Using Sensors to Exploit Heterogeneity
(Another lever towards Grade Engineering)
Different sensing technologies at different spatial scales

<table>
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<tr>
<th>SCALE</th>
<th>SENSING TECHNOLOGY</th>
<th>SEPARATION PROCESS</th>
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<td>BLOCK</td>
<td>• Mine plan drilling, downhole tools</td>
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<td>• Bench sampling (manual &amp; auto)</td>
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<td>Dynamic truck routing In-pit conveying</td>
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<td>BENCH / SUB BENCH</td>
<td>• Blast hole logging</td>
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<td>• Instrumented shovels/ trucks</td>
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<td>• Sensing in intermediate shovel-truck gantries</td>
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<tr>
<td>“FINE SCALE” (1-100t)</td>
<td>THIS TALK! Post primary crush on-conveyor sensing</td>
<td>Bulk sorting using divertors</td>
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<td>INDIVIDUAL PARTICLE</td>
<td>• Variety of fast sensors</td>
<td>Sorting using pneumatic actuators</td>
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</table>
Bulk Ore Sorting

- Fast, bulk sensor
- Primary conveyor
- "Conventional" ore handling
- CONTROL
- Groups of rocks measured at the same time
- High grade
- Low grade
Bulk Ore Sorting

Value Proposition

• Advisian techno-economic bulk sorting analysis tool, based on CSIRO heterogeneity models
• Grade uplift depends on heterogeneity, “mixing index”
• Very significant NPV under various scenarios

Knowledge Gap

• Uplift uncertainty due to lack of firm data on fine scale heterogeneity and mixing
• Initial trial of CSIRO on-conveyor technology can fill the “fine scale” data void
Copper Bulk Sorting: Magnetic Resonance (MR)

Radio Spectroscopy (MHz band)
- Related technology to MRI
- Good penetration of radio waves into and out of rock
- Mineral specific response (not elemental)
- Excellent, robust detection limits
- Cu, Fe, As minerals favoured

- Already at TRL 6 for on-conveyor chalcopyrite detection
- Existing CRC Centre funded project to enhance MR technology for covellite detection (completion March 2017)
MR Bulk Sensing Trial

- MR advanced prototype sensor trial at Ridgeway Deeps 2013/14
- Configured for direct, quantitative chalcopyrite detection (as a gold proxy)
- Robust, continuous operation
- 1300tph belt, 300mm top size
- Sensor scalable to > 5000tph
MR Bulk Sensing Trial

- 20 s measurement time
- 7 tonne pod size
- 470ppm resolution Cu-as-chalcopyrite
- 1200ppm detection limit (3-σ)
- Recent X3 speed improvement obtained

Variation persists (despite block cave operation)
MR Bulk Sensing Trial

Grade Histogram
7t pod population versus grade, on Ridgeway Deeps block cave primary conveyor (6-month period)

MR Trial Readiness

• An initial MR sensing trial (retrofittable installation) can provide a pod frequency vs grade histogram for an open pit copper mine.
• Inform bulk sorting techno-economic analysis with firm data relating to exploitable grade variation at the measurement position.
• Test-bed towards a full sorting solution
Gold Bulk Sorting: Gamma Activation Analysis (GAA)

GAA Attributes
- Direct Au detection
- Extreme sensitivity
- Good gamma ray penetration

- Related technology to CSIRO GAA sample analysis
- On-conveyor GAA at TRL 3
- Current Centre funded feasibility project near completion
- CRC Centre proposal for 2017 to bring to buildable design TRL 4
GAA Current CRC Feasibility

- 0.1ppm sensitivity predicted by Monte Carlo modelling
- Sensitivity depends on levels of K, Th, U, throughput
- 10s measurement time, up to 1000tph, 150mm bed depth max
- Radiation dose at public limits, modelled by radiation transport code
- Assumptions to be tested by sample and detector measurements in the next few months
GAA Current CRC Feasibility

Gold Heterogeneity

- Anecdotally gold “high variation”
- WA Geoview core library
- Initial study shows potential for exceptional grade uplift and NPV
GAA Path to Implementation

Current CRC Centre Project
- Concept design completed, with some supporting modelling/testwork
- Very encouraging estimates for GAA performance
- Completion early 2017

Follow-on CRC Centre Project (Current Proposal)
- Complete full build design, supported by extensive modelling and lab testwork. Construction of key detector hardware
- Explore opportunities for pilot site
- Completion early 2018

Construction / Testing of Pilot Unit
- 2018-2019
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