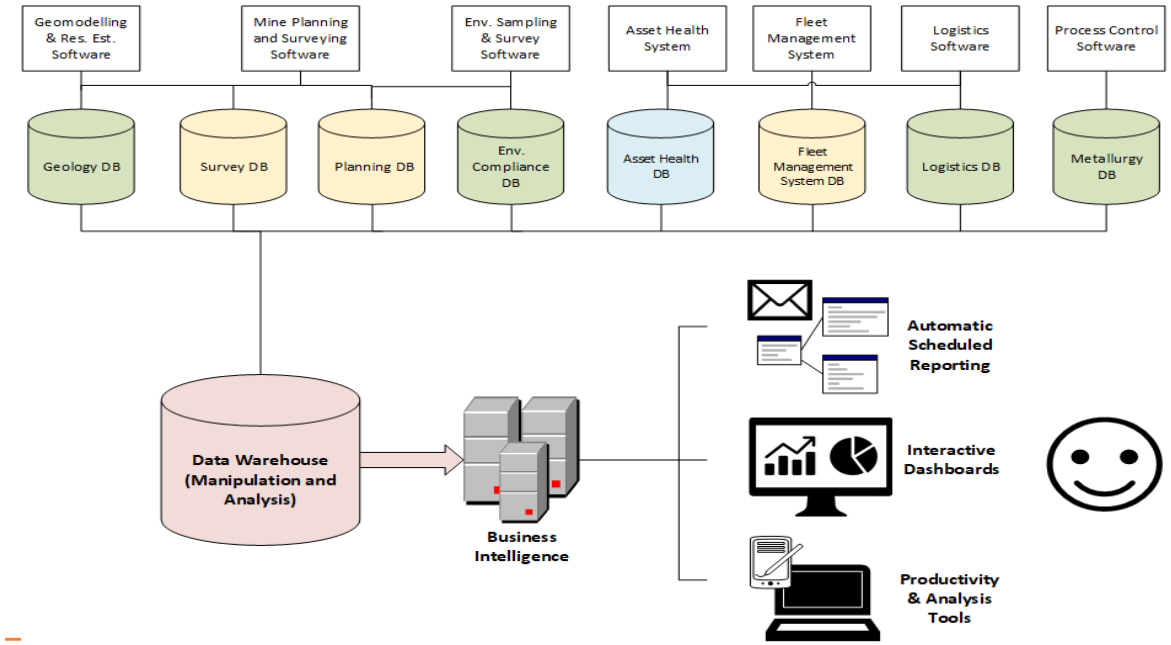


Image Source: [Delaware Consulting Firm]

Key trends: Significant progress with faster communication & data collection

- Most Open Pits now have Fleet Management Systems; many underground mines as well
- Some Open Pits installing private 4G LTE cell systems;
  - Telstra installing a similar system underground at Cannington mine
- Some sites evaluating satellite broadband (Starlink; Project Kuiper)
- Some sites are beginning to move towards data warehouses/consolidation of data



Key trends: making data visible

- In order to make a better decision, you need to identify what exactly is happening

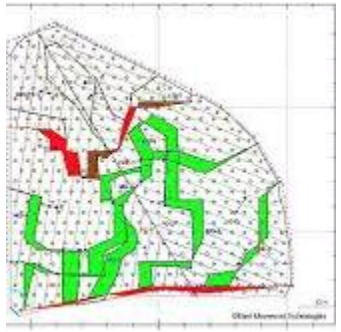
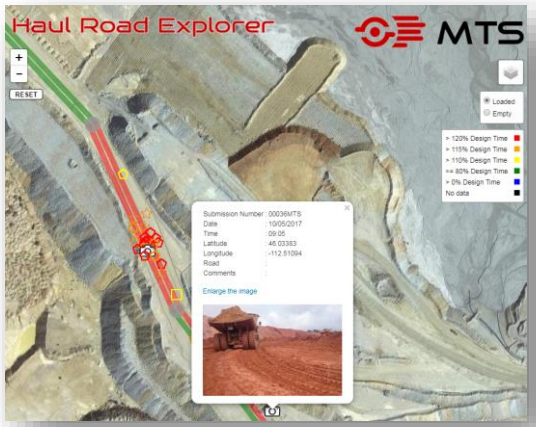
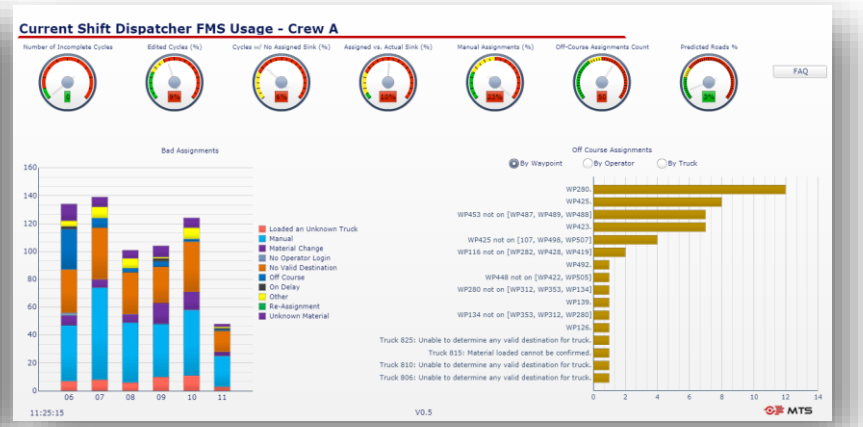


Image courtesy of Blast Movement Technologies





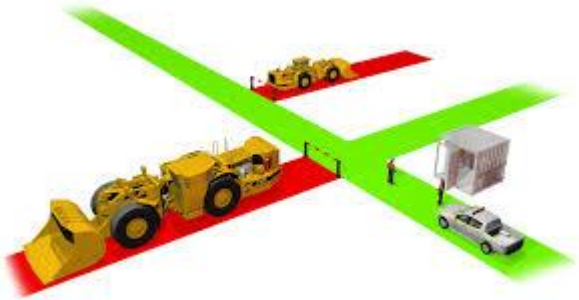
Courtesy of MineTech Services

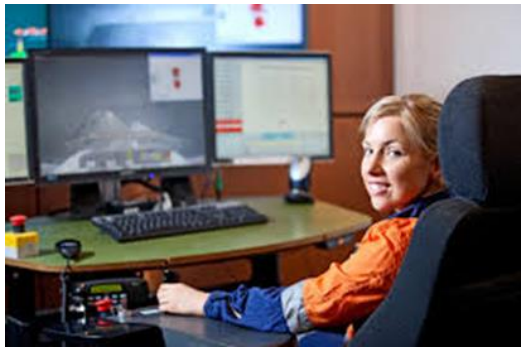
Key trends: Sensors are becoming smarter and providing more insight

- For example, Caterpillar's Driver Safety System (DSS)
  - Installed on over 5000 trucks.
  - Identifies fatigue events: 600,000 fatigue events in 8 million hours. 1641 miles travelled whilst asleep
  - Also identifies distraction events – highlights junctions where visibility needs to be improved

Key trends: remote control of underground mining equipment firmly established

- Currently most operators still site based but could be off-site
- Each operator can operate several machines
- Key challenge is managing interaction with other underground users without upsetting the production cycle



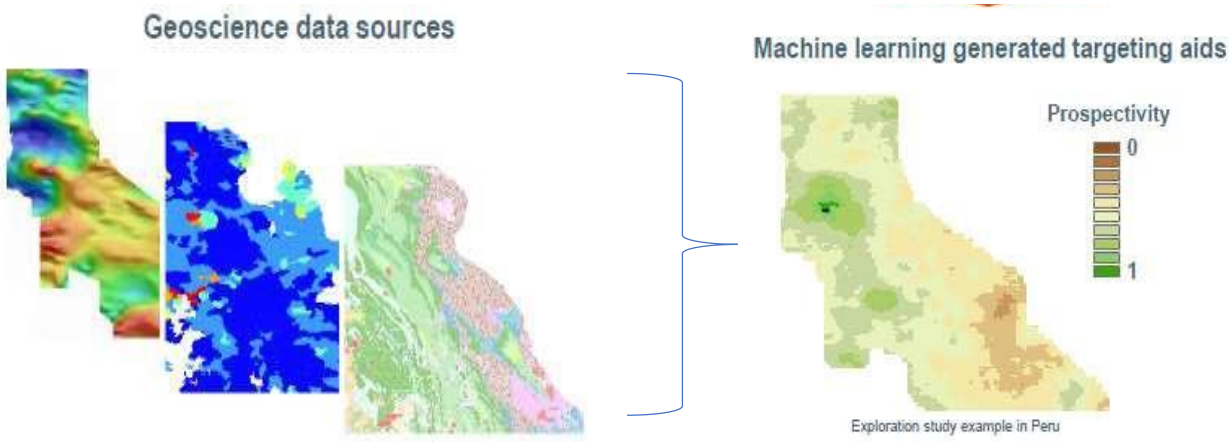


Key trends: Automation is gaining traction outside high wage economies

- Over 400 automated trucks in Western Australia
- 30% of iron ore and 6% of gold from (semi) autonomous operations
- Principal benefits:
  - Increased operating time though can be off-set by delays at junctions or in shared working areas
  - Reduces need to recruit and train labour especially if there is high turnover
- Technology likely to accelerate as automobile manufacturers develop driver-less cars

Key trends: Big Data / Predictive Analytics requires some clear thinking

- Still in the development stage
  - Some projects abandoned as the team overwhelmed by volume of data collected and limited time to process and respond
  - Challenge with getting clean data as well as understanding patterns to search for
  - Successful projects ensure technical specialists are involved
  - Successful projects are being phased to learn the problems whilst they are manageable



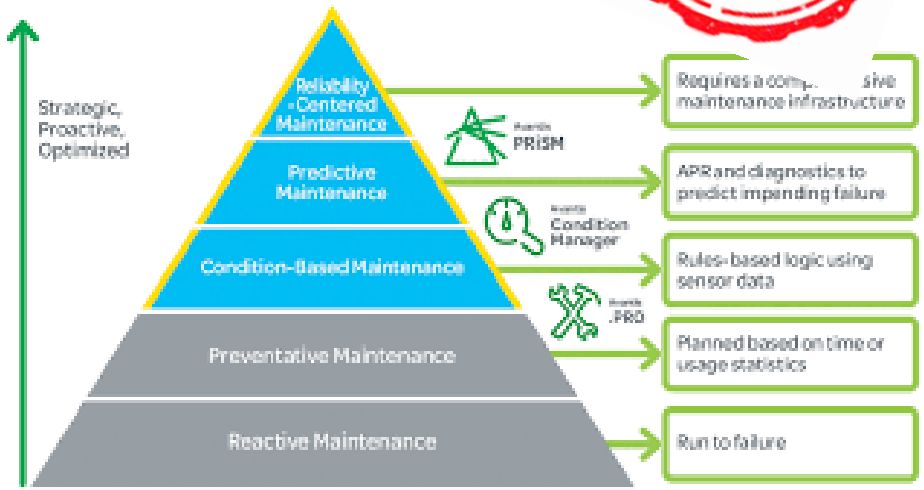


Image courtesy of Schneider Electric

Key trends: Digital twins – true twins or just simulations?

- Ideally a “Digital Twin” models an actual operation to allow what-if scenarios, trade-offs, test out different operational configurations, or operating strategies to be evaluated.
  - Most models are principally simulation models of greenfield projects but still valuable
- Most recent breakthrough is to use simulation models with short term interval control plans in mine plans

Key trends: Augmented reality – currently a niche opportunity

- Aimed at providing field teams with information from databases
- Not in widespread use

Checking conformance with plan

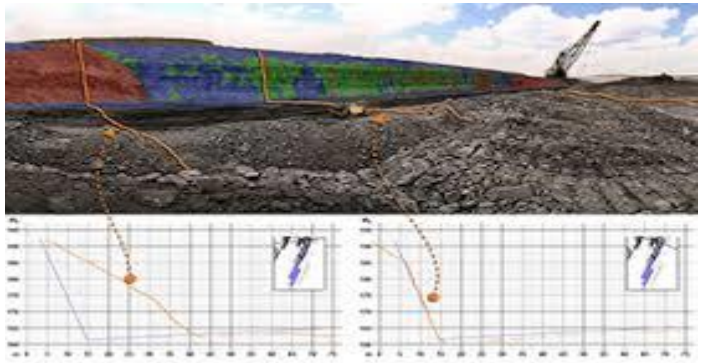


Image courtesy of Maptek

Equipment maintenance

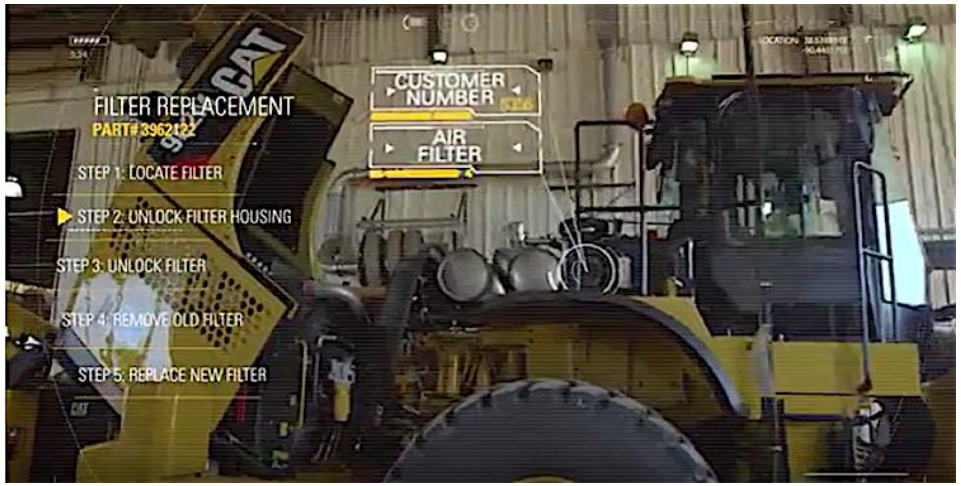


Image courtesy of Caterpillar

Key trends: Changing the paradigm – redesigning trucks

- Komatsu's cab-less truck avoids need to reverse into loading area but has not converted the removal of the cabin into increased payload

Key trends: Changing the paradigm – ore sorting

- Significant economic potential:
  - Reduce comminution costs
    - 3% of global electricity use
  - Enable more productive, less-selective mining methods to be used
- Two key steps
  - Measure
  - Sort – current challenge

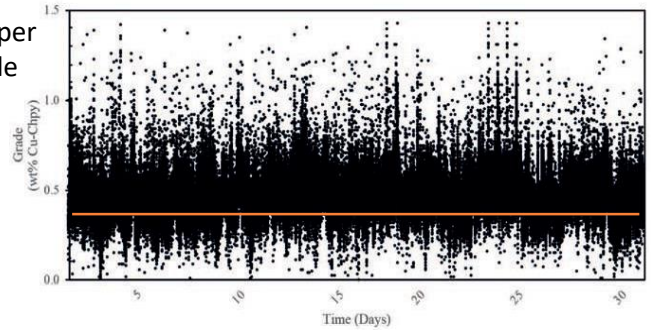
Sensor Type	XRF, Laser, Near Infra-Red, Colour	Gamma	X-Ray transmission	PGNAA*	Magnetic Resonance
Measures / Senses	Surface Composition, Colour	Radiation	Atomic Density	Elemental Composition	Mineral Composition
Sorts	Individual particles	Large pods	Individual particles	Large Pods	Pods (1 – 10 tonnes)
No extra prep (wash, etc)	×	✓	✓	✓	✓
Measures all material	×	✓	×	✓	✓
Accurate grade estimate	×	✓	×	✓	✓
Instantaneous (<10s) result	✓	×	✓	×	✓
Single calibration only	×	×	×	×	✓
Example companies	MineSense; NGMK		TOMRA		NextOre
Example sites	Highland Valley Copper, CA Kokpotas, Uzbekistan	Rossing Uranium, Namibia	Many diamond mines	N/A	Ridgeway block cave, AU
Sorting location	Shovel bucket; truck; belt	Truck	Belt		Belt

* Prompt Gamma Neutron Activation Analysis

Gold sulphide ore sorting in Uzbekistan

	Ore tonnage	Gold contained
Below cut-off	34%	20%
Above cut-off	66%	80%

Copper grade



Consequences of fractal grade distribution for bulk sorting of a copper porphyry deposit, Peter Coghill, David Miljak, Elizabeth Williams

Key barriers

- Unreliable communication network
  - Especially underground and especially when buying “cheap”
- Being over-whelmed with data
  - Need data warehousing system and Business Intelligence tools
  - Need to understand what data is needed to make decisions
- Lack of imagination
  - Be ready to redefine KPIs and what information you need to manage the operation
- Poor maintenance reliability
  - Operational optimisation works best with a stable operation; frequent maintenance events create instability
- Lack of consistency in equipment platforms
  - Difficult to collect data if you operate many different equipment types
- Lack of skilled people with site experience
  - Analysts need to know operational processes

Steps that can be taken now to develop capability

- Develop capability & think about what you really need to measure
  - Review what data you collect now and what data you would like to collect
  - Install appropriate, scalable communication network
  - Develop appropriate data warehouses and BI skills
  - Recruit people to analyse data
  - Review KPIs and dashboards; focus on quick wins
- Understand what you already have
  - The VIMS system on Caterpillar trucks collects a lot of data
- Add sensors & collect more detail
- As you build capability, the next steps become clearer and easier to realise

Enjoy the journey!