Tech Talk: How engineers and geologists are using machine learning for digital mine-to-mill and pit-to-port value chain optimisation.

AusIMM Kalgoorlie Chapter
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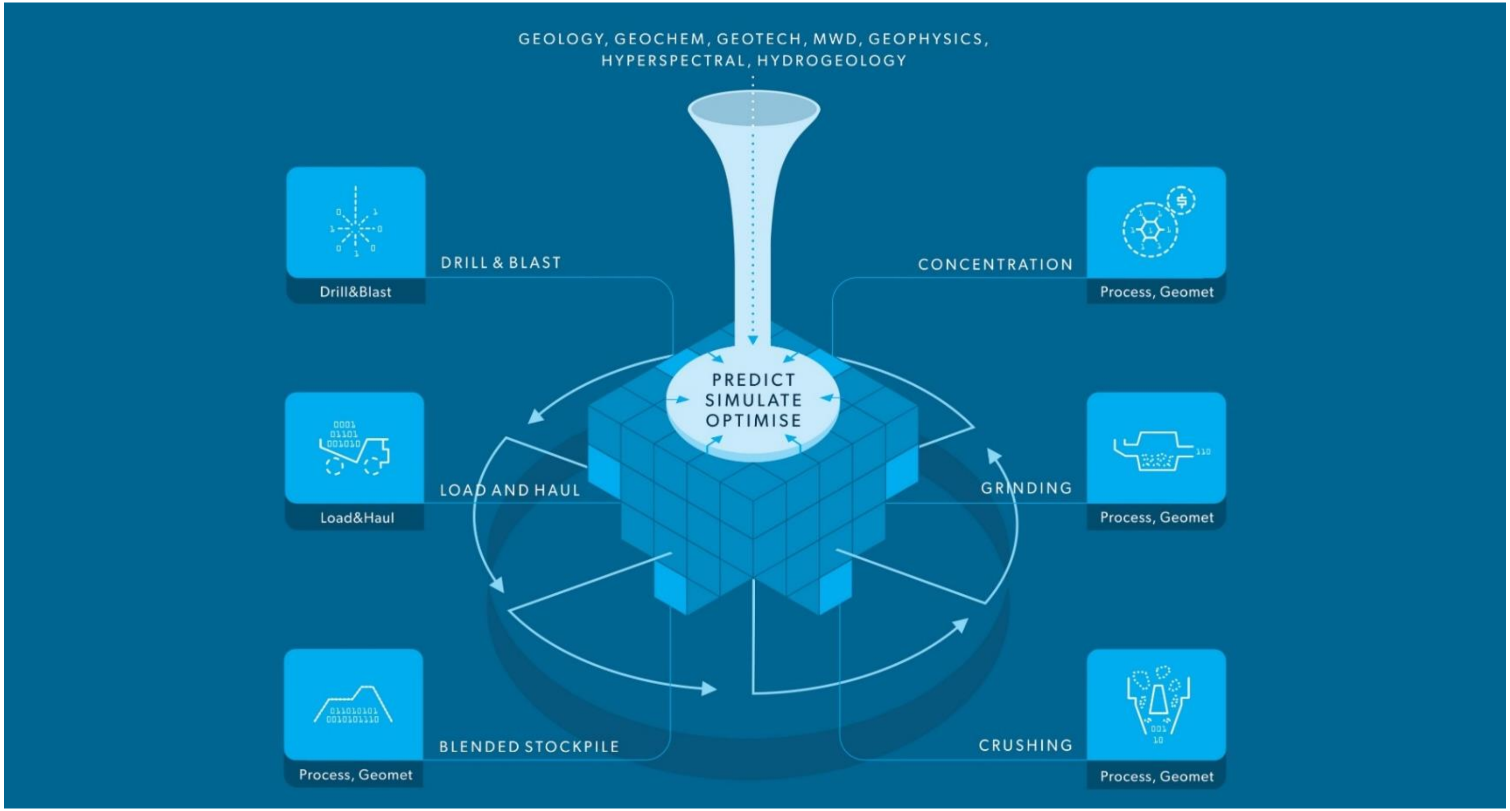
Digital Mine-to-Mill/Pit-to-Port

Machine learning models learn from operational data – “twinned”.



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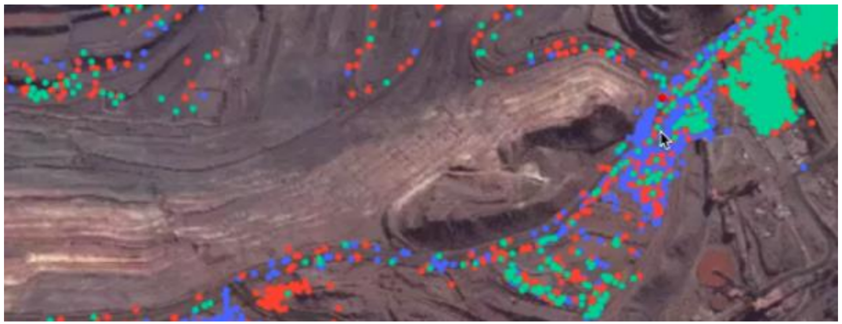
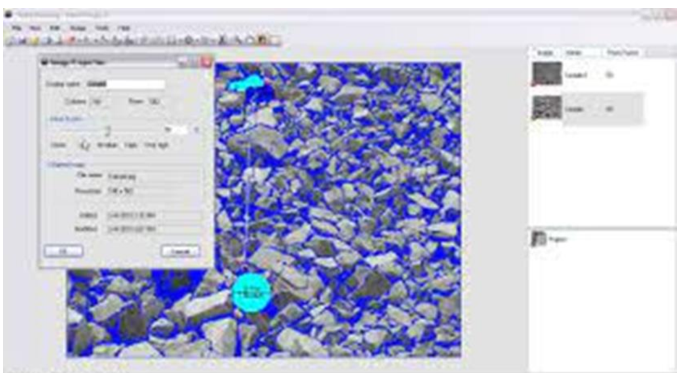
Ore Characterisation Methods

- Proprietary ore tracking through blended stockpiles, COS, conveyors, etc



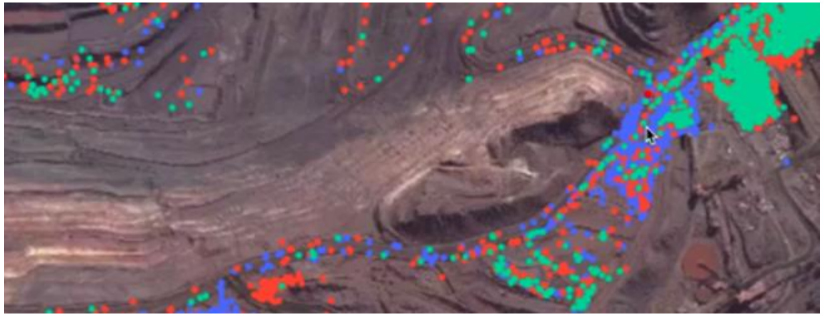
- Ore characterisation using fragmentation



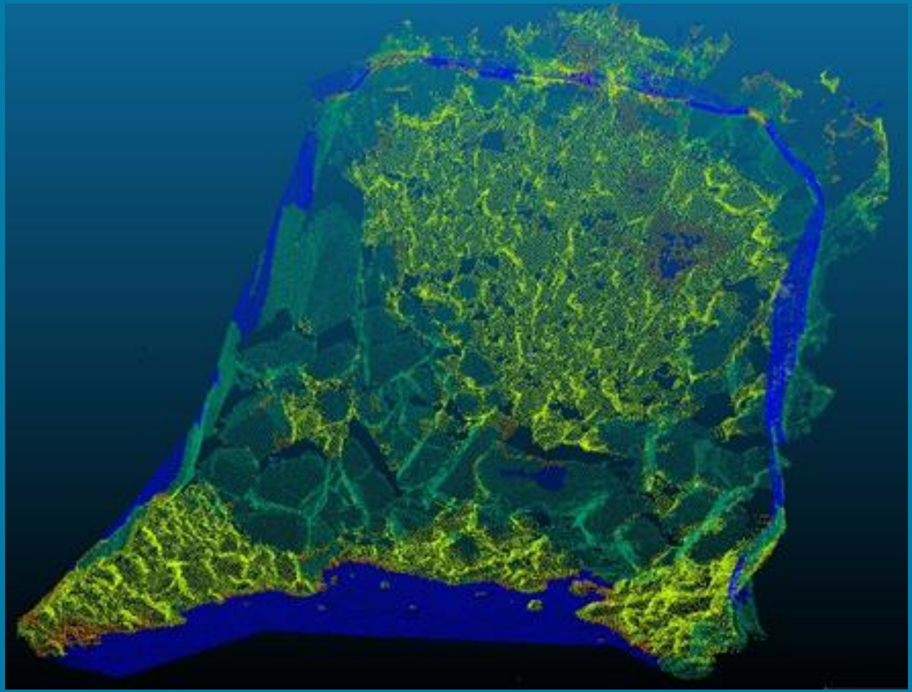
Ore Tracking

- 10s to 100s of millions of tonnes of ore tracked to downstream process e.g. shovel, crusher, mill, recovery, specific energy etc.

- 10s of thousands of ore batches matched to the downstream process data e.g. crusher downtime.



Fragmentation for Underground Ore Characterisation (Point Cloud Scans e.g Hovermap). PETRA is providing FRAGx and MAXTA free to ARC PhD students.



ARC TRAINING CENTRE FOR
INTEGRATED
OPERATIONS FOR COMPLEX RESOURCES

DELIVERING THE VITAL ENABLING TOOLS – ADVANCED SENSORS, DATA ANALYTICS AND ARTIFICIAL INTELLIGENCE – FOR AUTOMATED, INTEGRATED AND OPTIMISED MINING.

BHP

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Geometallurgy Recovery Prediction Case Study 1

PanAust Ban Houayxai, Silver-Gold Operation, Loas. Geometallurgy machine learning model deployed into the block model based upon 10 million tonnes of historical data (AusIMM Complex Orebody Conference, Carpenter et al 2018)

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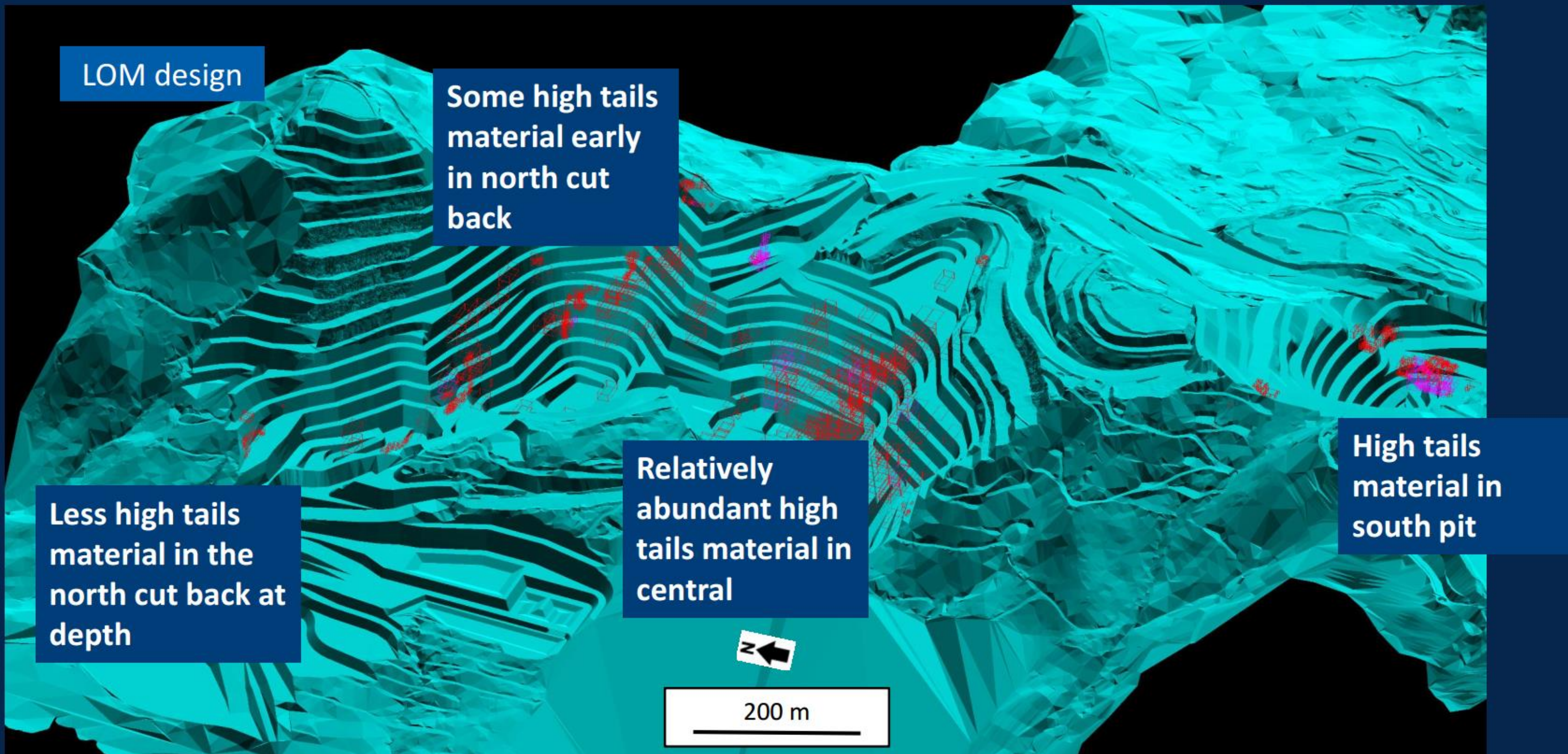
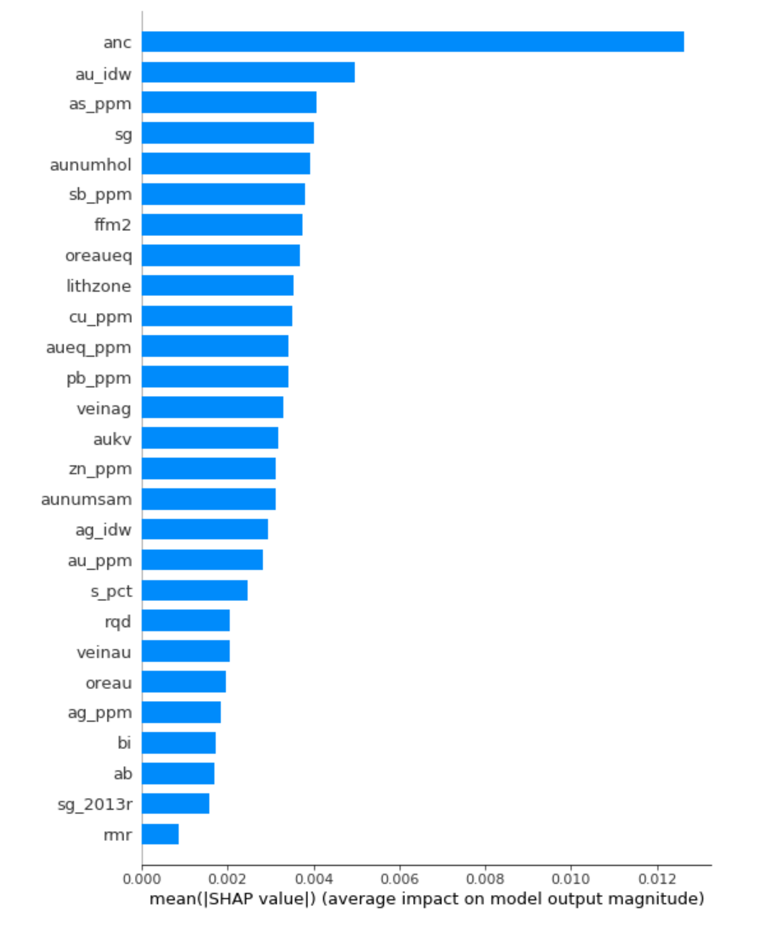
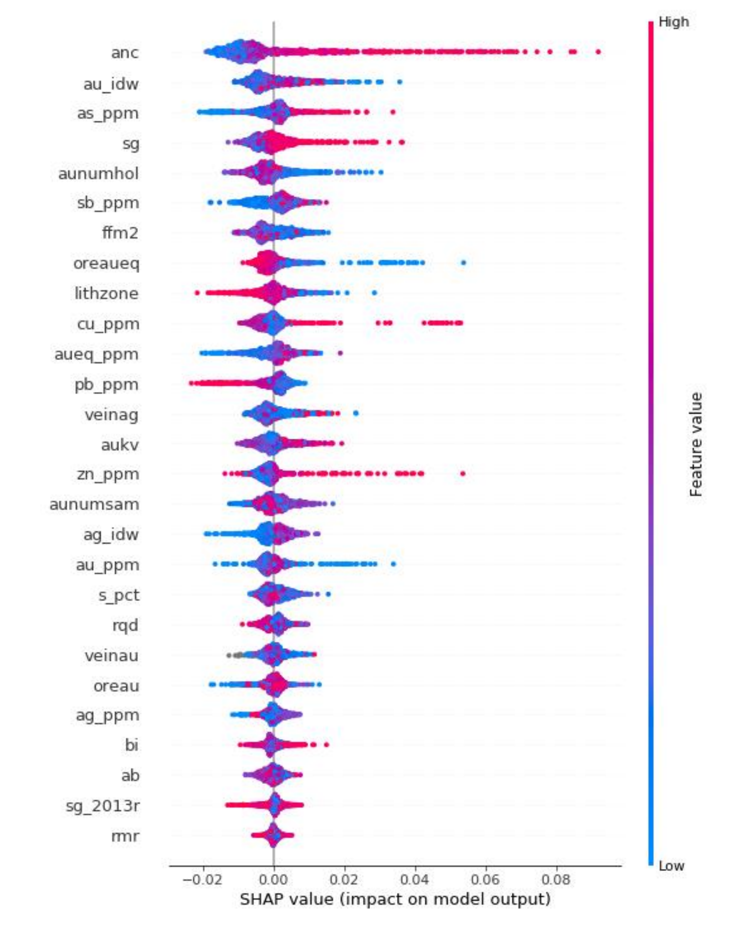
Predict Tailing Grade – Revenue Increase through Higher in Recovery



Interpreting Digital Twin ML models with SHAP





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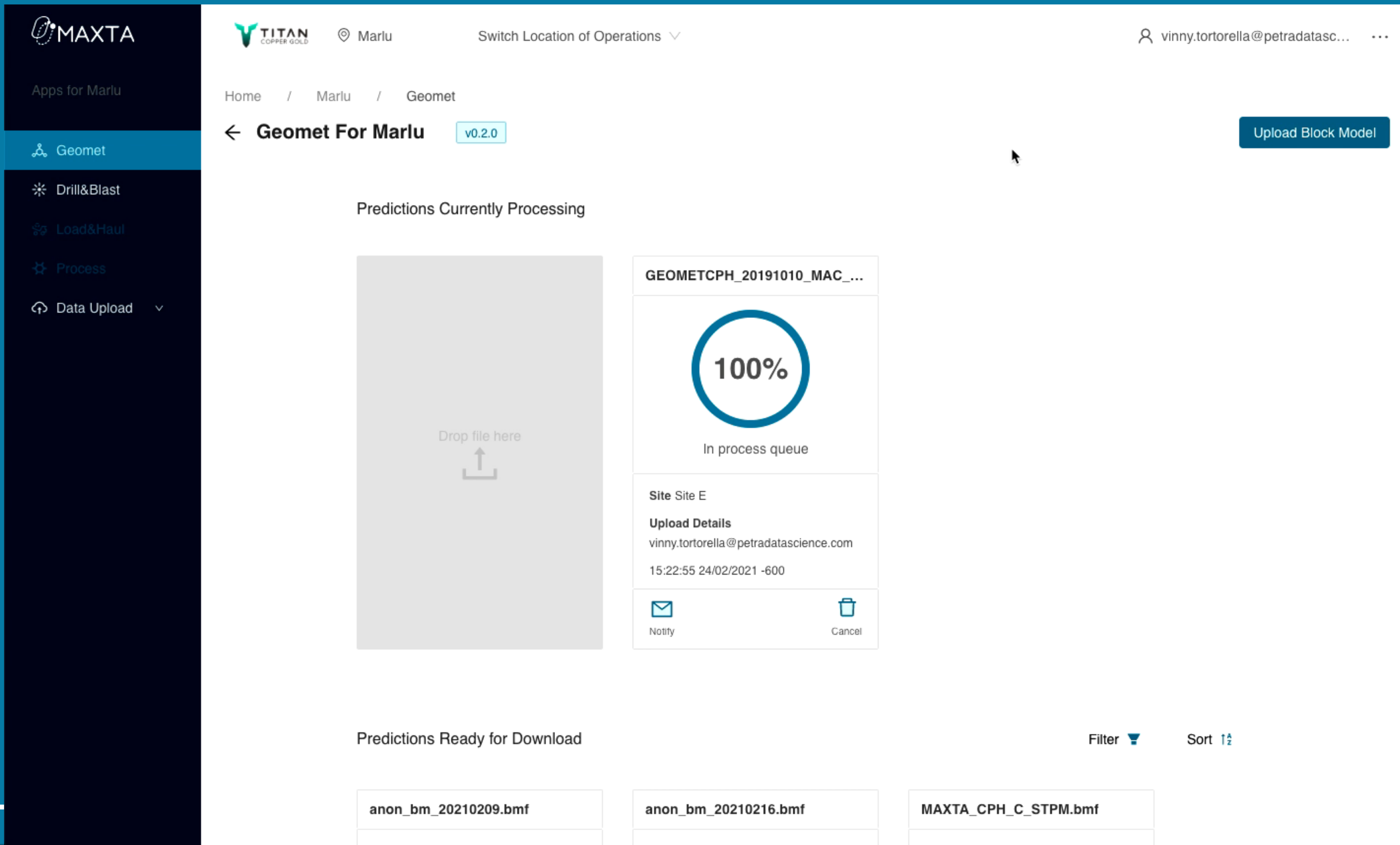
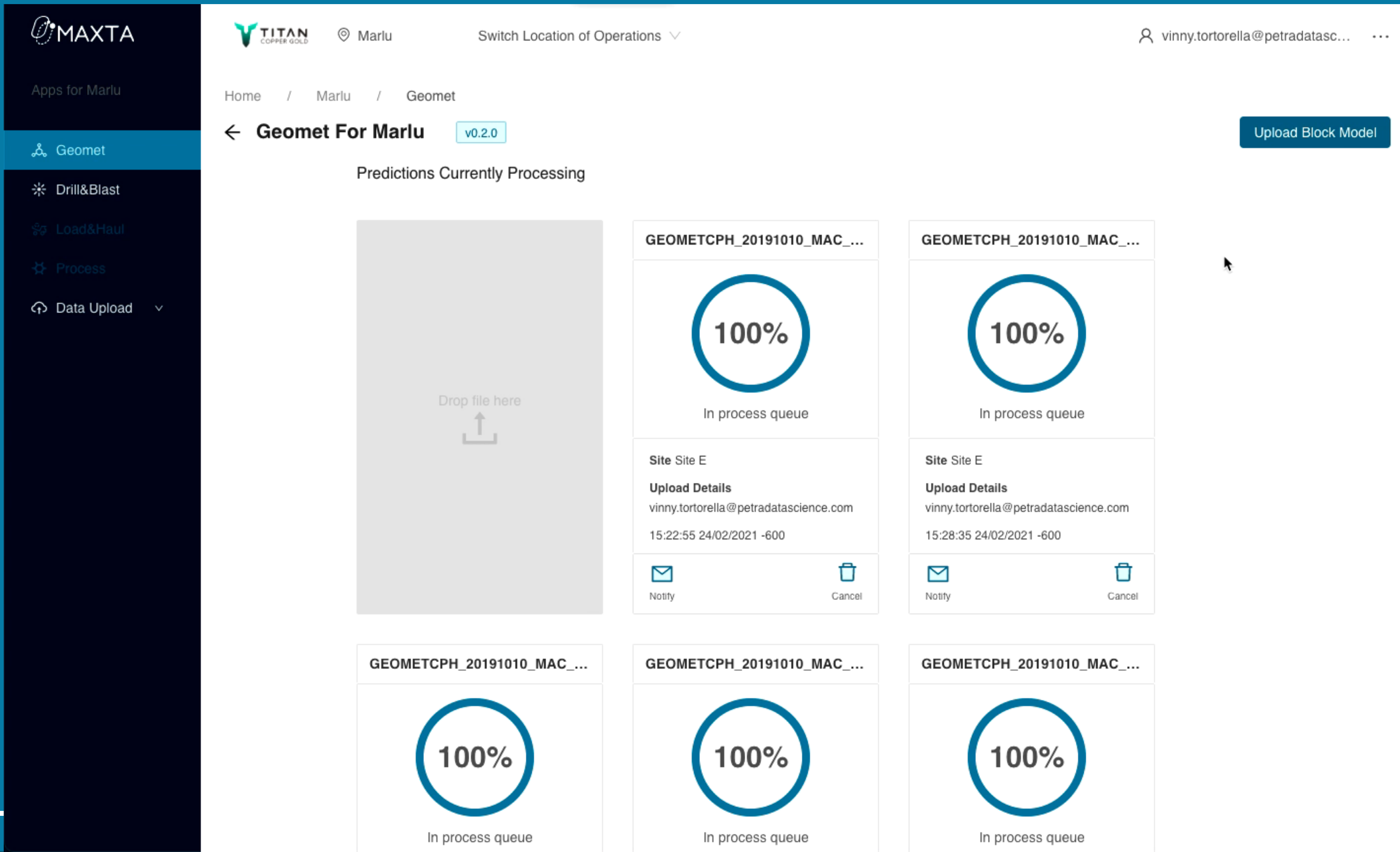
Upload Block Model



Download Block Model



Geometallurgy Case Study 2

Open Pit Iron Ore mine. Mill throughput prediction model deployed into the block model for mine planning and blending.

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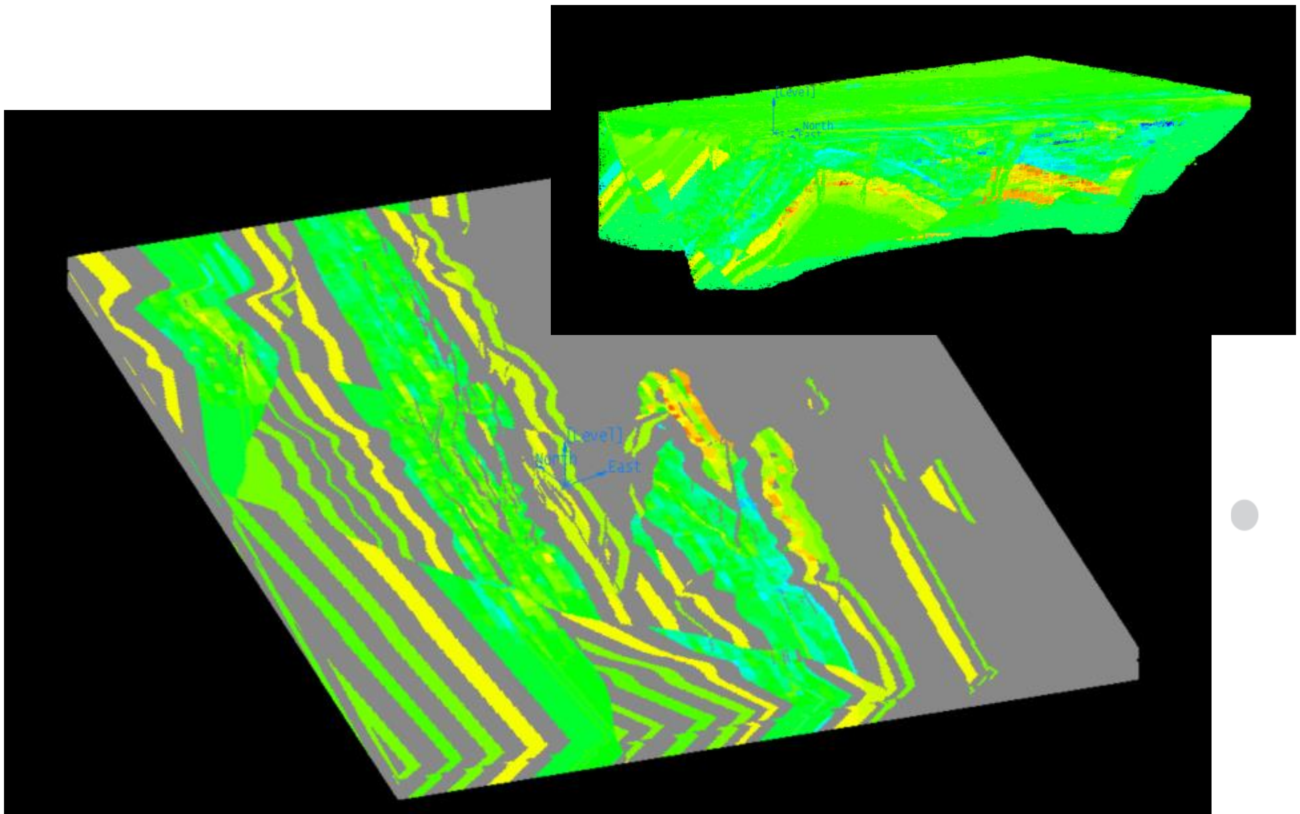
Machine learning models feedback actual mine performance into mine planning: Blending increases mill throughput.



Drill & Blast Case Study 1

Iron Ore Case Study – Drill & blast optimisation to minimise crusher downtime due to blockages at the crusher.

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Minimise crusher downtime due to oversize

- Drill and blast simulation identifies the best design for each geological domain
- Identify with 78% accuracy location of oversize allows operation to proactively manage.

Simulate effect of drill&blast design on crusher downtime.

Simulation Results

Simulation | Crusher One Blocks | Crusher Two Blocks

Conf	ID	Polygon Used (filename)	Explosive Density	Dip (degrees)	Diameter (mm)	Subdrill (m)	Burden , Spacing (m,m)	Explosive Quantity (kg/m³)	Stemming (m)	Fraction of crusher 1 blocks with predicted downtime	Average non-zero Crusher 1 Downtime (seconds)	Fraction of crusher 2 blocks with predicted downtime	A
✓	0	downtime (1).poly...	1	90	229	1.8	5.0,6.0	362	3.2	0.04	367 seconds (19 blocks)	0.03	25
✓	1	downtime (1).poly...	0.82	90	229	1.8	5.0,6.0	308	3.2	0.05	346 seconds (23 blocks)	0.04	26
✓	2	downtime (1).poly...	0.82	90	229	1.8	5.5,6.5	308	3.2	0.05	348 seconds (23 blocks)	0.11	27
✓	3	downtime (1).poly...	1	90	229	1.8	5.5,6.5	362	3.2	0.04	367 seconds (19 blocks)	0.02	24
✓	4	downtime (1).poly...	1.1	90	229	1.8	5.5,6.5	399	3.2	0.02	295 seconds (9 blocks)	0.03	20
✓	5	downtime (1).poly...	1.15	90	229	1.8	5.5,6.5	417	3.2	0.02	301 seconds (9 blocks)	0.08	22

Export | Export Selected | Reset table view

Simulation Options

Explosive Density : 1 | Design Diameter : 165 | Subdrill (m) : − 1.5 + | Stemming Length (m) : − 3 + | Burden,Spacing : | Explosive Quantity : na kg/m³

Drill & Blast Simulation Case Study 2

Iron Ore Case Study – Drill & blast optimisation to simultaneously maximise dig rate and crusher throughput whilst reducing blasting cost.

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MAXTADrill&Blast Simulation

Increase crusher throughput and 25-30% reduction in explosive costs by switching to ANFO.

MAXTA | Drill and Blast | Process | Geomet | Interp

Simulation Inputs

Found 6 blast boundaries

Select file | throughput (4).polygons selec...

Clear Boundaries

Simulation Results

All | 1 | 2 | 3 | 4 | 5 | 6

Conf	Boundary	Explosive Choice	Burden x Spacing (m x m)	Hole Diameter (m)	Stemming (m)	Digrate (tph)	Primary Crusher (tph)	% Diff. in Primary Crusher (tph)	% Diff. in Powder Factor	Cost	Total Tonnes Blasted
	Baseline for 2	1.10	6.0 x 7.0	0.251	3.9	3770	3200		0		315236
	throughput (4).polygons - 2.0	0.82	7.0 x 8.0	0.251	4.8	3980	3450	7.8%	-51.7%		315236
	throughput (4).polygons - 2.0	0.82	6.0 x 7.0	0.251	4.8	3940	3430	7.2%	-34.5%		315236
	throughput (4).polygons - 2.0	0.82	7.0 x 8.0	0.251	4.4	3890	3330	4.1%	-48.3%		315236
	throughput (4).polygons - 2.0	0.82	6.0 x 7.0	0.251	4.4	3900	3310	3.4%	-31.0%		315236
	throughput (4).polygons - 2.0	0.82	6.0 x 7.0	0.251	4.2	3920	3310	3.4%	-27.6%		315236
	throughput (4).polygons - 2.0	0.82	6.0 x 7.0	0.251	4.0	3970	3310	3.4%	-27.6%		315236
	throughput (4).polygons - 2.0	1.10	7.0 x 8.0	0.251	4.4	3910	3310	3.4%	-31.0%		315236

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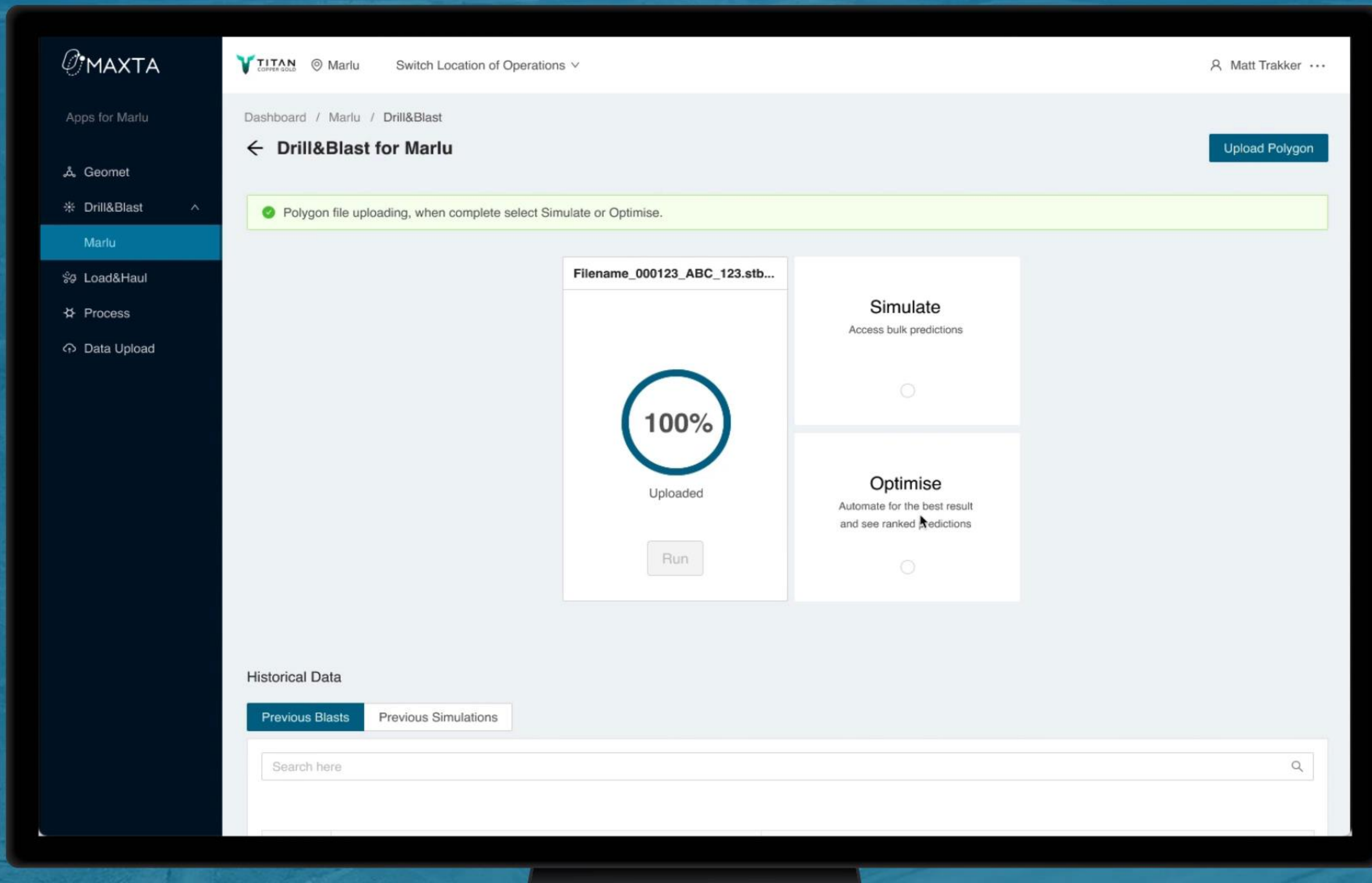
MAXTA
Apps for Marlu
Geomet
Drill&Blast
Marlu
Load&Haul
Process
Data Upload
TITAN
COPPER GOLD
Marlu
Switch Location of Operations
Matt Trakker
Dashboard / Marlu / Drill&Blast
Drill&Blast for Marlu
Upload Polygon
Polygon file uploading, when complete select Simulate or Optimise.
Filename_000123_ABC_123.stb...
100%
Uploaded
Run
Simulate
Access bulk predictions
Optimise
Automate for the best result
and see ranked predictions
Historical Data
Previous Blasts
Previous Simulations
Search here

Load&Haul Performance Prediction
Case Study 1: Excavator digrate.

Iron Ore mine in Western Australia. Accurate estimation of excavator digrate to improve fleet efficiency through reduced under-trucking and over-trucking.

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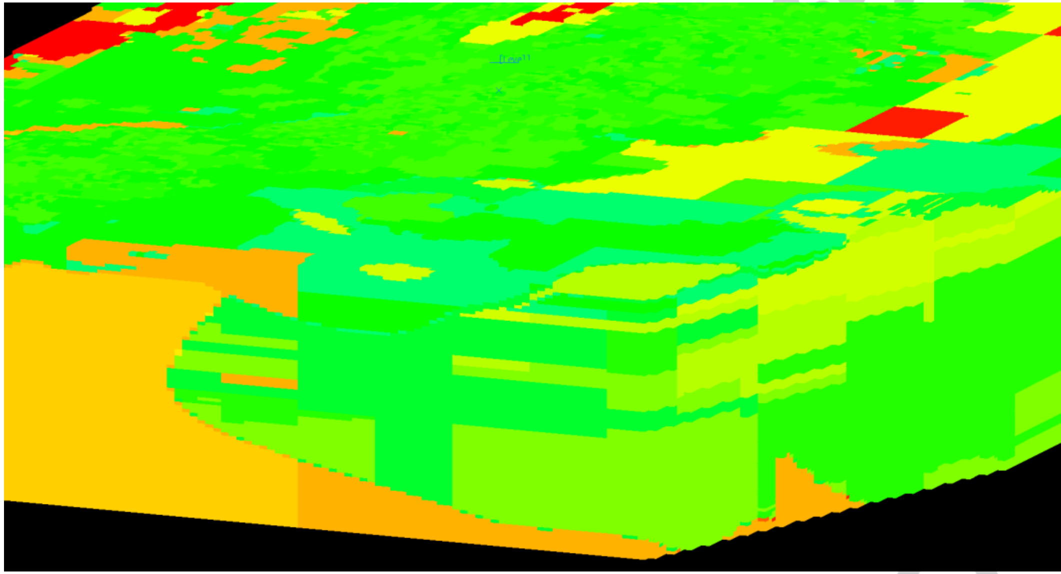
Digrate actual performance fed back into block model:

- All planning horizons from LoM to short-interval control.
- Interoperable with mine planning tools e.g. Vulcan.
- Increase in fleet efficiency by reducing over and under trucking

Block-by-block dig rate prediction accuracy +/- 1-5%



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Dynamic Set Point Optimisation Case Study 1: Recovery/Yield

Open Pit Copper-Gold Porphyry operation: Predict rougher scavenger copper grade six hours in advance, minimise tailings grade (optimisation algorithm recommends set points every shift) & provide predictor importance insights.

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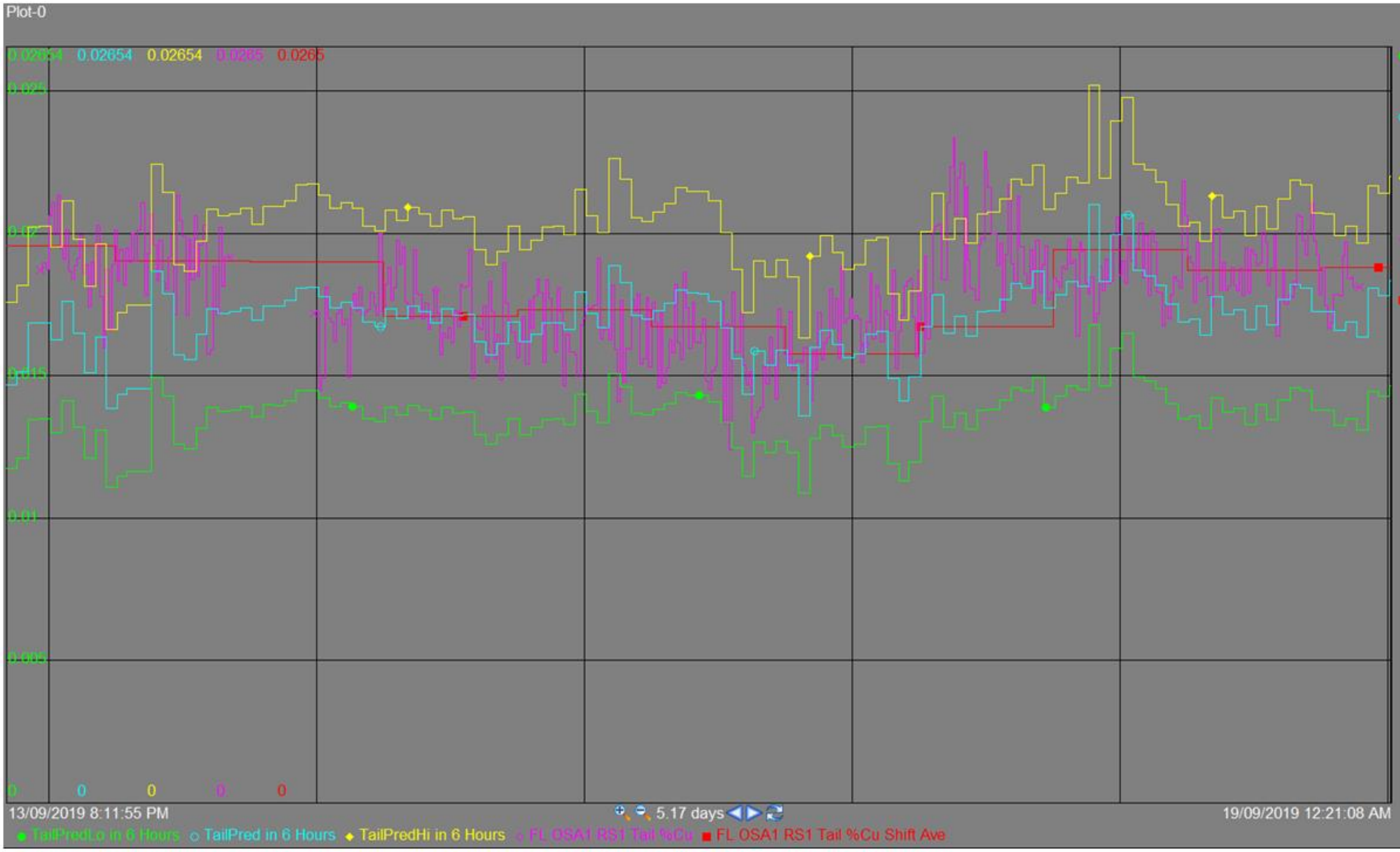
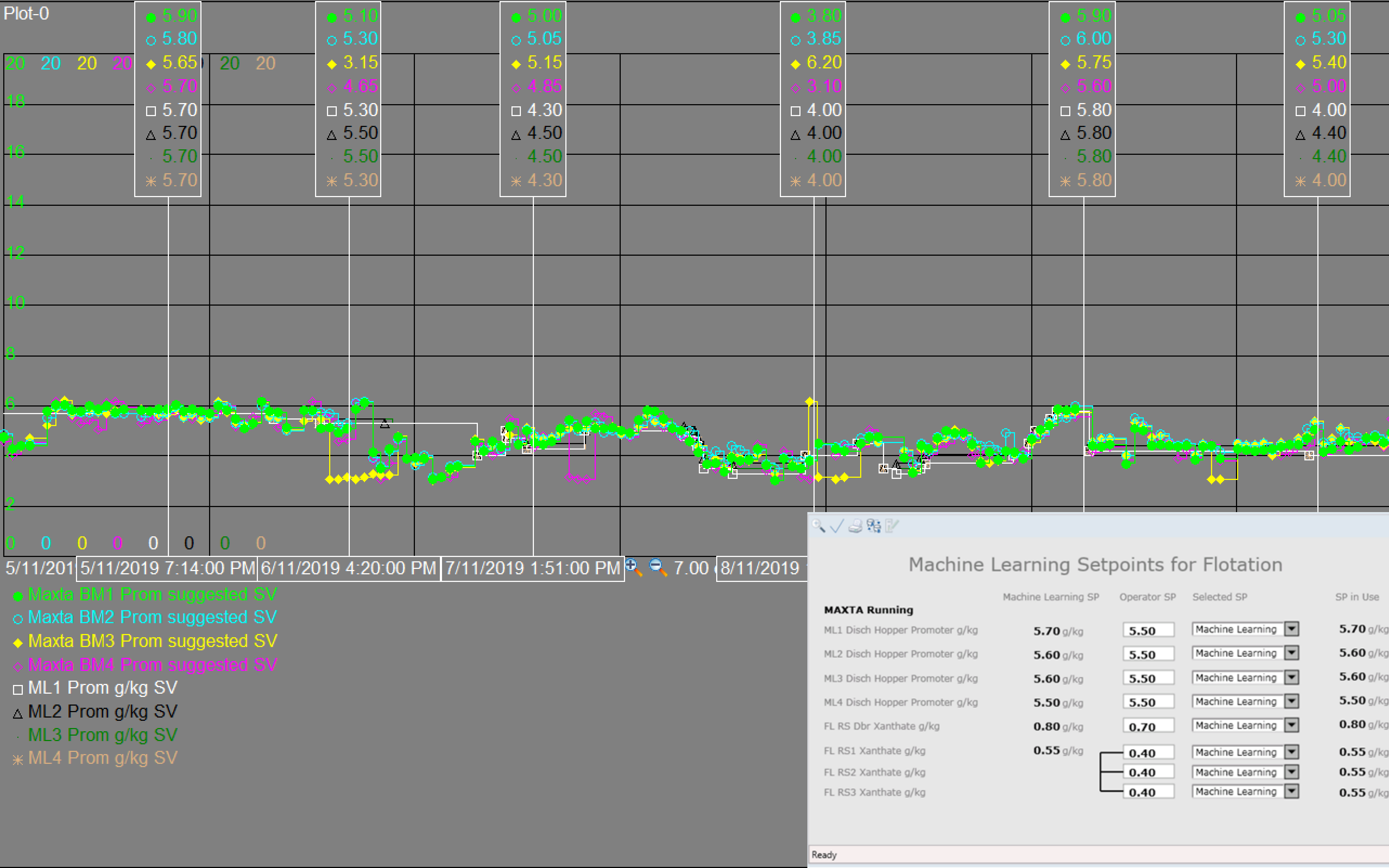


Plot-0
0.02654 0.02654 0.02654 0.0265 0.0265
0.025
0.02
0.015
0.01
0.005
0 0 0 0 0
13/09/2019 8:11:55 PM
5.17 days
19/09/2019 12:21:08 AM
TailPredLo in 6 Hours
TailPred in 6 Hours
TailPredHi in 6 Hours
FL OSA1 RS1 Tail %Cu
FL OSA1 RS1 Tail %Cu Shift Ave



Machine Learning Setpoints for Flotation

MAXTA Running	Machine Learning SP	Operator SP	Selected SP	SP in Use
ML1 Disch Hopper Promoter g/kg	5.70 g/kg	5.50	Machine Learning	5.70 g/kg
ML2 Disch Hopper Promoter g/kg	5.60 g/kg	5.50	Machine Learning	5.60 g/kg
ML3 Disch Hopper Promoter g/kg	5.60 g/kg	5.50	Machine Learning	5.60 g/kg
ML4 Disch Hopper Promoter g/kg	5.50 g/kg	5.50	Machine Learning	5.50 g/kg
FL RS Dbr Xanthate g/kg	0.80 g/kg	0.70	Machine Learning	0.80 g/kg
FL RS1 Xanthate g/kg	0.55 g/kg	0.40	Machine Learning	0.55 g/kg
FL RS2 Xanthate g/kg		0.40	Machine Learning	0.55 g/kg
FL RS3 Xanthate g/kg		0.40	Machine Learning	0.55 g/kg

Ready

Crusher Set-point Optimisation Case Study 2

8 significantly differently ore classes identified. Optimal ranges for target tonnes for each ore classes and apron feeder rate. No benefit operating below 1000 tonnes per hours - no need to ramp up – Overall 12 % improvement by using both the fast start-up and optimised operation for single crusher operation. Theoretical improvement of 24% if there was no tonnage restriction on the crusher's conveyors circuit.

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Stockpile Ore Characterisation

Ore Characterisation

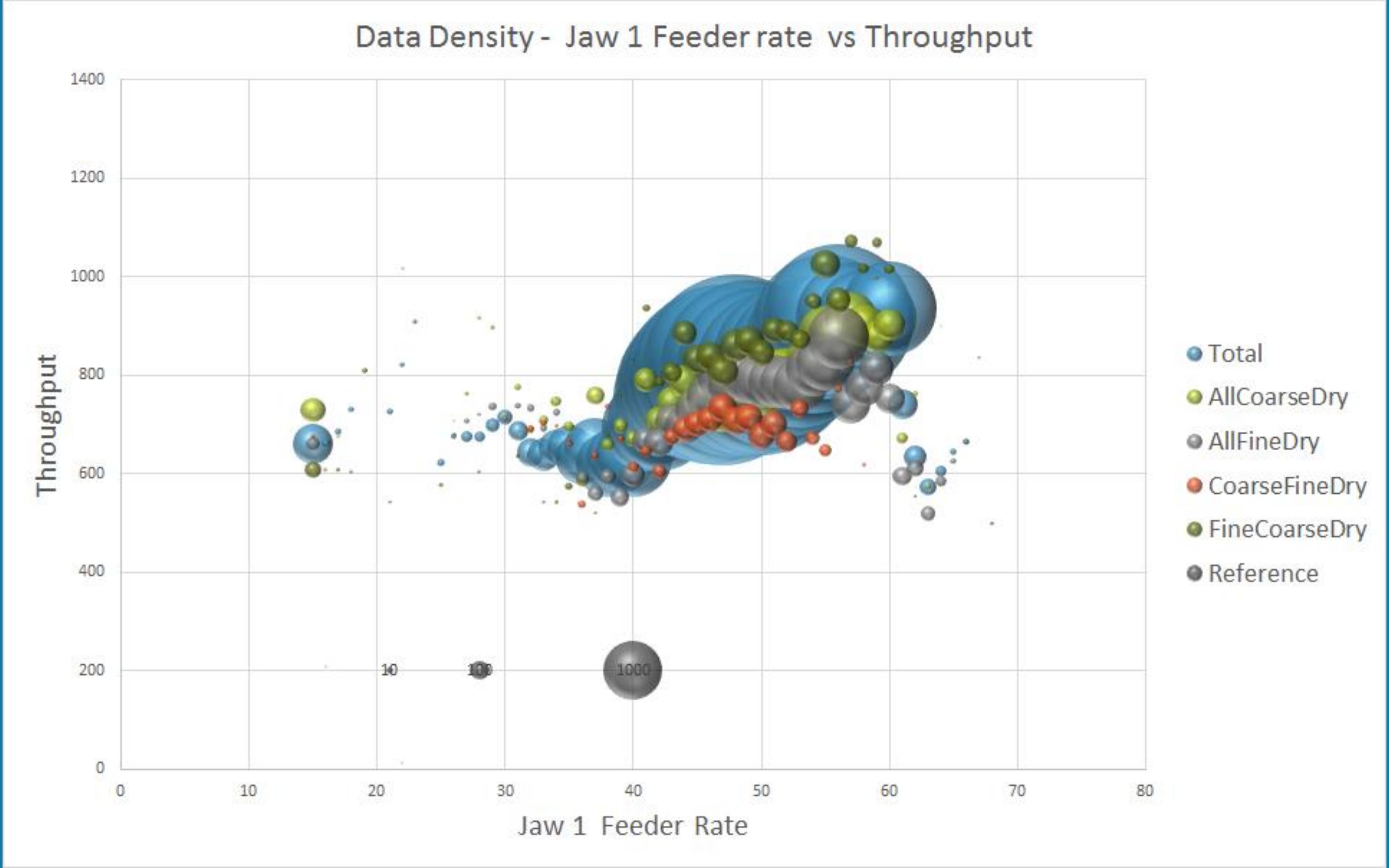
Wet - 110mm in a week

Fragmentation Classes:

PSD p50 (Fine < 87mm, Coarse > 87mm)

PSD p80 (Fine < 200mm, Coarse > 200mm)

jaw	Wet FineFine	Dry FineFine	Wet CoarseFine	Dry CoarseFine	Wet FineCoarse	Dry FineCoarse	Wet CoarseCoarse	Dry CoarseCoarse
1	607	448	386	463	554	610	537	538
2	543	465	495	503	532	642	543	547



Data Density - Jaw 1 Feeder rate vs Throughput
Throughput
Jaw 1 Feeder Rate
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
70
80
10
100
1000
Total
AllCoarseDry
AllFineDry
CoarseFineDry
FineCoarseDry
Reference

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