PRIF RCP
‘Unlocking Complex Resources through Lean Processing’

2021 Annual Assembly

1st October 2021

Brochure

Watch it on YouTube: https://youtube.com/playlist?list=PLIgDYZIzNDZK4Q-lUWORz8yZnfZuDjfDy

Outline

** Presentation slides are available on UoA Box on request (tatiana.khmeleva@adelaide.edu.au)*

2021 PRIF MINING CONSORTIUM ANNUAL ASSEMBLY

AGENDA

#	Time	Project Code	PhD/PDRF/ CIs	University/ School	Project Title	Supervisor	Translation Partner
1	9:30 – 9:35		**Prof Nigel Cook** Consortium Director	UoA, School of Civil, Environmental and Mining Engineering	Welcome and Introduction		
2	9:35 – 9:55	**Guest Speaker**	**Prof Caroline McMillen** Chief Scientist	Department for Innovation and Skills (DIS), SA Government	Innovation and Integration, Increasing Productivity for South Australia		
				PROGRAM A			
3	9:55 – 10:00		**Prof Peter Dowd** Program A Leader	UoA, School of Civil, Environmental and Mining Engineering	Program A overview		
4	10:00 – 10:15	A RP2	**Yusha Li** PhD Candidate	UoA, School of Civil, Environmental and Mining Engineering	Resource heterogeneity modelling for optimal ore extraction	Prof Peter Dowd A/Prof Chaoshui Xu	OZM
5	10:15 – 10:30	A RP3	**Yerniyaz Abildin** PhD Candidate	UoA, School of Civil, Environmental and Mining Engineering	Constraints and quantifying uncertainty on resource domain boundaries	Prof Peter Dowd A/Prof Chaoshui Xu	Maptek
6	10:30 – 10:45	A RP5 Linked to A TP4	**Hirad Assimi** PhD Candidate	UoA, School of Computer Science	Resource heterogeneity modelling from trucking to multiple stockpiles to mill feed	Prof Frank Neumann Dr Markus Wagner	Eka
7	10:45 – 11:00	A TP4 Linked to A RP5	**Dr Shi Zhao** Postdoc	UoA, School of Mechanical Engineering	Fast ROM Stockpile Modelling for Blending Optimization	Dr Tien-Fu Lu A/Prof Larissa Statsenko	Eka
8	**11:00 – 11:15**	**Morning Tea**					
9	11:15 – 11:30	A RP6 Linked to A TP5	**Yue Xie** PhD Candidate	UoA, School of Computer Science	Blend strategy optimisation	Prof Frank Neumann	OZM
10	11:30 – 11:45	A TP5	**Dr Aneta Neumann** Postdoc	UoA, School of Computer Science	Advanced ore mine optimisation under uncertainty	Prof Frank Neumann	Maptek
11	11:45 – 12:15	**Guest Speaker**	**Gavin Yeates** Chair of the PRIF Consortium	Gavin Yeates Consulting Pty Ltd	Copper for Tomorrow CRC		
12	12:15 – 12:30	Program A - Discussions and Questions					
13	**12:30 – 13:15**	**Lunch**					

AGENDA (continues)

PROGRAM B							
14	13:15 – 13:20		**Prof Bill Skinner** Program B Leader	UniSA, Future Industries Institute	Program B overview		
15	13:20 – 13:35	B RP1	**Kwaku Boateng Owusu** PhD Candidate	UniSA, Future Industries Institute	Sensing and optimisation of autogenous and semi-autogenous grinding mills	A/Prof Max Zanin Prof William Skinner Dr Richmond Asamoah	Manta Controls
16	13:35 – 13:50	B RP2	**- Pranay Prakash,** **- Tosan Bolorunfe,** **- Haodong Chun,** **- Sakib Shafayet,** **- Khaled Bin Zia**	UoA, School of Mechanical Engineering – Honours Students	Predictive machine health monitoring for SAG/AG mills	Dr Lei Chen	BHP
17	13:50 – 14:05	B RP3	**Dr Difan Tang** Postdoc	UoA, School of Mechanical Engineering	New Sensor Development for particle size measurement in Hydrocyclones	Dr Lei Chen	Manta Controls Rockwell Automation
18	14:05 – 14:20	B RP4	**Bismark Amankwaa-Kyeremeh** PhD Candidate	UniSA, Future Industries Institute	Sensing and optimisation of flotation circuits and integration with grinding	A/Prof Max Zanin Prof William Skinner Dr Richmond Asamoah	Manta Controls Magotteaux
19	14:20 – 14:35	B RP5	**Linda Rozenberga** PhD Candidate	UniSA, Future Industries Institute	Metal Organic Framework based fibre-optic sensors	Prof David Beattie A/Prof Marta Krasowska Prof William Skinner Prof David Lancaster	Magotteaux
20	14:35 – 14:50	B RP6	**Kirsten Louw** PhD Candidate	UniSA, STEM	Diffusive processes in mineral processing	Dr Bronwyn Hajek A/Prof Marta Krasowska Prof Jim Hill Prof William Skinner	Magotteaux
21	**14:50 – 15:05**	**Afternoon Tea**					
22	15:05 – 15:20	B RP7 Linked to B TP9 and B TP10	**Dr Todd Gillam** Postdoc	UniSA, Future Industries Institute	Formation of MIP particle film on substrate and successful detection of flotation frothers via gravimetric detection	A/Prof Marta Krasowska A/Prof Anton Blencowe Prof William Skinner Prof David Beattie	Magotteaux
23	15:20 – 15:50	TP7&11 Linked to RP1, 2 TP8 Linked to RP3 TP9&10 Linked to RP4, 5, 6, 7	**Dr Richmond Asamoah** Postdoc	UniSA, Future Industries Institute	TP7: Manta Mic Acoustic Analyser TP8: Ultrasonic PSD sensors TP9: Pulp Chemistry Monitor (PCM®) TP10: Tails Leach Circuit/ MOF sensors TP11: Development of Laboratory AG/SAG mill	A/Prof Max Zanin Prof William Skinner Prof David Beattie	Manta Controls Magotteaux
24	15:50 – 16:00	Program B - Discussions and Questions					
25	16:00 – 16:10	**Panel: Wrap Up and Discussions** Prof Nigel Cook, Prof Peter Dowd and Prof William Skinner					
26	**16:10 – 17:00**	**Networking and Drinks**					

Government of South Australia
Department of State Development

PREMIER RESEARCH AND INDUSTRY FUND RESEARCH CONSORTIA PROGRAM

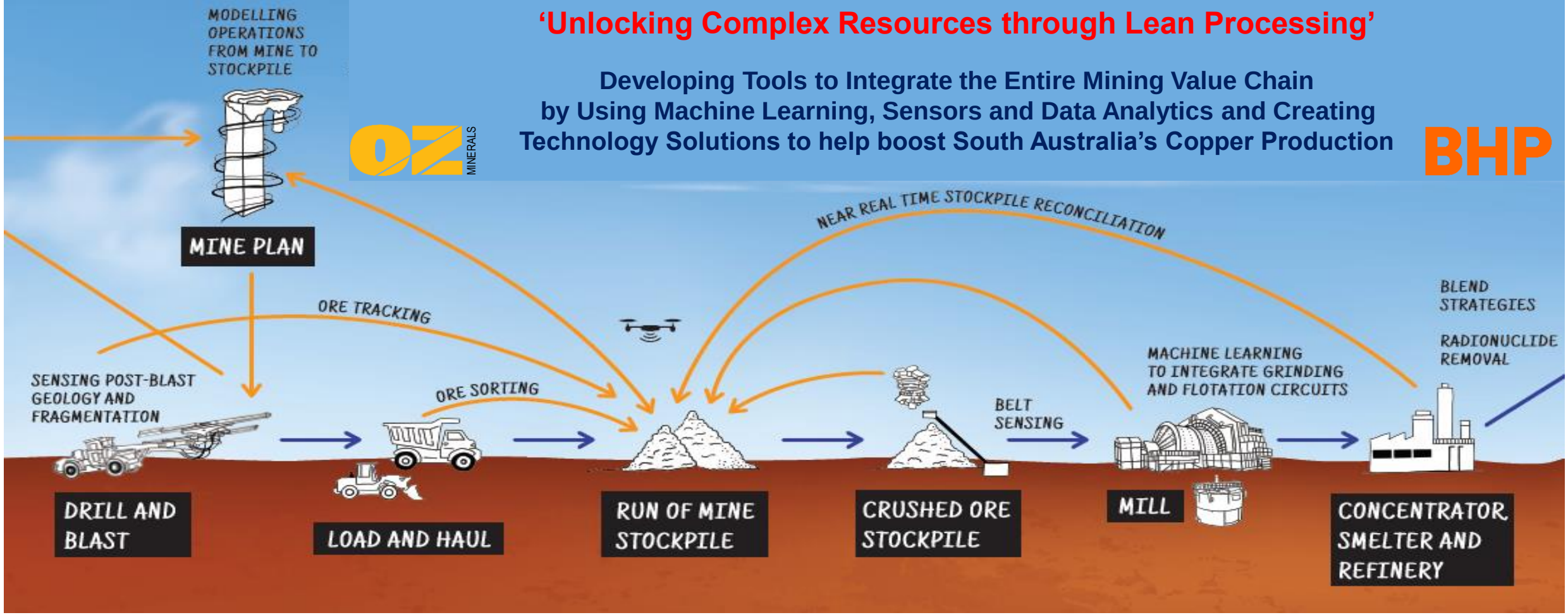
INTEGRATED MINING CONSORTIUM

'Unlocking Complex Resources through Lean Processing'

Developing Tools to Integrate the Entire Mining Value Chain by Using Machine Learning, Sensors and Data Analytics and Creating Technology Solutions to help boost South Australia's Copper Production

OZ MINERALS

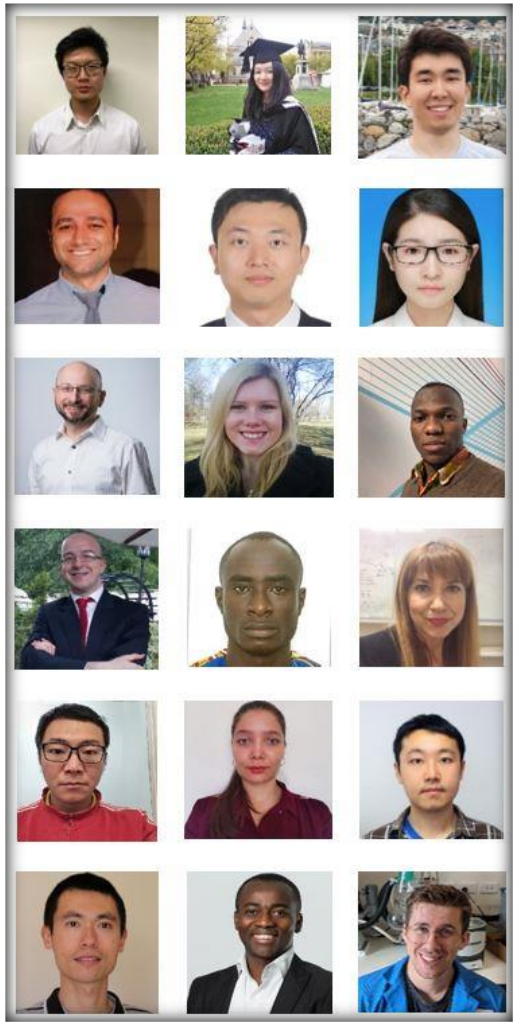
BHP



Government of South Australia
Department of State Development

INTEGRATED MINING CONSORTIUM

OZ MINERALS
BHP
amira

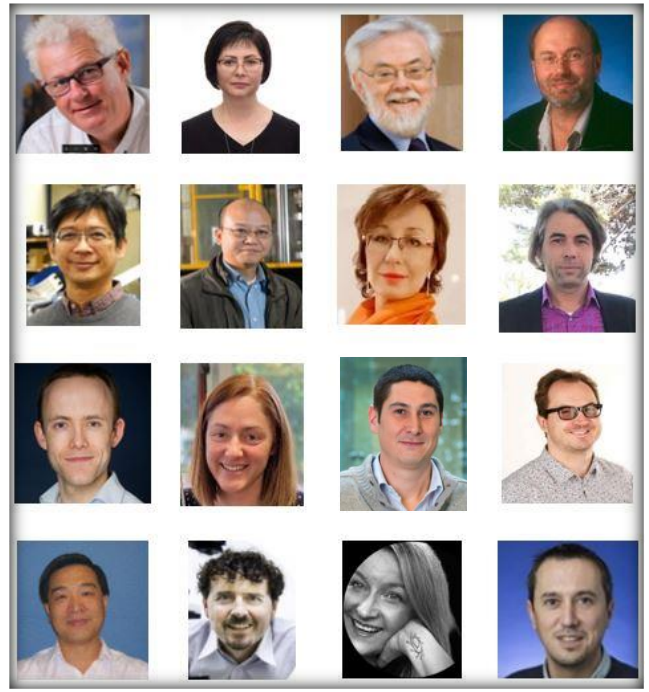


WHO ARE WE?

- Five-year initiative started in October 2017 with total cash and in-kind ~ $14.1M.
- The End Date – 28th February 2023
- 17 industry partners and 2 university partners.
- Two Programs: Program A focus is the optimisation of Upstream processes of the mining value chain; Program B focuses on mineral processing – Downstream.

14 Research Projects, 11 Translation Projects.

- Projects aligned and focussed to the specific areas of interest of the key End-User Partners (OZ Minerals - Program A and BHP - Program B)
- 15 experienced researchers in mining, mineral processing and computer science, 10 research students, 8 postdoctoral researchers, 4 Masters, 2 Bachelor and 9 Honour students.



consilium TECHNOLOGY
BOART LONGYEAR
BUREAU VERITAS 1828
datanet BARCODE RFID WIRELESS
eka
SCANTECH
MAPTEK
MANTA CONTROLS LEADERS IN ADVANCED PROCESS CONTROL
MAGOTTEAUX

Consortium objectives

1. Address End-User Partner challenges to maximise value from complex resources and minimise environmental impacts;

2. Demonstrate the value of, and provide innovative tools for, integration between the resource, mining, ore delivery, processing and leaching stages;

3. Commercialise technological outcomes for global market opportunities in collaboration with our Translation Partners.

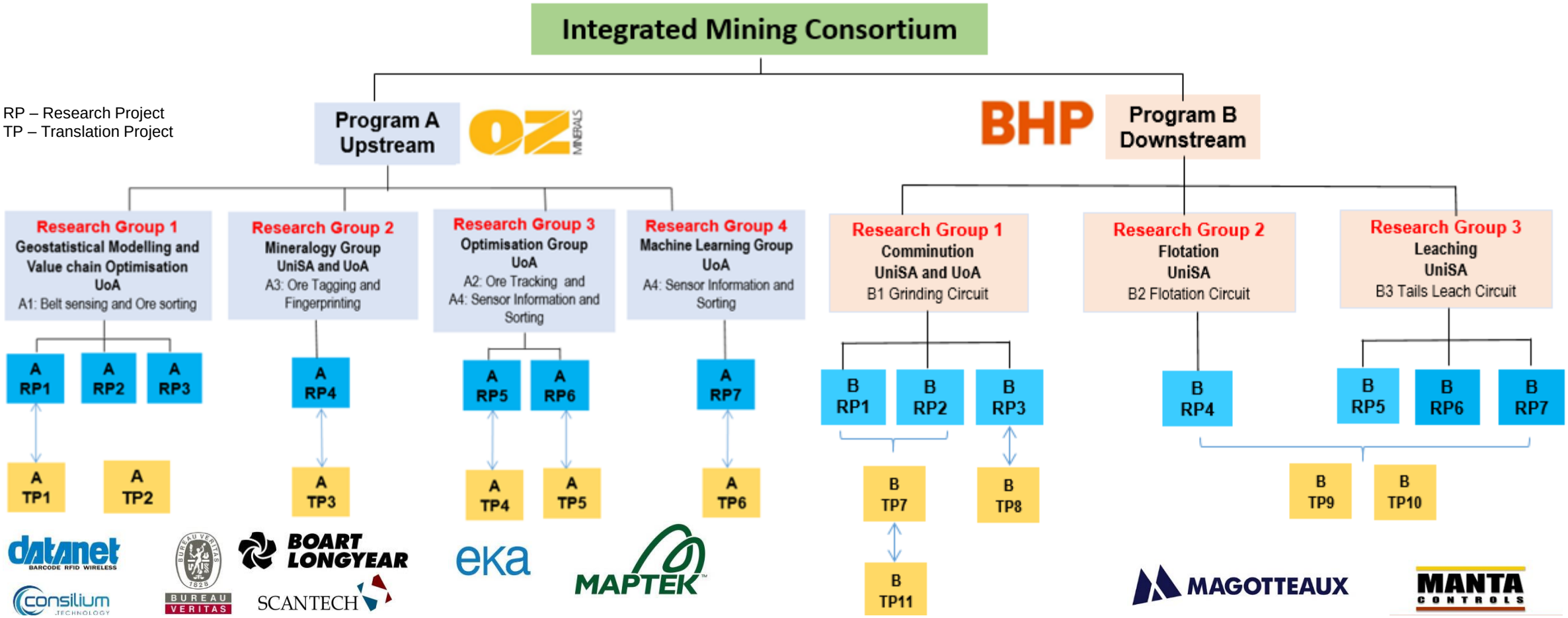
2021 Highlights

- First of our students have completed their research theses;
- Training of skilled confident researchers ready to join the workforce;
- More than 100 publications and participation at major conferences;
- Significant progress in reaching real data milestones in partnership with our translation partners;
- Platform for development of new multi-university, multi-partner initiatives consolidating Adelaide's position as the hub for collaborative research with the minerals industry;
- Visit our website: https://www.adelaide.edu.au/imer/integrated-mining-consortium/

INTEGRATED MINING CONSORTIUM

STRUCTURE

RP – Research Project
TP – Translation Project



Project Summaries

Program A – Upstream

A RP2: Yusha Li

A RP3: Yerniyaz Abildin

A RP5: Hirad Assimi

A RP6: Yue Xie

A TP4: Dr Shi Zhao

A TP5: Dr Aneta Neumann

A TP1-2: Dr Amir Adeli (video and poster presentation)

RP – research project

TP – translation project

Program B – Downstream

B RP1: Kwaku Boateng Owusu

B RP2: Group of Honours Students

B RP3: Dr Difan Tang

B RP4: Bismark Amankwaa-Kyeremeh

B RP5: Linda Rozenberga

B RP6: Kirsten Louw

B RP7: Dr Todd Gillam

B TP7 - B TP11: Dr Richmond Asamoah

PhD candidate: **Yusha Li**

Research Project: A RP2

Title: Resource heterogeneity modelling for optimal ore extraction

Supervisors: Prof Peter Dowd, A/Prof Chaoshui Xu

Translation partner: OZM

Start and End dates: Jan 2018 – Dec 2021

Summary

A rapid downscaling and updating method based on Kalman filter is proposed in this project for investigating small-scale grade heterogeneity in a resource model. In this approach, the model assimilates newly acquired data from blastholes to be downscaled and updated, so as to reflect small-scale grade heterogeneity in near real-time. The updated model can provide better information for short-term decision-making in terms of improving mining selectivity. The updating process is efficient, as it avoids the complexity of kriging fine-scale data or co-kriging different types of data. It also provides a more flexible way of incorporating new data into the resource model. In addition, this method is also applicable when there are multiple non-Gaussian variables. All variables are updated simultaneously and the results are obtained in near real-time.

An evaluation framework is derived to investigate the relationship between mining selectivity and scale. The framework includes simulating realisations using drillcore samples, generating the prior model and using blasthole samples to update it at different scales, evaluating the true metal recovery, and investigating its relationship with scale. It is expected that the metal recovery will increase when the scale decreases. This framework is expected to be a new potential approach for determining the optimal SMU size.

As the proposed updating method is already proved to be applicable to synthetic cases, a case study using real blasthole data will be useful to provide further demonstration in practice.

PhD candidate: **Yerniyaz Abildin**

Research Project: A RP3

Title: Constraints and quantifying uncertainty on resource domain boundaries.

Supervisors: Prof Peter Dowd, A/Prof Chaoshui Xu

Translation partner: Maptek

Start and End dates: October 2019 – November 2022

Summary:

End-User challenge:

To quantify uncertainty on domain boundaries to reduce uncertainty in the resource model as well as mill feed to meet saleable product specifications.

Value proposition:

Delivery of a more accurate resource model that will reduce uncertainty on mill feed and enable product optimisation.

Project Background and Workflow:

Geological modelling and defining the domains of interest are meant to model 2D/3D domains envelopes and mesh them into wireframes. A definition of domain characteristics (e.g., number of domains, geological features) is an important part of the modelling for stationarity assessment, but boundary modelling of the domains is the most critical. In mining industry, the boundary of the domains impacts on recoverable reserves of a target commodity (e.g., copper, iron, gold and oil), the extraction plans from the subsurface and economic forecasting.

The proposed method of domaining consists of two parts: ***1)*** Simulation of grades obtained from assay data; ***2)*** Training classifier based on available geological logs, and then the use of results from simulation for classification lithology in order to predict potential geological domains. ***3)*** Analysis of the impact of the domains on mill feed.

Expected outcomes:

Provide a more accurate resource model and domain boundaries based on different spatial statistics and machine learning algorithms. The model will be applied in mine planning to improve the prediction of mill feed with quantified uncertainty and to optimise strategies to meet product specifications.

PhD candidate: **Hirad Assimi**

Research Project: A RP5

Title: Resource heterogeneity modelling from trucking to multiple stockpiles to mill feed

Supervisors: Prof Frank Neumann, Dr Markus Wagner

Translation partner: Eka

Start and End dates: Apr 2019 – Dec 2021

Summary:

Stockpile schedulers plan stockpile recovery to prepare deliveries to the supply chain's next stage. “Failure to meet” deliveries with their requirements can lead to significant penalty fees, increased operational costs due to poor operational plans, or over-delivery to material specifications. Human decision-making to plan stockpile recovery is error prone contributing to an inability to foresee upcoming deliveries efficiently. Eka has the capability to discretise a whole bulk stockpile and provide information on each part of the stockpile. In this presentation, we model the stockpile recovery problem as an optimization problem considering multiple reclaimers working in parallel subject to technical restrictions in real-world issues. We develop search strategies to deal with this problem. We report on our recent findings.

Objectives:
• Modelling of the problem to investigate difficulty in planning reclaim sequences;
• Optimisation methods to tackle the problem.

Outcomes:
• Optimisation methods to deal with stockpile recovery.

Significance for PRIF program:
• Rapid decision-making for planning stockpiles;
• Reducing operating costs;
• Maximising value and productivity.

Usefulness for End-users:
• Providing practical solutions where undesirable properties do not exceed certain limits;
• Reducing penalty fees;
• Reducing operation costs;
• Determining blend with good accuracy;
• Planning for upcoming blends.

Future work:
Future work can focus on adding stacking component to the problem for dynamic simulation of the reclaiming/stacking to plan for months subject to real-world technical restrictions.
Please feel free to contact me for further discussion.

PhD candidate: **Yue Xie**

Project number: A RP6

Title: Blending Strategy Optimization

Supervisors: Prof Frank Neumann

Translation partner: OZM

Start and End dates: Jul 2018 – Aug 2021 (thesis submitted in Aug 2021)

Summary:

The objective of the project is to maximize the revenues from the resource and subject to some constraints, such as the constraints related to mills, market demand, mine plan and parcels themselves. For research demand, we formulate the project as a continuous optimization problem named stockpile blending problem. The problem aims to blend material from stockpiles and create parcels with optimal metal grades based on the material available. The volume of material that each stockpile provides to a given parcel is dependent on a set of mine schedule conditions and customer demands. Two repaired methods are presented to tackle two complex constraints to convert the infeasible solutions into the solutions without violating the two tight constraints.

A number of heuristic methods are introduced to solve the problem and are compared with real solutions provided by the end-user (OZ Minerals). The experimental results show that heuristic methods are significantly better in terms of the values of results than the results in real-world instances. Motivated by the uncertainty in the geologic input data which can affect optimization, we consider the stockpile blending problem with uncertainty in material grades. Chance constraint optimization is used to guarantee the constraints are violated with a small probability to tackle the stochastic material grades. Research conducted within this project demonstrates the benefits of using heuristic methods to solving the problem and provides a number of suggestions for future work.

Postdoc: **Dr Shi Zhao**

Translation Project: A TP4

Title: Fast ROM Stockpile Modelling for Blending Optimization

Supervisors: Dr Tien-Fu Lu, A/Prof Larissa Statsenko

Translation partner: Eka

Start and End dates: Nov 2019 – Dec 2021

Summary

A Run-Of-Mine (ROM) stockpile is widely accepted as an effective method to reduce the short-term quality variations. However, it is difficult to trace the grade of a ROM stockpile accurately using current fleet management systems. This project aims to build a near real-time, high resolution, multiple layered, 3D models for ROM stockpiles with fine-grained grade information through integrating known data, provided by the end-user partner, OZ Minerals. First, using the datasets and reports provided, the quality of mined materials is traceable throughout the load haul dump (LHD) cycle (from underground stopes to ROM stockpiles). Secondly, entering the quality, quantity and geographical information of each LHD operation into the management system developed by EKA, 3D models for ROM stockpiles can be produced and the quality distribution of a stockpile is calculated with great confidence. Finally, the 3D models are also expected to be calibrated to ensure it has the most accurate representation of real stockpiles using the monthly triangulation models generated from laser scans. Another objective is to apply such a modelling strategy to the coarse ore stockpiles (COS) for quality control.

Using such a stockyard model, it is possible to predict blend information with high accuracy and high efficiency continuously. Thus, further optimize the materials handling system. The suggested future work could be: 1) Improve the modelling accuracy using better data sets. 2) Evaluate different optimization algorithms in real size stockyard.

Postdoc: **Dr Aneta Neumann**

Translation Project: A TP5

Title: Advanced ore mine optimisation under uncertainty

Supervisors: Prof Frank Neumann

Translation partner: Maptek

Start and End dates: March 2019 – Mar 2023

Summary:

In this project, we investigate the impact of uncertainty in advanced mine optimisation. Mine planning is one of the key optimisation problems in mining. We consider the problem of mine planning and focus on uncertainties which highly impact the mine planning process. We introduced and evaluated a new approach which allows the effect of uncertainties in the source geological data on which extraction sequences are based to be economically quantified i.e., to maximize net present value (NPV) over the life of the mine.

In our approach, uncertainty is quantified by an ensemble of neural network interpolations that predict the grade of ore in the different blocks for process and recovery considerations. The approach allows mine planners to consider the effects of what they do not know during crucial planning periods and possibly take manual steps to mitigate downside risk. This project outcomes have been already implemented in Maptek's software system Evolution with Uncertainties which is a commercial product.

Furthermore, we investigate the impact of staging on the obtained optimized solutions, create objective functions based on the uncertainty model in constrained mine optimisation, and consider a wide range of components for this large scale stochastic optimisation problem which allow us to mitigate the uncertainty in the deposit while maintaining high profitability.

Postdoc: **Dr Amir Adeli** *(video* and poster presentation)*

Translation Project: A TP1-2

Title: Geostatistical approach to validating geological loggings

Supervisors: Prof Peter Dowd

Translation partner: Datanet, OZM

Start and End dates: Dec 2020 – Apr 2021, then changed to a part-time position (0.4 FTE) 7 Jun 2021 – 21 Dec 2021

Summary:

The information gathered from geological core logging is the basis for constructing geological and geo-metallurgical models for mineral resource evaluation and classification, ore reserves definition and mine planning. But the visual nature of core logging makes the classification of petrophysical attributes to be qualitative and subject to error due to factors such as: the presence of complex rock textures caused by overprinting processes, a lack of chemical analyses during logging, a lack of experience among mining geologists, and non-unique logging criteria among geologists.

Inaccurate logs generate data that are inconsistent with geochemical analyses and geo-metallurgical tests. Given the limited time and resources available for relogging, inconsistent logs are often seen as outliers or discarded in the geological or geo-metallurgical modelling stage. The rationale of this research project is to identify and remove mis-logged geological samples to enable a reclassification of orebody characteristics and construct more reliable geological and geo-metallurgical models of mineral resources and ore reserves and quantify geological uncertainty.

To date, different steps including literature review, data acquisition, data analysis, grouping rock types, geological domaining, developing a new algorithm for validating geological loggings and programming the algorithm in Matlab are done. The developed algorithm is in the model validation step. After validation the model, the possibility of including geometallurgical data in the model will be investigated.

* Amir's video and poster presentations are available on UoA Box on request

PhD candidate: **Kwaku Boateng Owusu**

Project number: B RP1

Title: Sensing and Optimisation of Autogenous and Semi-autogenous Grinding Mills

Supervisors: Dr Richmond Asamoah, A/Prof Max Zanin, Prof William Skinner

Translation partner: Magotteaux, Manta Controls

Start and End dates: February 2019 – February 2022 (Extension: August 2022)

Summary:

It is well-known that autogenous/semi-autogenous (AG/SAG) grinding mills consume the greatest proportion (25-30%) of energy used in mineral processing. This challenge is exacerbated in recent years by decreasing ore grades coupled with increasing variability/complexity of available resources. The control and optimisation of in-mill processes using built-in or on-mill sensors have shown promising results over the years, however, the harsh and hostile of large-scale milling conditions render in-mill or on-mill sensors sustainably unreliable. Also, modelling and simulation from first principles are not fully representative due to the complex in-mill interactions, less explained by generic and unpractical assumptions used for the models.

This study, therefore, aims to employ an acoustic-based sensing technique as an indirect sensing tool to explicitly investigate the response of ore variabilities such as hardness and feed size distribution inside an AG/SAG laboratory mill coupled with critical operating variables. Specifically, this work will collect acoustic sensed data as proxy under different grinding conditions, followed by signal processing and feature extractions (time-domain, frequency-domain, and time-frequency domain) coupled with machine learning algorithms using the MathWorks-MATLAB/Simulink software. Relationships among ore-product characteristics, grinding conditions and acoustic signals would be established with appropriate models developed and validated both with laboratory and large-scale AG/SAG mills sensed data.

Preliminary results show distinct variations of acoustic signal characteristics for different mill operating conditions and charge composition (e.g. empty mill, milling with steel balls only, steel balls and ore sample, and steel balls, ore and water), showing significant promise in optimising mill performance from acoustic sensed data.

Group of Honours Students:

Pranay Prakash, Tosan Bolorunfe,

Haodong Chun, Sakib Shafayet, Khaled Bin Zia

Research Project: B RP2

Title: Predictive machine health monitoring for SAG/AG mills (Stage 2)

Supervisors: Dr Lei Chen

Translation partner: BHP

Start and End dates: Mar 2021 – Nov 2021

Summary:

Semi-Autogenous Grinding (SAG) mills are widely used in comminution circuits of mineral processing. The purpose of this project is to estimate SAG mill load by measuring vibration signals and to develop a practical model to forecast the health conditions in real-time. To achieve this aim, a mathematical model is developed using an array of operational variables and parameters from the established Morrell and Austin power models. Moreover, a physical 3D model is developed via Computer-Aided Designs, machining, 3D printing, and assembling. The 3D prototype will be controlled by motors through coupling pinions and gears. Vibration characteristics are then measured along with data acquired from accelerometers strategically placed along the SAG mill shell. After completing analysis for both the mathematical and 3D models, a real-time predictive health monitoring model is developed. This will provide predictions for changes in parameters such as mill liner wear and tear conditions that produce uncharacteristic results.

Presently, the mathematical model is near completion with analysis to be conducted as soon as possible. Analysis on the 3D model is underway with only the final predictive model left to be developed. After completion of the various analyses, experimental results will then be collated including a validation process.

Postdoc: **Dr Difan Tang**

Research Project: B RP3

Title: New Sensor Development for Particle Size Online Measurement in Hydrocyclones – A New Particle Percent Passing Size Gauge

Supervisors: Dr Lei Chen

Translation partner: Manta Controls, Rockwell Automation

Start and End dates: Dec 2019 – Dec 2021

Summary:

This project deals with online monitoring of particle percent passing in the overflow of hydrocyclones, which has the potential to enable energy-efficient comminution and to increase downstream flotation efficiency. Online monitoring of particle percent passing has been challenging and existing approaches are costly and bespoke, most of which are also sensitive to operational changes.

Therefore, this study proposes a new low-cost alternative based on force measurement in the overflow of hydrocyclones. In the proposed method, a sensing probe is inserted into the overflow pipe of a hydrocyclone to measure particle impact and fluid included drag, with the other end connected to a transducer mounted outside the pipe for force/torque acquisition. An analytical particle-probe impact model is proposed to map measured impact signals to mean size of high-momentum particles impacting the probe. Correlations between the mass flow rate of total solid contents and total force including fluid induced drag are then derived. These two models together estimate the percentage of low-momentum particles that flow in streamline and further yield the percent passing of a target particle size.

Laboratory setups for investigating particle-probe impact in dry condition and simulating the hydrocyclone overflow environment have been built. Dry tests have been conducted to validate the proposed particle-probe impact model in dry condition, with new findings revealing the presence of signature frequencies that can be used to detect changes in mass flow rate and percent passing size. Wet tests are to be commenced for validation of the proposed method in simulated overflow environment.

PhD candidate: **Bismark Amankwaa-Kyeremeh**

Research Project: B RP4

Title: Sensing and Optimisation of Flotation Circuits and Integration with Grinding

Supervisors: Dr Richmond Asamoah, A/Prof Max Zanin, Prof William Skinner

Translation partner: Magotteaux, Manta Controls

Start and End dates: February 2019 – February 2022

Summary:

In the concentration process by froth flotation, the main key performance indicators are recovery and grade. While it can be relatively easy to attain high flotation performance in terms of recovery and grade, maintaining such performance is often a challenge due mainly to the heterogeneity of the processed ore. Technically, an increment as low as 0.5% in flotation recovery of valuable metals (e.g. gold, copper, nickel) is of major economic significance considering the large tonnages of material treated by the process. As such, modelling and optimisation of froth flotation is necessary in ensuring increased production efficiency in the resource market. With the availability of plant historical data and the application of modern day machine learning algorithms (artificial neural network, Gaussian process regression, support vector machine, fuzzy logic, principal component regression, decision trees and random forest), this research is aimed at developing an improved, cost effective, integrated sensor-based, real time control strategy for industrial flotation circuit with links to grinding.

PhD candidate: **Linda Rozenberga**

Research Project: BRP5

Title: Metal Organic Framework based fibre-optic sensors

Supervisors: Prof David Beattie, A/Prof Marta Krasowska, Prof William Skinner, Prof David Lancaster

Translation partner: Magotteaux

Start and End dates: 27/09/2018 – 27/03/2022

Summary:

B RP5 Metal Organic Framework based fibre-optic sensors

- Objectives

- Develop fluorescence based optical fibre sensor that can selectively and instantaneously measure Fe^{3+} ion concentration in water/solution.

- Outcomes

- A prototype of fluorescent Metal Organic Framework – optical fibre sensor for fast and accurate measurements of Fe^{3+} concentration in water/solution;
- Contribution to practical Metal Organic Framework based sensor fabrication methodology;
- Development of a Metal Organic Framework-polymer composite significantly improving the sensor selectivity and analyte sensing range;
- Metal Organic Framework-polymer composite transfer on optical fibre surface can potentially enable sensor to be effectively used different environments and settings (laboratory or industrial site)

- Significance for PRIF Program

A new sensor prototype for Fe^{3+} ion concentration measurements is being developed. Methodology on assessing powder Metal Organic Framework group compounds for practical applications as sensors was created. Polymer matrix effect on Metal Organic Framework properties was studied and found to be highly beneficial. A potential technique for transforming fluorescent metal organic framework powder sensors to practical and effective optical fibre-based sensors was developed.

- Usefulness for End-users

The Metal Organic Framework – optical fibre sensor can be used to measure the Fe^{3+} ion concentration measurements in mineral leaching and wastewater treatment processes.

- Future work/Suggestions

- Optimisation of the prototype for Fe^{3+} ion sensor and its fabrication method;
- New fluorescent Metal Organic Framework – optical fibre sensor development for other analytes based on the findings of this research project.

PhD candidate: **Kirsten Louw**

Research Project: BRP6

Title: Diffusive process in mineral processing

Supervisors: Bronwyn Hajek, Marta Krasowska, William Skinner, Jim Hill

Translation partner: Magotteaux

Start and End dates: December 2019 – December 2022

Summary:

Knowing the concentration of ferric ions during the leaching process will enable informed decisions to optimise copper extraction. This theoretical project studies a new sensor that will be able to measure the ferric ion concentration in a leaching solution. This sensor is a thin film of polymer embedded with metal-organic framework (MOF) crystals and is placed in a cut-away section of an optic fibre.

Mathematical modelling is used to study the behaviour of the ferric ions in the sensor, with a view to making theoretical predictions to optimise sensor performance. The project has two main aims.

Firstly, we aim to understand how the ferric ions interact with the MOF crystals in the sensor. We have found that ferric ions are attracted to the MOF crystals but are too large to fit inside the MOF pores and are thus only bonded to the surface. This property will be useful because the sensor can more easily be “washed” and reused.

Secondly, we aim to understand the overall behaviour of the system and how the ferric ions diffuse to the sensor and through the sensor. This information will allow us to predict how long the sensor should be exposed to an analyte solution to give reliable results, and to determine the best film thickness for ferric ion detection.

Postdoc: **Dr Todd Gillam**

Research Project: BRP7

Title: Formation of MIP particle film on substrate and successful detection of flotation frothers via gravimetric detection

Supervisors: A/Prof Marta Krasowska, A/Prof Anton Blencowe, Prof William Skinner, Prof David Beattie

Translation partner: Magotteaux

Start and End dates: March 2020 – December 2022 (0.4 FTE basis to date)

Summary:

My research is directed toward the objective of designing, testing, and implementing of novel substrates for the detection of floatation reagents. I have evaluated the composition of the interfloat™ frother (F236N) mixture and have developed a polymer material which adsorbs components of the mixture via cyclodextrin mediated host-guest chemistry. These water-insoluble beta-cyclodextrin particles are capable of adsorbing components of the interfloat mixture in aqueous solution. Present research efforts are directed toward characterizing the adsorption attributes of these particles whilst also adapting them to a useful size for suitability to quartz crystal microbalance (QCM) application. Ongoing research is also directed toward finding a means of improving the binding selectivity of this system toward individual interfloat components. This research assesses the capability of cyclodextrin host-guest interaction in applied materials and may lead to the fabrication of an inline sensor for monitoring frother concentration in floatation processes.

Postdoc: **Dr Richmond K. Asamoah**

Translation Projects: B TP7, B TP8, B TP9, B TP10, and B TP11

Titles: TP 7 – Manta Mic Acoustic Analyser for Autogenous Grinding

TP 8 – Ultrasonic PSD Sensor for Grinding Circuit

TP 9 – Pulp Chemistry Monitor for Flotation Prediction

TP 10 – Tailings Acid Leach Circuit, Novel MOF Sensor

TP 11 – Laboratory AG/SAG Mill Development

Supervisors: A/Prof Max Zanin, Prof William Skinner, Prof David Beattie

Translation partner: Magotteaux, Manta Controls, Rockwell Automation

Start and End dates: August 2019 – December 2022

Presentation Summary:

In this presentation, the five translation projects (TP 7, TP 8, TP 9, TP 10 and TP 11) in the Program B of the Consortium (Unlocking Complex Resource through Lean Processing) will be highlighted. Specifically, an overview of each translation project, key objectives, current status and expected outcome, including significance to PRIF program and end-users, will be presented alongside plans for the future. Evidently, there is good communication and collaboration between translation partners (Manta Controls Pty Ltd and Magotteaux Australia Pty Ltd), end-user industry (BHP Olympic Dam) and researchers (University of South Australia and University of Adelaide) in executing the translation projects. COVID-19 restrictions delayed some of the project deadlines owing to associated travel restrictions and limited access to mine site, however, with the easing of restrictions, efforts have been made to make up the lost time. Major outcomes of the Program B translation projects include installation of the Pulp Chemistry Monitor (PCM®) at BHP Olympic Dam, development of a laboratory AG/SAG mill drum for acoustic response monitoring, and development of predictive algorithms for flotation recovery and mill load measurement. The translation partners have further provided new data sets to support development of robust models. The translation projects provide a good platform for extending the success of laboratory-based research activities in the program to end-user industry implementation.

B TP7: Manta Mic Acoustic Analyser for AG/SAG Grinding Mill

Summary

Ever-decreasing ore grades coupled with increased ore variability present challenges for mill optimisation. Poor mill condition monitoring causes high energy consumption and low mill throughput. Increasing mill throughput within particle size and mineral liberation constraints at a lower operating cost using new sensor suites may thus add value to the overall plant. Translation project 7 aims at installation of Manta Mic Acoustic Analyser on AG/SAG grinding mill for robust process control in response to changing feed characteristics. Until now, assessment of suitable on-plant location for installation of the sensor has been completed coupled with detailed scoping of work which has been submitted to BHP Olympic Dam. Current studies for this project include development of a predictive model, linking measured acoustic response and existing sensors in the grinding circuit. The new developed predictive models will be evaluated with additional data from site in the future. Translation project 7 supports research projects 1 and 2.

B TP8: Ultrasonic PSD Sensor for Grinding Circuit

Summary

Translation project 8 aims at addressing end-user challenges such as ever-decreasing ore grades together with increased ore variability which presents challenges for mill optimisation. Poor mill condition monitoring causes high energy consumption and low mill throughput, ore overgrinding and gangue flotation entrainment due to poor on-line size monitoring, and increasing mill throughput within particle size and mineral liberation constraints. Translation project 8 seeks to install Ultrasonic Particle Size Monitor in the grinding circuit for continuous particle size monitoring which will address the above end-user challenges. Until now, a suitable on-plant location for installation of the sensor has been determined with detailed scoping of work developed and submitted for approval by BHP Olympic Dam. Future work involves development of new models which will establish the contribution of the sensor to production performance, subject to the acquisition and installation of the sensor which is beyond financial scope of PRIF. Translation project 8 supports research projects 1, 3 and 4.

B TP9: Pulp Chemistry Monitor for Flotation Prediction

B TP9 Summary

Continuous increase in ore complexity and variability, leading to less predictable flotation response, in addition to the lack of efficacious process on-line monitoring strategies has limited concentrator performance. There is a good relationship between pulp chemistry (pH, Eh, temperature, dissolved oxygen and oxygen demand) and flotation performance, in terms of concentrate grade and recovery. Changes in pulp chemistry also served as proxy for ore variability, hence, prudent adjustments can be made to improve overall flotation recovery and grade. Translation project 9 seeks to install Pulp Chemistry Monitor (PCM®), first at the rougher cells, and incorporate the data collected in a predictive flotation model for better flotation performance. A suitable on-plant location for installation of the sensor has been determined with detailed scope of work submitted to BHP Olympic Dam. Data collection from the PCM® is currently ongoing. The newly developed model will be refined and tested with additional data from the PCM® as part of future work. Translation project 9 supports research projects 4 and 7.

B TP10: Advanced Metal Organic Framework (MOF) Sensors for Improved Uranium Extraction

B TP10 Summary

Pulp gelation reduces uranium extraction efficacy. Research project 5, which relates to translation project 10, is concerned with the development of novel sensors for detection of ferric/ferrous ion concentrations and pH in highly aggressive solution environments, useful for tails leach, however, synthetic systems are investigated. Investigating the ability of the new sensor in monitoring ferric/ferrous ion concentrations in real leaching systems will be useful, hence the focus of translation project 10. Preliminary leaching behaviour of plant flotation tails has been performed. Once the new MOF sensor is developed, real ores from BHP Olympic Dam with different mineralogy will be investigated to establish the robustness of the new sensor and performance during uranium leaching. Translation project 10 supports research projects 5 and 6.

B TP11: Laboratory AG/SAG Mill Development

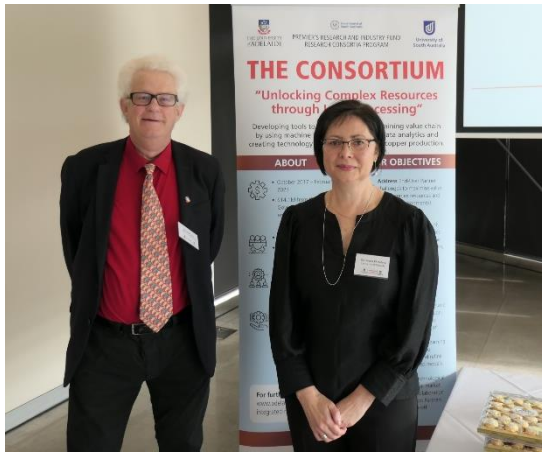
Summary

Translation project 11 was developed as part of Program B in support of HDR student Kwaku Boateng Owusu. The project aimed at designing and fabricating an autogenous/semi-autogenous (AG/SAG) grinding mill drum, which can be installed on the Magotteaux Mill at the University of South Australia. The research student can then investigate different conditions of AG/SAG operation while measuring acoustic and vibration response at the laboratory level. The specific project objectives coupled with their status are as follows:

- Design laboratory AG/SAG mill for fabrication - completed
- Fabrication of laboratory AG/SAG mill – completed
- Install laboratory AG/SAG mill in the UniSA laboratory – completed

Translation project 11 is now complete. The new laboratory AG/SAG mill has been useful in studying the acoustic response during grinding processes as part of research project 1.

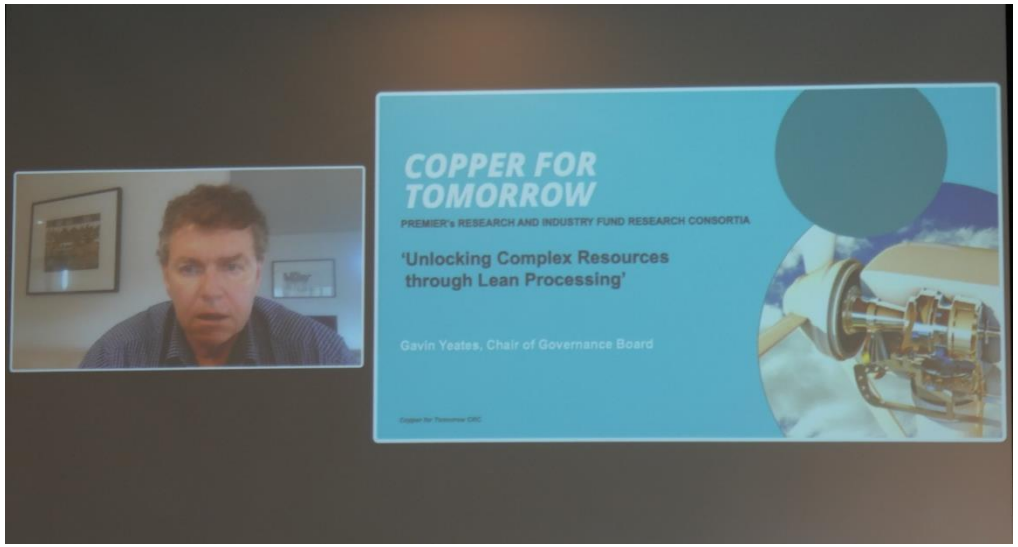
Photo Reportage from the 2021 Annual Assembly by Dr Dylan Peukert



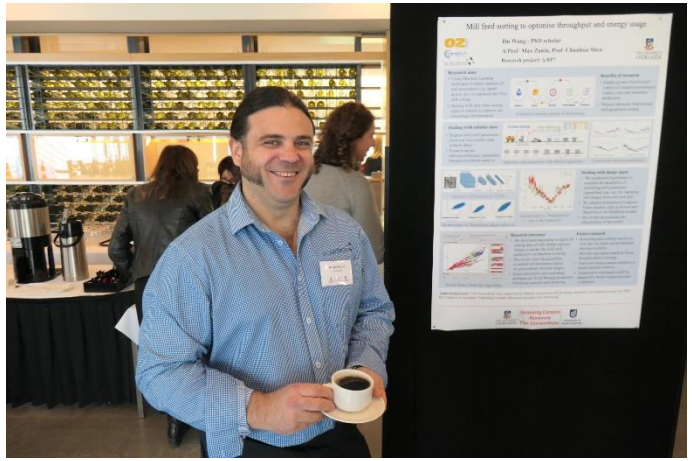

PREMIER'S RESEARCH AND INDUSTRY FUND
RESEARCH CONSORTIA PROGRAM
THE CONSORTIUM
"Unlocking Complex Resources through Lean Processing"
Developing tools to integrate the entire mining value chain by using machine learning, sensors and data analytics and technology solutions to maximise copper production.
OUR OBJECTIVES


adelaide.edu.au/imer
THE UNIVERSITY of ADELAIDE
INSTITUTE FOR MINERAL AND ENERGY RESOURCES
PREMIER'S RESEARCH AND INDUSTRY FUND
RESEARCH CONSORTIA PROGRAM
THE CONSORTIUM
"Unlocking Complex Resources
Lean Processing"
OUR OBJECTIVES
Answering the challenge of sustainable and efficient use of global resources


ARC TRAINING CENTRE FOR
INTEGRATED
OPERATIONS FOR COMPLEX RESOURCES
BHP
Delivering the vital enabling tools – advanced sensors, data analytics and artificial intelligence – for automated, integrated and optimised mining.
OBJECTIVES
Demonstrate
Deliver
Advance
Increase
further information contact:
@adelaide.edu.au


COPPER FOR TOMORROW
PREMIER's RESEARCH AND INDUSTRY FUND RESEARCH CONSORTIA
'Unlocking Complex Resources through Lean Processing'
Gavin Yeates, Chair of Governance Board

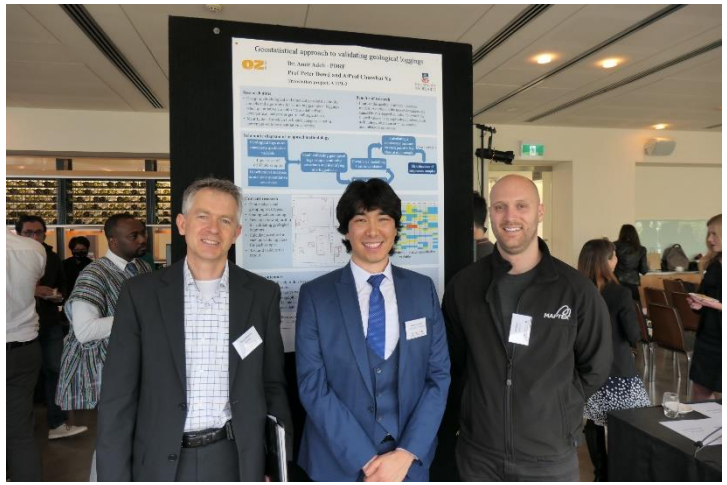

BHP
SUSTAINABLE COPPER FOR A SUSTAINABLE FUTURE
INSTITUTE FOR MINERAL AND ENERGY RESOURCES


Mill feed sorting to optimise throughput and energy usage


THE CONSORTIUM


BHP
COPPER FOR TOMORROW


BHP




1st October 2021
Unlocking Complex Resources
The Consortium

ACKNOWLEDGEMENTS:

Consortium Researchers

Consortium Supervisor

Consortium Industry and Support Partners

State Government of South Australia - Department for Innovation and Skills

Institute for Mineral and Energy Resources

BHP - Special thanks to BHP, especially Kathy Ehrig, for financial support of this event.

2021 PRIF Mining Consortium Annual Assembly

Dr Tatiana Khmeleva

Consortium Manager – Unlocking Complex Resources

Institute for Mineral and Energy Resources – Modern Energy Systems

The University of Adelaide, AUSTRALIA 5005

M: +61 (0) 4 66 92 42 92

E: tatiana.khmeleva@adelaide.edu.au

Web: https://www.adelaide.edu.au/imer/integrated-mining-consortium/

Twitter: @IntegratedMini1 | Linkedin