Sensing and Sorting

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Program 1: Define
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GRADE ENGINEERING STUDY FRAMEWORK

1. Characterisation
   - Measure & quantify the Grade Engineering® responses of the orebody
   - Conducted through combination of physical testing & data analytics

2. Geometallurgy & Spatial Analysis
   - Understand geological controls on Grade Engineering® responses
   - Spatially map responses defining Grade Engineering® domains

3. Process Design & Simulation
   - Define Grade Engineering® “circuit”, equipment design & specifications
   - Quantify process simulation responses across mining value chain

4. Strategic Mine Planning
   - Develop strategic mine plan incorporating Grade Engineering®
   - Define impact on equipment, layout, material movement, mine development

5. Project Evaluation
   - Quantify the economic impact utilising Scenario Analysis
   - Define implementation options and viability

6. Pilot/Production Trials
   - Technical validation at production scale of Grade Engineering® technology
   - Detailed testing, validation, reconciliation process
GEOSENSING IS A DIVERSE FIELD WITH DIFFERENT USE CASES

GEOSENSING: Ability to routinely measure or infer rock properties at a range of scales using non-destructive scanning devices capable of providing information and data flows which support integrated decision making across the minerals value chain.
GEOSENSING FRAMEWORK BEST RESOLVED BY DISCRETE USE CASES

- Exploration
- Definition
- Resource definition and long term planning
- Planning
- Mining
- Extraction
- Short term planning and execution
- Delivery
- Recovery
- Storage
- Process control and optimisation
SOLUTION STACK EMBEDDED INTO CRC ORE DELIVERY THEMES

GeoSensing Relevant Delivery Themes

- INSTRUMENTING THE BENCH
- COARSE SEPARATION IN THE PIT – RaptORE
- ONLINE SENSING AND SEPARATION
MOST ROUTINE CURRENT GEOSENSORS ARE IN CONCENTRATORS
FAR FEWER ROUTINE GEOSENSORS IN THESE SETTINGS
Grade Engineering response and value driven by five main rock-machine interactions that drive coarse separation opportunity and value – each can see rock in different ways.

Significant delivery outcomes already in place from these two levers

GEOSENSING ADDRESSES THESE TWO LEVERS

Research projects in place
Sensor based bulk sorting involving diversion at truck, shovel or belt scale is logistically attractive.

- Involves bulk diversion of ROM material prior to sizing.
- Scale of separation are loads in the order of 100-300 tons.
- Can be applied to shovels, trucks and conveyors.
- Able to deal with fines and handle large volumes.

Sensor based stream sorting:

- Material needs to screened into specific size fractions.
- Often involves particulate air jet ejection or mechanical ejector fingers.
- Must be combined with other Grade Engineering levers reporting to screens.
- Difficulty dealing with fines with lower throughput compared to bulk.

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Optimising Resource Extraction
Sensor based stream sorting is usually applied to screened size fractions – this is a function of optimising sensor interactions generally involving individual particle ejection.

Particle ejection ideally requires a monolayer presented to the sensor. This can result in high separation efficiency but with much lower throughput compared to bulk sensor-based sorting.

Particulate sorting using high precision air jet ejection nozzles or mechanical ‘fingers’ across a falling conveyor discharge stream is widespread in recycling applications. This is the most common sorting technology concept promoted to the mining industry by the major sorting equipment manufacturers.
DEFINES CRC ORE DEVELOPMENT FOCUS FOR GEOSENSING

Detect
- Optical (VIS)
- 3D shape

Identify
- NIR/SWIR spectral
- Optical (colour)
- UV fluorescence

Quantify
- LIBS/LIFS
- XRF
- Neutron activation
- Gamma activation
- Magnetic resonance

Surface

Penetrate
- X-ray transmission
- Magnetics

CRC ORE focus

GeoSensing Development Participants
<table>
<thead>
<tr>
<th>PERSONAL OBSERVATIONS COMMENTS AND UNFORTUNATELY BIAS</th>
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<tbody>
<tr>
<td><strong>Very few GeoSensors generate unambiguous quantitative data</strong></td>
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<td>GeoSensors can’t compete with controlled ‘lab testing’</td>
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<td>Focus on integrated platforms which support collective decision making</td>
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<td>Not necessarily about data quality its about the decision</td>
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<td><strong>Solution stacks are more important than ‘new’ technologies</strong></td>
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<tr>
<td>Application of 80:20 rule in combination can be 100%</td>
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<td>Too many new technologies on offer when key problem is often industrialization</td>
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<td>Filter from a gap analysis cost/benefit perspective</td>
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<td><strong>Try to share same data types across use cases and function groups</strong></td>
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<tr>
<td>Aim for integration and sharing of GeoSensed data across use group silos</td>
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<tr>
<td>Scale and precision of data can vary but sharing promotes acceptance</td>
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<tr>
<td>What rock properties are fundamentally important across the system.....</td>
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Bulk sorting and differential blasting are to some extent competitive and alternative Grade Engineering levers.

Sensor-based bulk sorting would be expected to have a more precise and sensitive sensor-rock interaction than differential blast design giving superior yield response.

This will be reduced by mixing of in-situ grade heterogeneity by material movement during blasting and digging.
LIMITED EXAMPLES OF SENSOR BASED SORTING IN MINING INDUSTRY

Rough diamond separation from crushed kimberlitic matrix have been in successful use for many years.

This reflects the specialised high-value nature of diamonds and need for automated secure separation.

Sensor based decisions made at truck scale based on bulk element response (uranium content) and a contaminant mineral (laser induced fluorescence of apatite in iron ore).

Particle sorting has also been successfully applied to tungsten ores given the distinctive fluorescence of scheelite and the X-ray attenuation qualities of wolframite.
EMERGENCE OF SENSORS AS ON-LINE CROSS BELT ANALYSERS

Sensing on conveyor belts has been driven by blending and product specification needs of bulk material industries such as cement, coal and more recently iron ore with a focus on detecting major elements and dominant mineralogies.
Current term of CRC ORE will focus on validation and optimisation to ensure that sensors become part of a value-driven integrated solution.

Major ongoing challenges in understanding how predicted grade variability expresses itself at bulk separation scale. These challenges need to be solved and validated to integrate sensors into Grade Engineering system value.

Immediate need to progress understanding is to install and monitor appropriate sensors on a production belt for extended periods. This needs to be linked to variability and heterogeneity assessments of related production areas.
Involves bulk diversion
Scale of separation are loads in the order of 100-300 tons
Can be applied to shovels, trucks and conveyors
Able to deal with fines and handle large volumes

Sensor based bulk sorting

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Often involves particulate air jet ejection or mechanical ejectors
Must be combined with other GE levers reporting to screens
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Sensor based stream sorting

Different Scales of Heterogeneity
MAGNETIC RESONANCE BULK SENSING ON PRODUCTION BELT
PARTICLE SORTER SEPARATION MECHANISM

Video Source:
USE CASE SUMMARY OF CRC ORE GEOSENSING INTEGRATION STRATEGY

**DOWN HOLE PFTNA TOOLS**  
*Sodern, CSIRO*

**CROSS BELT PFTNA TOOLS**  
*Sodern, CSIRO, suppliers*

**CROSS BELT GA TOOLS**  
-CSIRO

**IN/TOP OF HOLE TOOLS**  
*Imdex, suppliers*

**LASER-BASED NEXT-G LIBS AND LIFS**  
-Univ Adelaide, NRC Canada

**HETEROGENEITY TOOLS**  
*DATA 61, QUT*

**DYNAMIC PARTICLE SIZE DISTRIBUTION**  
-suppliers

**MAGNETIC RESONANCE CPY**  
-CSIRO, suppliers

**SWIR and NIR SPECTRAL SCANNING**  
-suppliers

**OTHER PHASING AND CROSS BELT TOOLS**  
-suppliers

**OTHER SCANNING AND CROSS BELT TOOLS**  
-suppliers

**BLAST MOVEMENT MONITORING and ORE TRACKING**  
-suppliers

**NEXT-G TRACKING**  
-Under development

**DYNAMIC PARTICLE SIZE DISTRIBUTION**  
-NEXT-G options

**MAGNETIC RESONANCE CPY**  
-OTHER PHASES - CSIRO

**SWIR and NIR SPECTRAL SCANNING**  
-OTHER PHASES - CSIRO

**as is technology**  
-CRC ORE Centre Funded projects
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