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General Manager
- Research & Innovation

CRC ORE Research Pipeline Overview
CRC ORE Annual Assembly 2017
CRC ORE Applied Research Program Overview – Based on End Point Deployment

**Current**

1. Preferential grade deportment by size
2. Differential blasting for grade by size
3. Sensor based BULK sorting
4. Sensor based STREAM sorting
5. Coarse gravity separation

**Planned**

1. In-situ Sensing Mineral
   - Elemental: Imex, Sodern, CSIRO
   - Mineral: Scan Sensing – IDEX, Sodern, CSIRO

2. Instrumentation & Application – Imex, Sodern, Atlas, Mining3, Orica, IDG (ITB)

3. Heterogeneity Tools – CODES, Mining3, Data61, Uni. of Adelaide, Curtin

4. Blast Design – Orica, Mining3, IDG

5. Spatial Modelling – IDG, University of Adelaide

6. Response Ranking & Economic Optimisation – IDG

7. In Pit Crush, Separate & Surge Control – Hatch, Mining3

8. Breakage Response Modelling – P420F - Curtin, P9Q - JKMRC

9. Comminution Optimised for Grade Engineering – JKMRC, Curtin, CSIRO, Gekko, IDG

10. Integrated Extraction Simulator – IDG, JKTech, P9Q, P420F, Curtin, UQ, QUT

11. Program 4: Control Architecture for Grade Engineering (GE)
   - GE Scenario Planning, GE Mine Planning & Scheduling, Multi-dimensional Data Analytics, Decision Logic, Organisational Change (Manufacturing Execution System)

12. Blast Design – Orica, Mining3, IDG

13. Breakage Response Modelling – P420F - Curtin, P9Q - JKMRC

14. Coarse Separation – DMS, IPJ, Leach, Reflux Classifier, Coarse Particle Flotation
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Future Research themes

**Geo-sensing**
- Multi-sensor integration.
- Rapid hold drilling & in-situ sensor applications.
- Direct sensing of mineralisation & blast optimisation parameters.

**Resource Interpretation**
- Geo-spatial modelling.
- Enhanced orebody characterisation within Grade Engineering context.
- Integrating Grade Engineering attributes into mine planning tools.

**Separation**
- Gravity separation technologies (GE lever 5).
- Enhancing the linkage between comminution & flotation models.
- Developing the control architecture for Grade Engineering implementation.
P1-005: Upconversion Fluorescence (UF) for real-time mineral identification

Create Upconversion Fluorescence facility and explore UF from minerals to find mineral-specific UF for real-time mineral sensing

**Affiliation**
- 4 academic staff
- 1 PhD students
- Sept 2016 - Sept 2019

**Resources**
- Laser and optics development
- Luminescence studies

**Key results to date**
- Facility creation on track – key hardware integrated into facility; software integration on track.
- Initial tests of system performance, data collection and processing techniques underway.

**What success looks like**
- Goal 1: Library of UF wavelengths suitable for real-time identification of specific mineral species.
- Goal 2: Concept demonstration of sensor systems for excitation and detection UF from target minerals.
- Benefits: real-time, mineral species-specific, non-contact; applicable to multiple areas of mining and processing.
P1-006: Geometallurgical controls on grade by size
Evaluate how mineralogical/textural heterogeneity drives grade by size fractionation for predictive modelling

Affiliation
• Nathan Fox and Ron Berry
• 2 PhD and 2 MSc students
• October 2016 to June 2021

Resources
• Mineral systems
• Ore mineralogy and textures
• Geometallurgy

Key results to date
• Workflow designed to utilise emerging technologies for mineral mapping and feature extraction
• Dedicated study sites (Au) with integration in other CRC ORE study sites (porphyry Cu).

What success looks like
• Geometallurgical framework for predicting grade by size fractionation as a block model attribute.
• Provides a physical understanding of controls on mineral fractionation in mineral systems.
**P1-009:** **Gamma activation for bulk gold ore sorting**

A design study for a pilot bulk sorting plant capable of measuring gold on-belt at ~0.1-0.2ppm

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**Affiliation**

- 4 researchers
- 1 student
- Apr 2018 - Mar 2018

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**Resources**

- Measurement Physics

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**Key results to date**

- Good results for simulated sensitivity and plant shielding.
- Proven success with switching of detectors.
- Sensible sample results.
- No direct measure of gold on-belt contemplated before this research project.

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**What success looks like**

- Direct gold measurement for relevant grades and ore flow rates.
- A pilot demonstration of the technique, preferably at Kalgoorlie Hub.
- Apply in mining situations to reject significant fractions of gangue through bulk ore sorting.
# In-Situ Rock Mass Characterisation - Phase 1

Identify superior approaches and systems for characterising in-situ material to enable optimal blast designs for ore upgrading

## Affiliation

- 4 Mining3 staff,
- Technology experts
- Nov 2016 - Dec 2017

## Resources

- Differential blasting
- Ore body knowledge

## Specialisation

- Identified existing and emerging technologies for application to in-situ rock mass characterisation.
- Assessed new approaches to combining these for application and deployment.

## Key results to date

- Platforms such as enhanced MWD, drones or rovers with multiple sensors, integrated via data fusion techniques
- Determination of in-situ spatial heterogeneity at the sub-metre scale required for differential blast design

## What success looks like
P2-002: Advanced blast design for maximising value through Grade Engineering levers
Developing optimised designs for GE in a production environment

Affiliation
• 6 Mining3 staff,
• 1 MEng student
• July 2017 - Feb 2018

Key results to date
• Fragmentation models and optimisation methods reviewed and selected.
• MVP architecture decided and being coded.

Resources
• Differential Blasting
• Optimisation

Specialisation
• 6 Mining3 staff,
• 1 MEng student
• July 2017 - Feb 2018

What success looks like
• A module that enables any Drill and Blast Engineer on site to create a GE differential blast design with the optimal value identified via IES
• Moving from a single blastability index for the blast to consider spatial heterogeneity of grade, rock mass and response ranking.
P2-003: Searching for Orebody DNA

Testing methods to identify and learn the recurring patterns in orebody mineralogy and then predict mineral heterogeneity within sparse datasets

Affiliation

• 6 people, 1.8 fte
• Students etc..
• Mar 2017 - Mar 2018

Resources

• Data analytics
• 3D feature and pattern detection

Specialisation

Key results to date

• Results obtained for non-linear analytics, k-means clustering, image and signal processing methods, feature detection, machine learning.

What success looks like

• Demonstration of algorithms that avoid large scale averaging that occurs with conventional (e.g. Kriging) resource modelling methods

• Spatial and volumetric prediction of grades at higher resolution than conventional methods.
P2-004: Real-time elemental and mineralogical analyser based on combined LIBS and Mid-IR spectroscopy

Proof of concept study to develop a novel new application of combined LIBS - Mid-infrared quantum cascade laser (QCL) spectroscopy for real time on-line mineralogical characterisations.

Affiliation

- 9 Research Officers
- 3 Technical Officers
- Aug 2017 - July 2019

Resources

- Optical sensors for
- Real-time process control

Key results to date

- Review of current LIBS and IR technologies for mineral industry applications nearly completed
- Comparison of XRF, MLA and LIBS measurements on the same tiles in progress.

What success looks like

- Positive outcomes would generate a TRL5 ready application with proof-of-concept at lab scale for mineralogy measurement.
- Ready for field deployment and transfer to METS companies
- Fast, non-nuclear, in-field method for mineral assessment
P3-005: Coarse Particle Liberation & Recovery

Develop an ore characterisation method and subsequent model to evaluate liberation and separation methods for Au ore in the 4.75 – 0.3 mm size range

**Affiliation**
- WASM Gold Technology Group at Curtin University

**Resources**
- 5 of 15 staff
- 4 of 10 HDR students
- Feb 2017 – Feb 2020

**Specialisation**
- Ore characterisation
- Gangue rejection
- Optimisation

**Key results to date**
- Have developed and are refining ore characterisation method.
- Applying method to multiple ores with multiple crush types to investigate preferential liberation.
- Investigating various separation devices to determine optimal recovery scenarios for each ore and crush type.

**What success looks like**
- Understand attributes that make an ore amenable to coarse particle liberation by building a database of responses for various ore types, crushing modes and separation devices.
- Standardise the method and build a model in IES to predict responses and optimise recovery.
**P3-006: AMIRA P9Q**

Translate P9 research outcomes to an integrated process improvement tool (IES)

**Affiliation**
- 6 research institutes
- 11 industry sponsors
- 2017-2020

**Resources**
- Mineral processing
- Modelling

**Key results to date**
- Delivery of 6 process models in IES P9Q platform.
- Training workshop:
  - *Introduction to IES.*
  - *Introduction to process models.*

**What success looks like**
- Integration of comminution and flotation.
- 11 validated multi-component models.
- 2 test circuits for validation of process integration.
**P3-008: Comminution optimised for Grade Engineering**

Enhancing coarse gangue liberation through precisely controlled breakage energy using traditional and next generation Vertical Shaft Impactor (VSI) technologies

**Affiliation**

- RM, VJ, CA, PW
- 3 MPhil students
- Nov 2017 - Oct 2019

**Resources**

- Ore characterisation
- Selective ore breakage

**Key results to date**

- Project is in the early stages.
- One student has started.
- Some preliminary testing has been carried and the results have been reported to CRC ORE.

**What success looks like**

- Rejection of coarse clean gangue from a wider range of ore types.
- Use precisely controlled breakage to enhance the current GE approach.
- Laboratory testing protocols to identify ores suitable for coarse liberation.
- Significant reduction in unite energy consumption
P4-003: Data-driven models

Develop robust and effective data analytics approaches to extract value from data typically collected in the ore mining industry

**Affiliation**

- QUT

**Resources**

- 5 academics
- Jan 2017 – Dec 2018

**Specialisation**

- Data analytics
- Mathematical modelling
- Data-driven models

**Key results to date**

- Methodology and scripts to pre-process and analyse disparate data sets with visualisation in Power BI.
- Paper: Computational Modelling 2017
- Implementation of *uncertainty quantification* approaches to calibrate a crusher process model
- Initial approach to create *machine learning models* using process data and ore data

**What success looks like**

- New data-driven approach to calibrate process models using online process data, based on uncertainty quantification.
- Collection of methods and scripts to generate machine-learning based process models.
- Methods and scripts to clean, pre-process, and extract useful information from data (e.g. processing recipes).
Implementation Accelerator

Embed a process to fast track the implementation of CRC ORE’s technologies, based on Clareo’s proven FastPath methodology, incorporating principles of LEAN start-up and learning

Affiliation
- 4 person Clareo team
- CRC ORE members
- Pilot project

Resources
- Rapid and lean approach to innovation implementation

Key results to date
- Kicked off engagement in November after alignment on scope and approach.

What success looks like
- Develop and deliver an Accelerator program designed for CRC ORE.
- Deploy on one demonstration project initially.
- Once proven, wider deployment of the Accelerator program across CRC ORE.

Proven approach

BHP
Anglo American
Edison International
Baker Hughes
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