Sensor-Based Sorting: Lithium

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Saskatchewan Research Council

SRC Overview

SRC is Canada's second largest research and technology organization and has worked with industry, government and communities around the world for over 75 years.

Role as a Treasury Board Crown Corporation

SRC is governed by The Research Council Act. It is overseen by an independent Board of Directors and is accountable to the Minister Responsible for SRC.

We receive a portion of our funding from government with the remainder coming from contract research and fee-for-service work.

OVERVIEW 2021-22

$277 MILLION IN ANNUAL REVENUE

CANADA'S 2ND LARGEST RESEARCH & TECHNOLOGY ORGANIZATION

23

1,400 CLIENTS IN 23 COUNTRIES

OVER 300 EMPLOYEES

+75 YRS OF RD&D EXPERIENCE

ECONOMIC PERFORMANCE 2021-22

$13.6 BILLION IN IMPACTS SINCE 2003

TOTAL IMPACTS ON PROVINCIAL ECONOMY: $1.8 BILLION

$1.2 BILLION IN DIRECT ECONOMIC BENEFITS

$627 MILLION VALUE OF JOBS CREATED/MAINTAINED

59x

59-TIMES RETURN ON PROVINCIAL INVESTMENT

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SRC HAS LOCATIONS IN

Saskatoon, Sask.
(Headquarters)

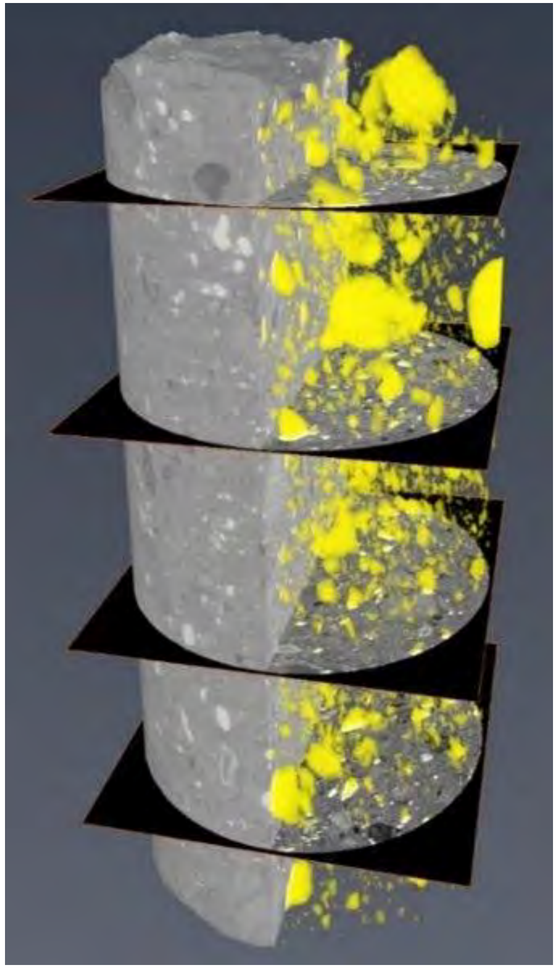
Regina, Sask.

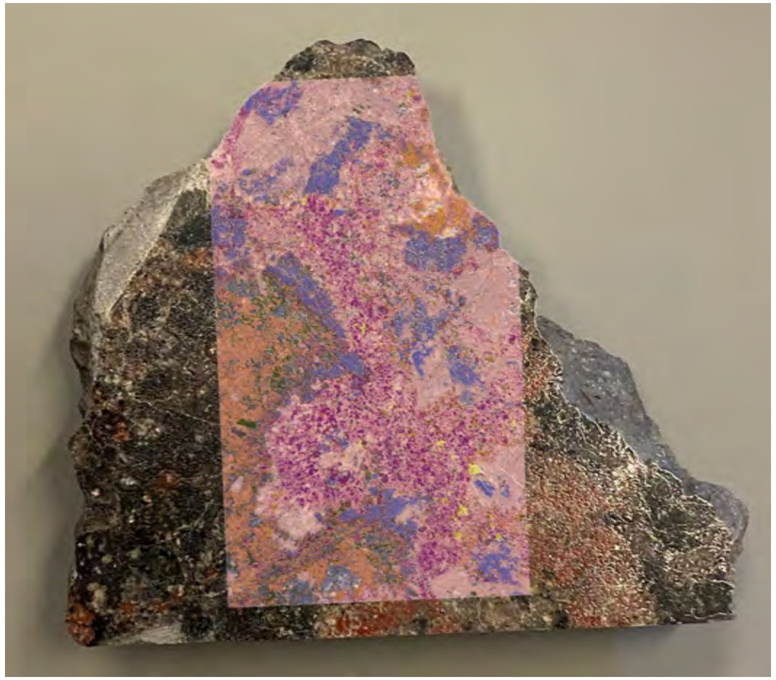
Uranium City, Sask.

Proudly serving 1,400 clients across the world.

Why is Sensor-Based Sorting Testwork Important?

- Based on physical mineral properties
- Quantitative
- Small samples can provide useful information
- Theoretical and actual data can be used





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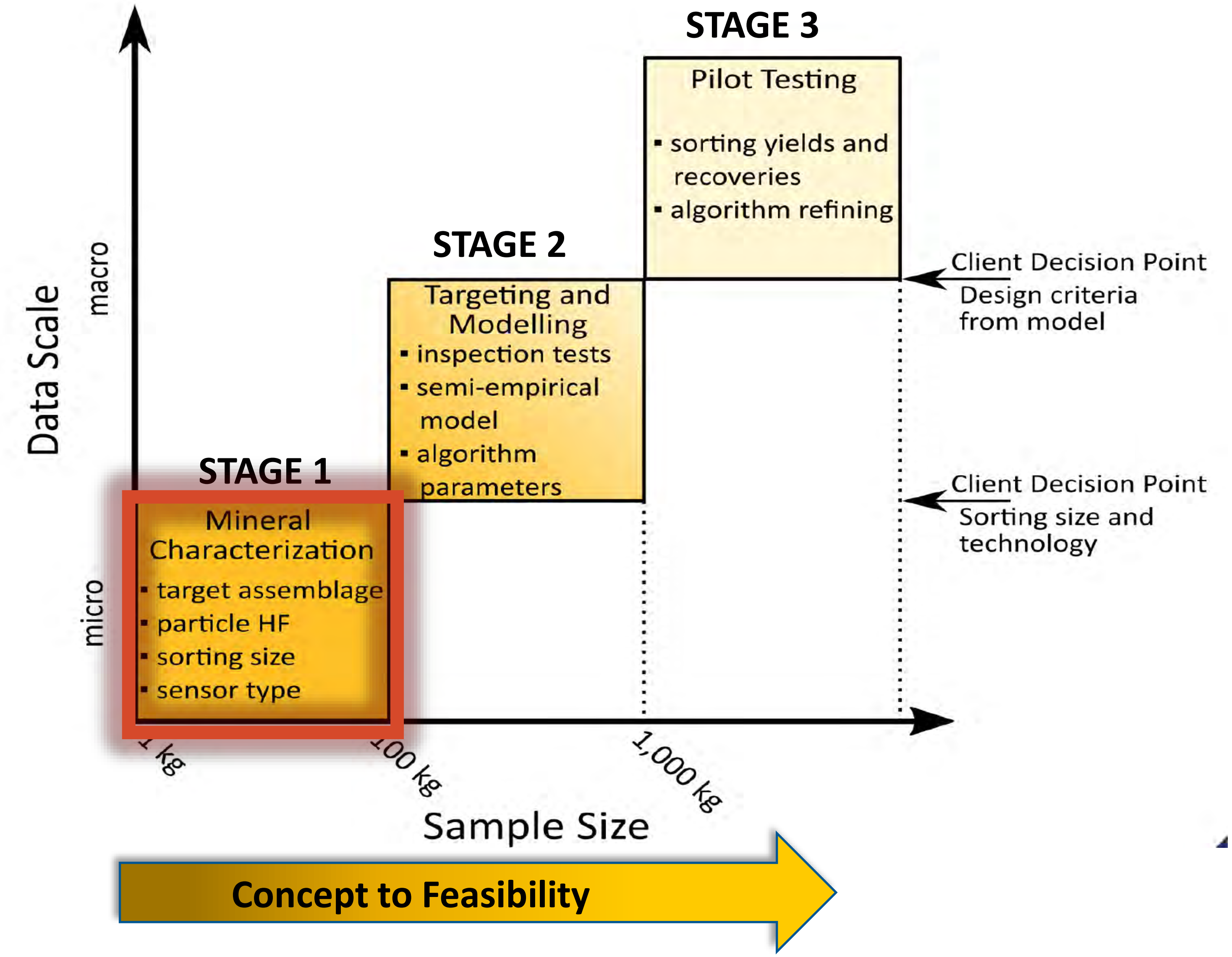
STAGE 1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▪ sorting yields and recoveries
▪ algorithm refining
STAGE 2
Targeting and Modelling
▪ inspection tests
▪ semi-empirical model
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STAGE 1
Mineral Characterization
▪ target assemblage
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1 kg
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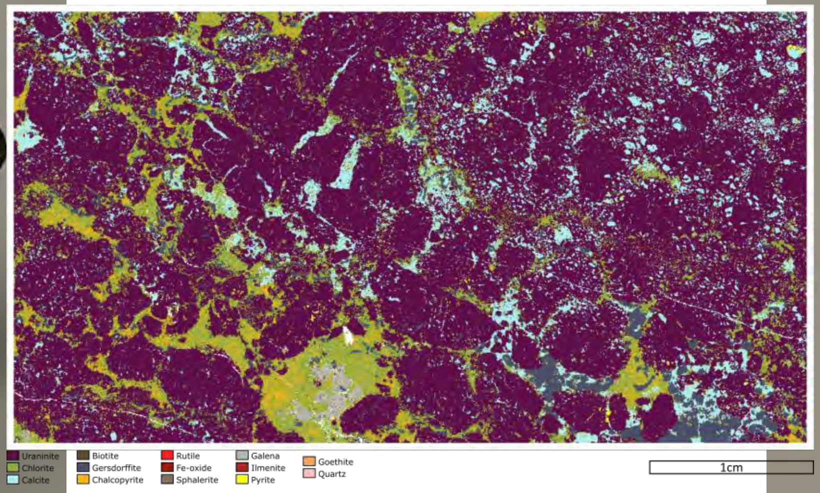
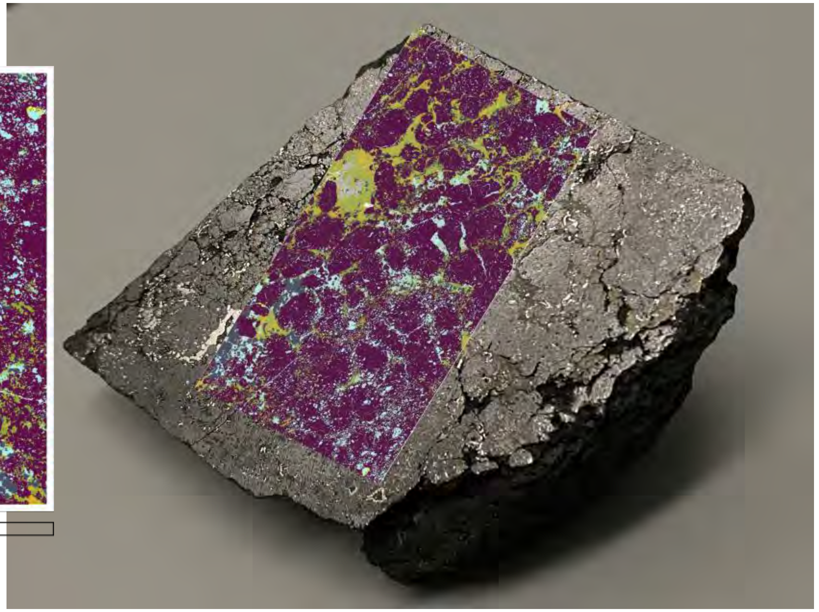
Concept to Feasibility

Mineral Characterization

Goal:

Identify target mineral assemblage and ideal particle size for sensor-based sorting





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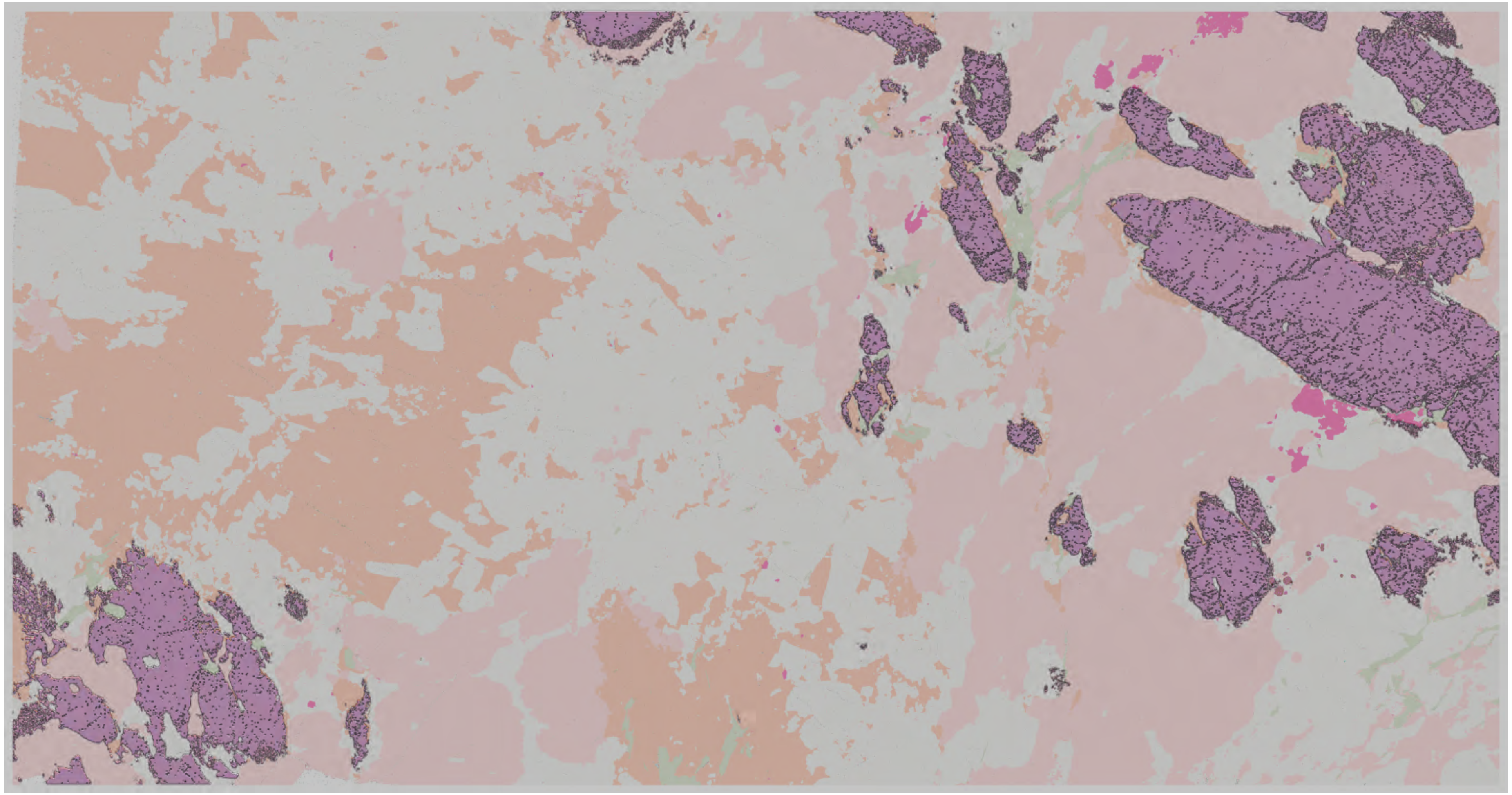
Lithium Mineralogy

- Lithium is incompatible and concentrates in late-stage crystallization products, e.g., pegmatites
- Over 120 mineral species and counting contain lithium
- Most common minerals (>200 deposits) include:
  spodumene, elbaite, triphylite, amblygonite and lithiophorite

Problems:

- High proportion of lithium minerals occur in just one location (50%)
- Can be hard to visually identify
- Lithium is hard to analyze by traditional X-ray instruments

Mineral Identification (Spodumene)



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Homogeneity and Sortability

- *Interparticle heterogeneity* is required for separating waste from ore, whereas *intraparticle homogeneity* is required for sorting
- Homogeneity is defined by the spatial distribution of the *target assemblage,* which may be composed of one or more minerals
- Higher particle homogeneity gives consistent, predictable sensor response
- **Homogeneity factor (HF)** is a single dimension parameter quantifying the proportion of the most abundant mineral relative to the total number of unique minerals and total number of interconnected mineral domains
- Homogeneity generally increases with decreasing particle size

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Quantifying Homogeneity

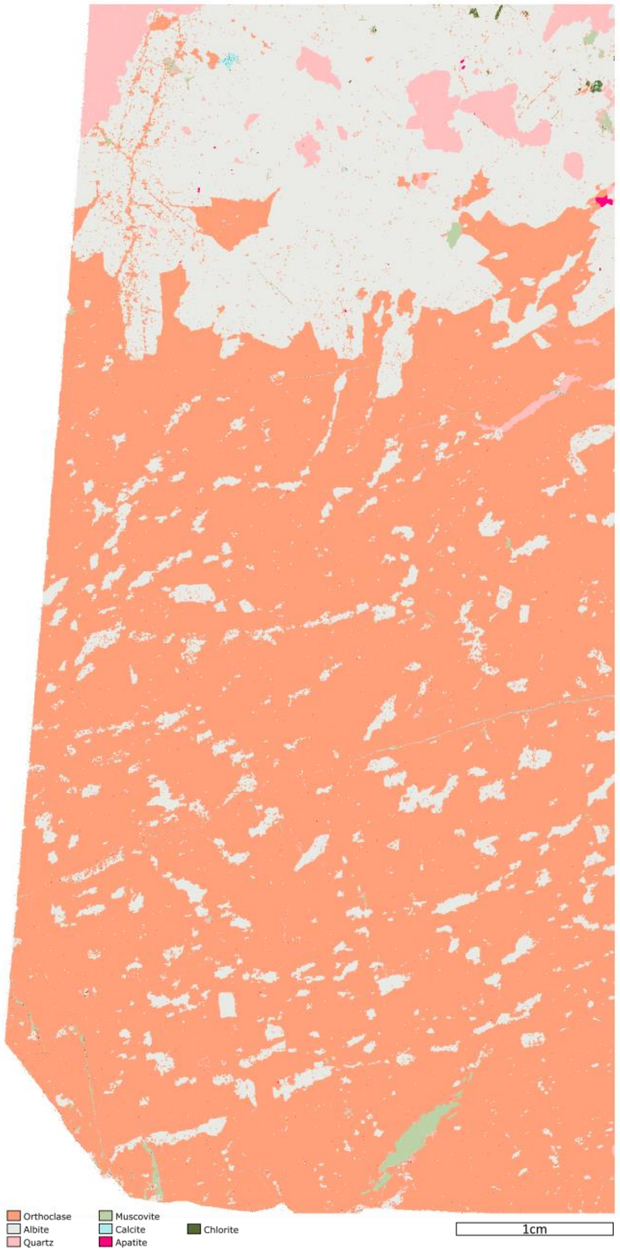
The homogeneity factor is a function of:

1. The percentage of the dominant mineral
2. The number of different minerals
3. The number of individual grains

Describes particle homogeneity in a single, numerical dimension

$$\text{HF} = 50 \text{ x} \log\left[\frac{2\ x\ Modal\ \%\ Major\ Mineral}{(No.\ of\ Minerals + No.\ of\ Particles)}\right]$$

High Homogeneity



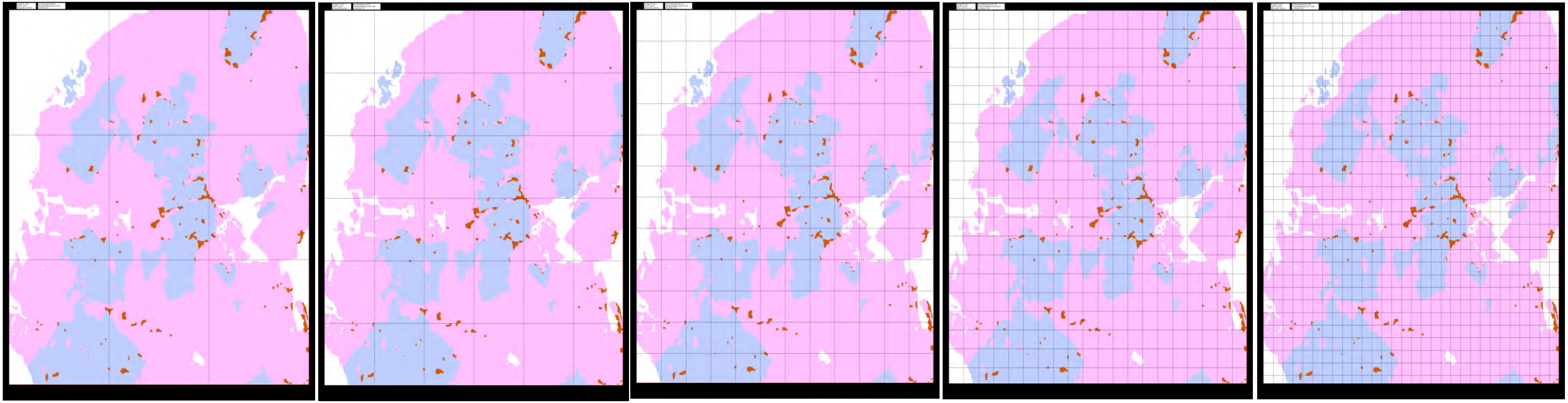
Low Homogeneity

High Homogeneity

Low Homogeneity

HF Size Grid

Modeling HF increase in by reducing particle size:



20 mm	10 mm	5 mm	2 mm	1 mm
HF = 9.8	HF = 39.7	HF = 67.7	HF = 82.1	HF = 90.3

Stage 1 Deliverable: Characterization Table

Mineral name	Ore/ Waste Rock	Chemical Formula	Modal %	Average Size Range (cm)	Major Associations	Mineral Group	Approx. Li %	Hardness (Mohs scale)	Specific gravity (kg/m^3)	Electron Density (gm/cc)	Molecular Weight (gm)	Atomic Density (N)	Colour	Luster	Transparency	Luminescence	Magnetic susceptibility
Spodumene	Ore	$LiAlSi_2O_6$	20	2-4	Qtz/Musc/ Orth	pyroxene	3.7	6.5-7.0	3.15	3.11	186.09	1.01E-24	Colourless to white	vitreous to dull	transparent to translucent	Fluorescent, Short UV= orange (blue) Long UV= pink-orange red	diamagnetic
Quartz	Waste Rock	SiO_2	45	2-6	Sp/Musc/ Orth/Alb	silicate	-	7	2.65-2.66	2.65	60.08	2.66E-24	Colourless	vitreous	transparent to translucent	Fluorescent, Short UV=yellow-orange, Long UV=yellow-orange	diamagnetic
Albite	Waste Rock	$Na_{0.95}Ca_{0.05}Al_{1.05}Si_{2.95}O_8$	15	2-4	Qtz/Orth/ Apa	feldspar	-	6-6.5	2.6-2.65	2.6	263.02	5.95E-25	White to colourless	vitreous	transparent to translucent	Fluorescent, Short UV=berry red blue, Long UV=white	diamagnetic
Orthoclase	Waste Rock	$K(AlSi_3O_8)$	5	0.5-1	Qtz/Alb	feldspar	-	6	2.56	2.53	278.33	5.47E-25	Pink	vitreous, resinous, porcelaneous	transparent to translucent	non-fluorescent	diamagnetic
Muscovite	Waste Rock	$KAl_2(AlSi_3O_{10})(OH)_2$	8	1-3	Alb/Qtz/Sp	mica	-	2.5	2.8-2.9	2.81	398.71	4.24E-25	grey to silver white	vitreous, silky, pearly	transparent to translucent	non-fluorescent	paramagnetic
Apatite	Waste Rock	$Ca_5(PO_4)_3(OH,F,Cl)$	5	0.5-1	Alb/Orth	apatite	-	5	3.2	3.17	509.12	3.75E-25	White to Green	vitreous	transparent to translucent	non-fluorescent	diamagnetic
Kaolinite	Waste Rock	$Al_2Si_2O_5(OH)_4$	<1	<0.5	Alb/orth	clay	-	1.5-2	2.6	2.62	258.16	6.11E-25	white to greyish white	dull	transparent to translucent	non-fluorescent	diamagnetic
Garnet (almandine)	Waste Rock	$Fe^{++}{}_3Al_2(SiO_4)_3$	<1	<0.5	Qtz/Alb/ Musc	garnet	-	7-8	4.2	4.08	497.75	4.94E-25	red	vitreous-resinous	transparent to translucent	non-fluorescent	paramagnetic
Andalusite	Waste Rock	$Al_2(SiO_4)O$	<1	<0.5	Qtz/Alb/ Musc	silicate	-	6.5-7	3.15	3.11	162.05	1.16E-24	dark green	vitreous	transparent to translucent	non-fluorescent	diamagnetic
Separation Technique:									DMS			XRT	Colour			UV	Magnetics

STAGE 1 Decision

CLIENT DECISION: *What target mineral, sorter and size?*

1. Based on sensor responses of each mineral
2. And the HF – size tables of each mineral

Separating Spodumene

Minerals of interest appear liberated at ~2-4 cm

- **DMS** – density separation - **feasible**
- **XRT** – combination of thickness/density/atomic density - **feasible**
- **Colour – Difficult** as little variation
- **Luminescence** – **feasible** for ore concentrating and/or waste rock removal
- **NIR – Possible** (minerals are translucent-transparent) - **more testing**
- **Laser – Possible** (minerals are translucent-transparent) - **more testing**
- **Magnetics – little benefit**

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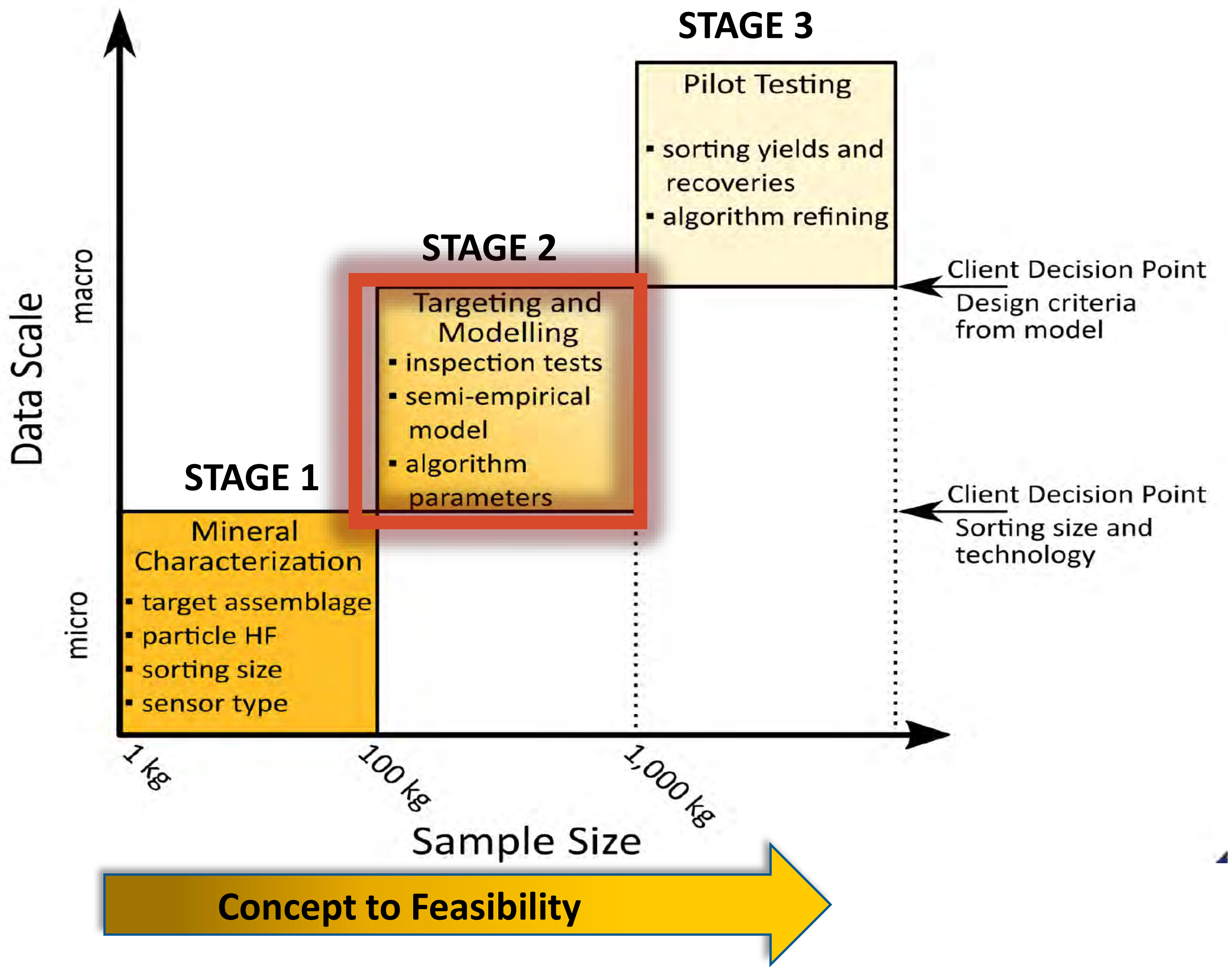
STAGE 2



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1,000 kg
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Concept to Feasibility

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STAGE 2: Targeting and Modelling

1. Evaluate the *sorting efficiency* of the identified technology
2. Develop *semi-empirical sorting models* for use by clients to build flowsheets and test different scenarios with small (but representative) amounts of sample; data is gathered from sorter first inspection as well as characterization results.

Lithium-bearing Pegmatite

Colour Calibration

Data	Red	Green	Blue	Brightness	Hue	Saturation	avg. Brt	Colour
1	166	166	168	168	170.0	3.0		
2	176	180	181	181	136.0	7.0		
3	164	163	160	164	31.9	6.2		
4	120	111	101	120	22.4	40.4		
5	155	156	158	158	155.8	4.8		
6	202	214	214	214	127.5	14.3		
7	191	192	194	194	155.8	3.9		
8	159	164	160	164	93.5	7.8		
9	156	162	162	162	127.5	9.4		
10	136	140	141	141	136.0	9.0	166.6	

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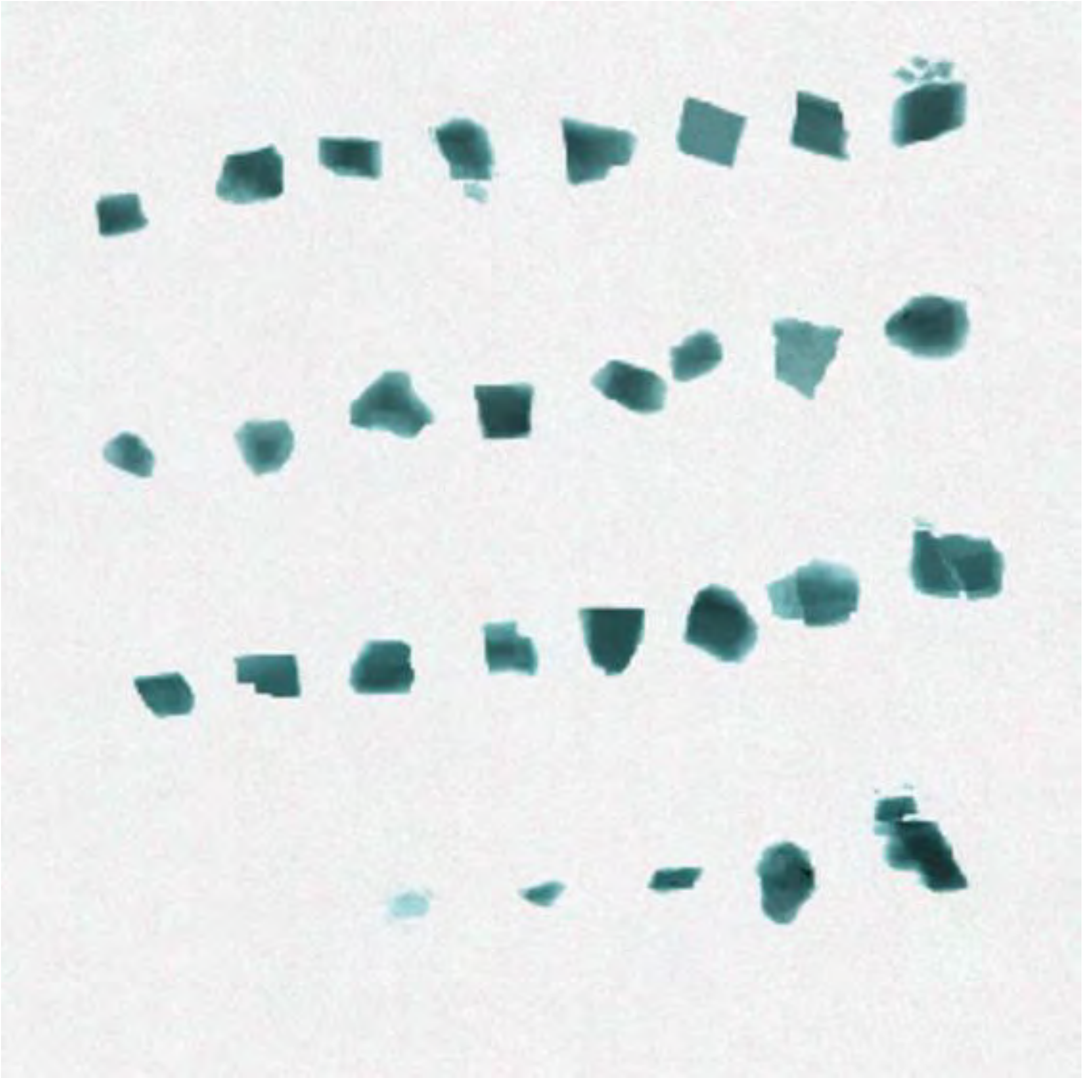
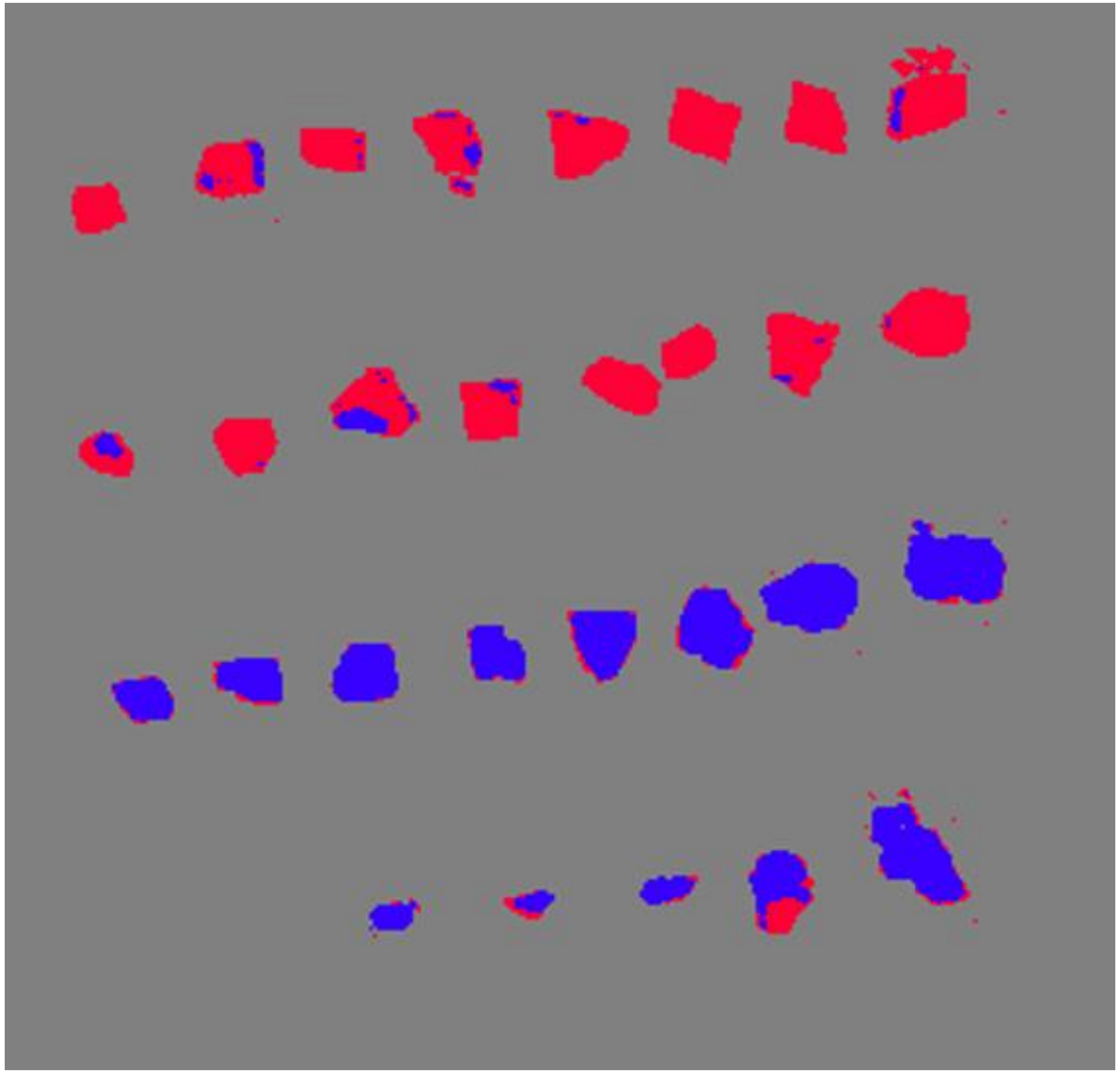
XRT Inspection Tests

- Spodumene
- Quartz
- Feldspar
- Mica



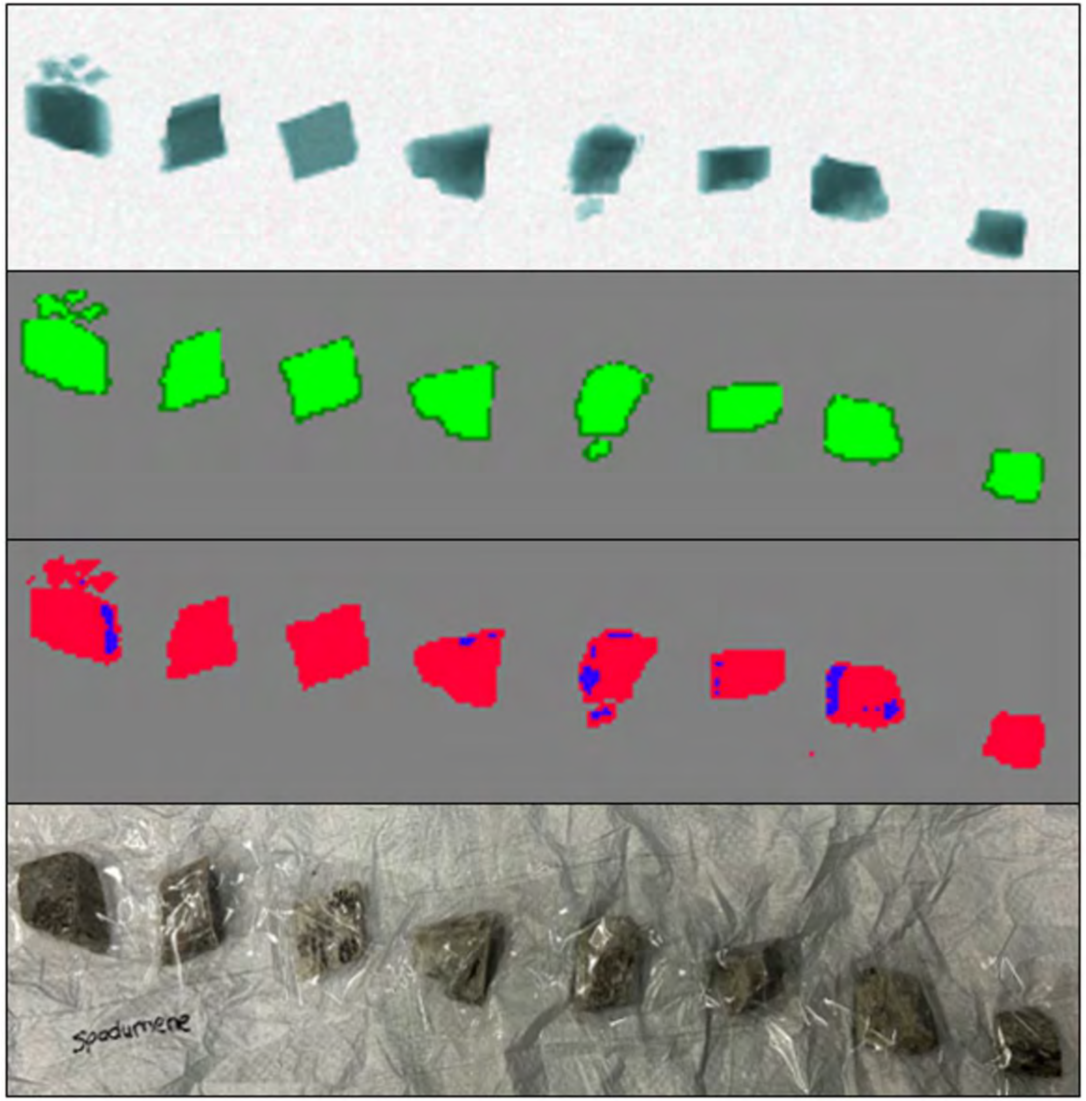
XRT Inspection Tests

- Red = High Density
- Blue = Low Density



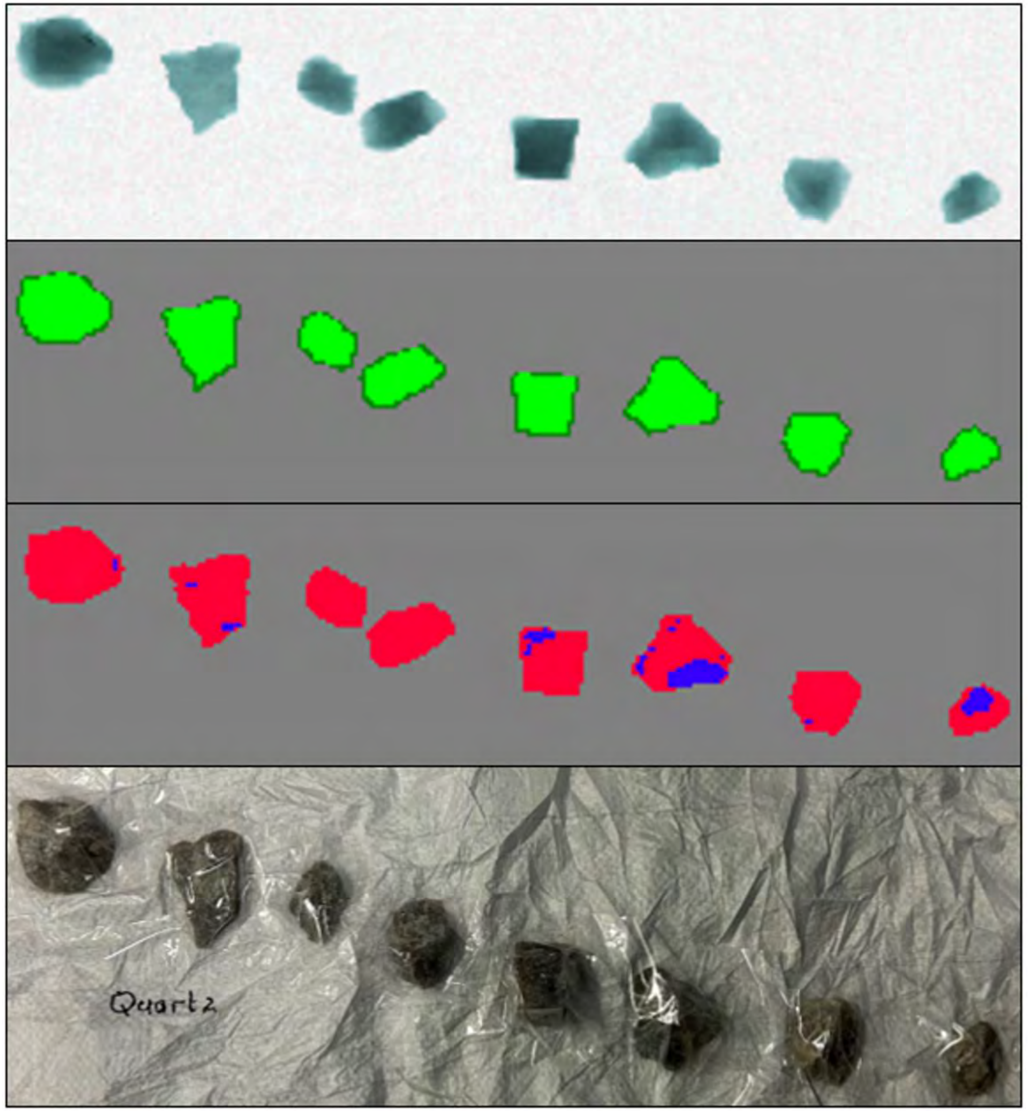
Spodumene

- $LiAlSi_2O_6$
- Pyroxene group
- Atomic Density 1.01E-24



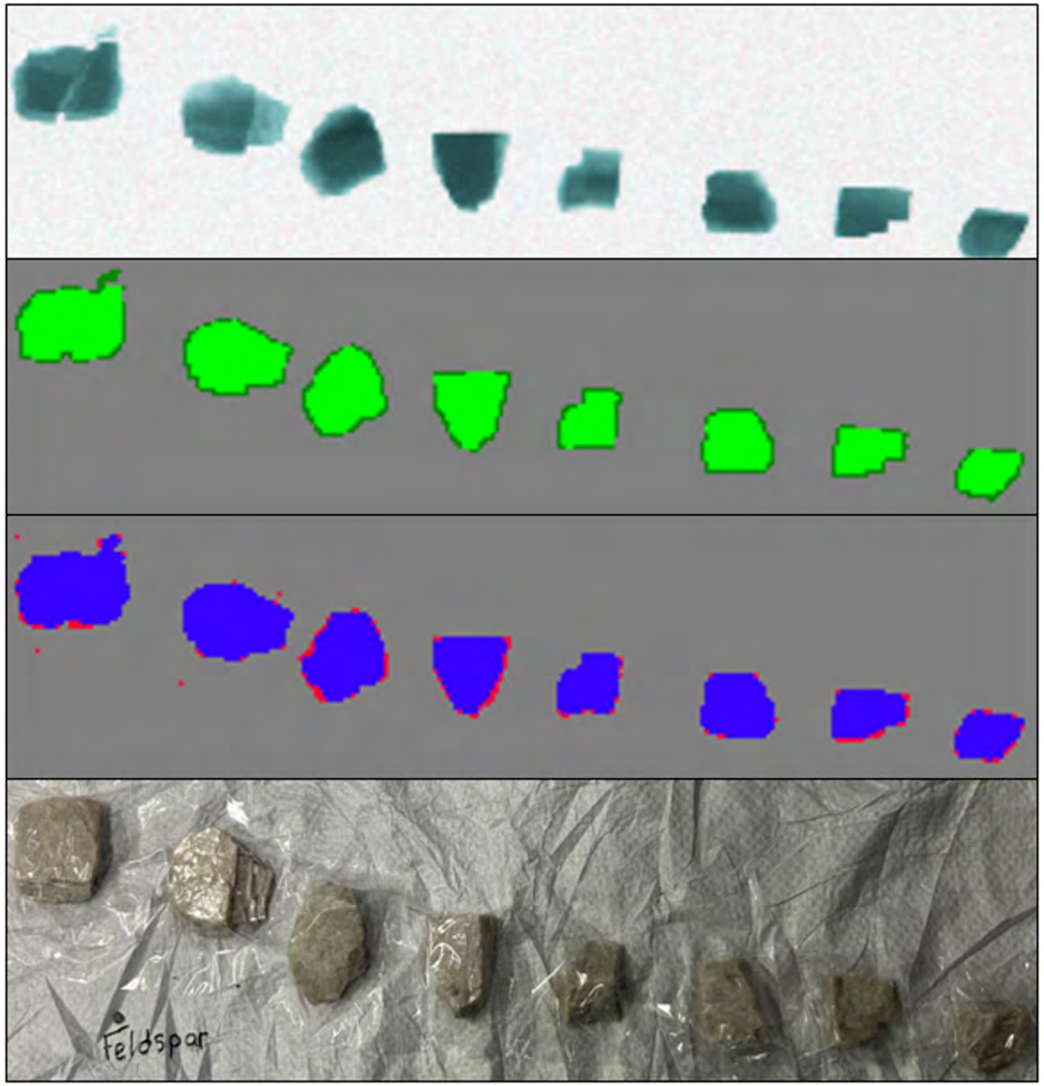
Quartz

- SiO_2
- Silicate group
- Atomic Density 2.66E-24



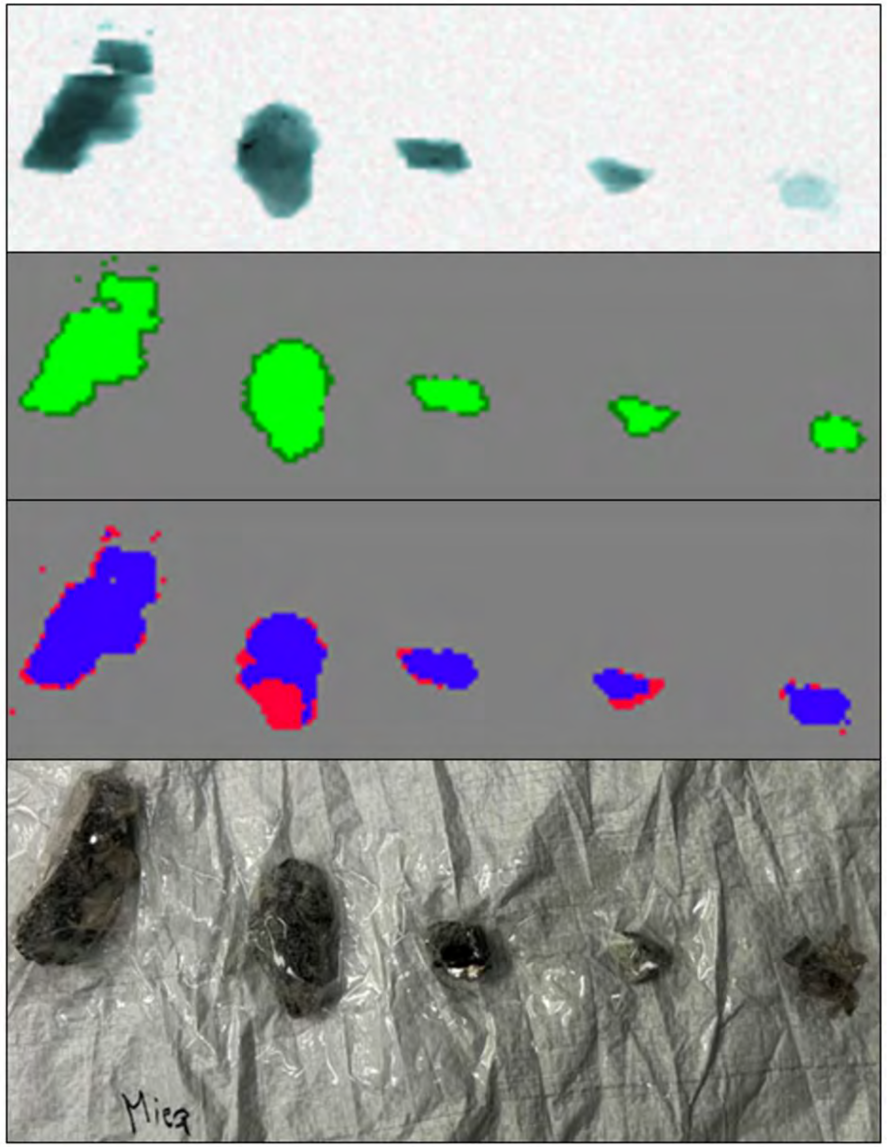
Orthoclase

- $K(AlSi_3O_8)$
- Feldspar group
- Atomic Density 5.47 E-25



Muscovite

- $KAl_2(AlSi_3O_{10})(OH_2)$
- Mica group
- Atomic Density 4.24 E-25



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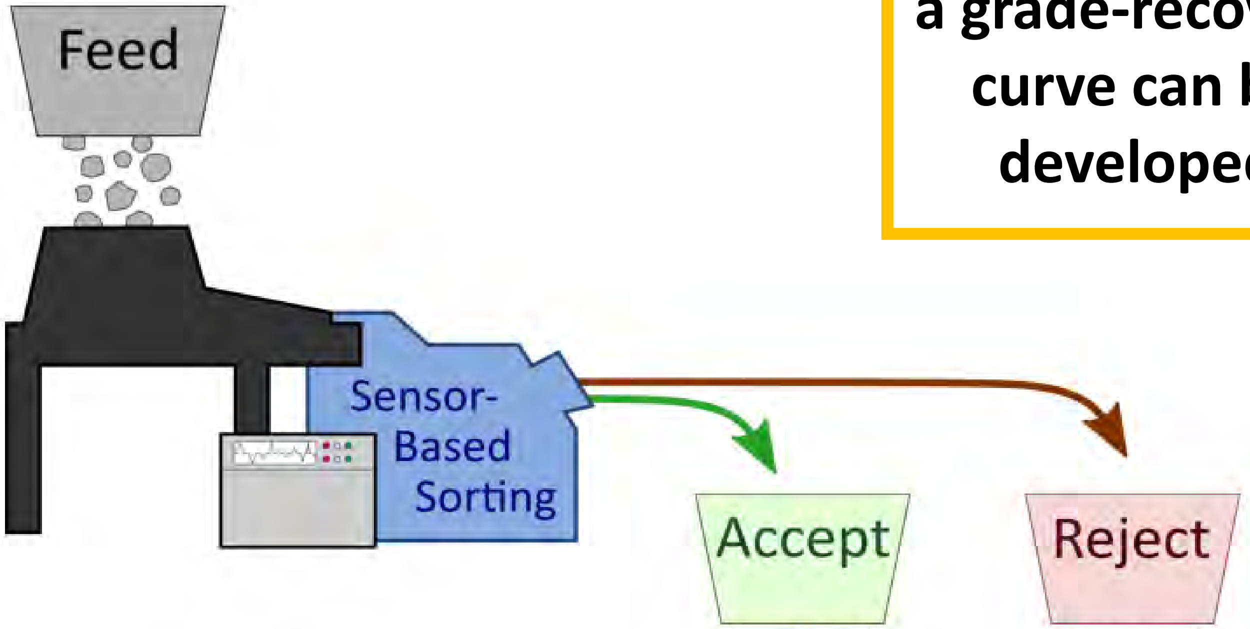
Stage 2 Deliverable: XRT Model for -10 mm

Lithium - XRT Sorting

Grade cutoff 0.07

Feed Grade (wt%) 0.880
Feed Mass (kg) 103.58



From this model, a grade-recovery curve can be developed

Sorting Efficiency	85.0%
Lithium recovery	12.1%
Upgrade Potential	315.9%

Accept Grade	Reject Grade
2.780	0.050
Accept Mass	**Reject Mass**
39.53	64.05
38%	62%

STAGE 2 Decision

CLIENT DECISION: *What are the optimal mass pulls and grade cutoffs?*

1. Adjust the design criteria
2. Refine modelling for scaled testwork

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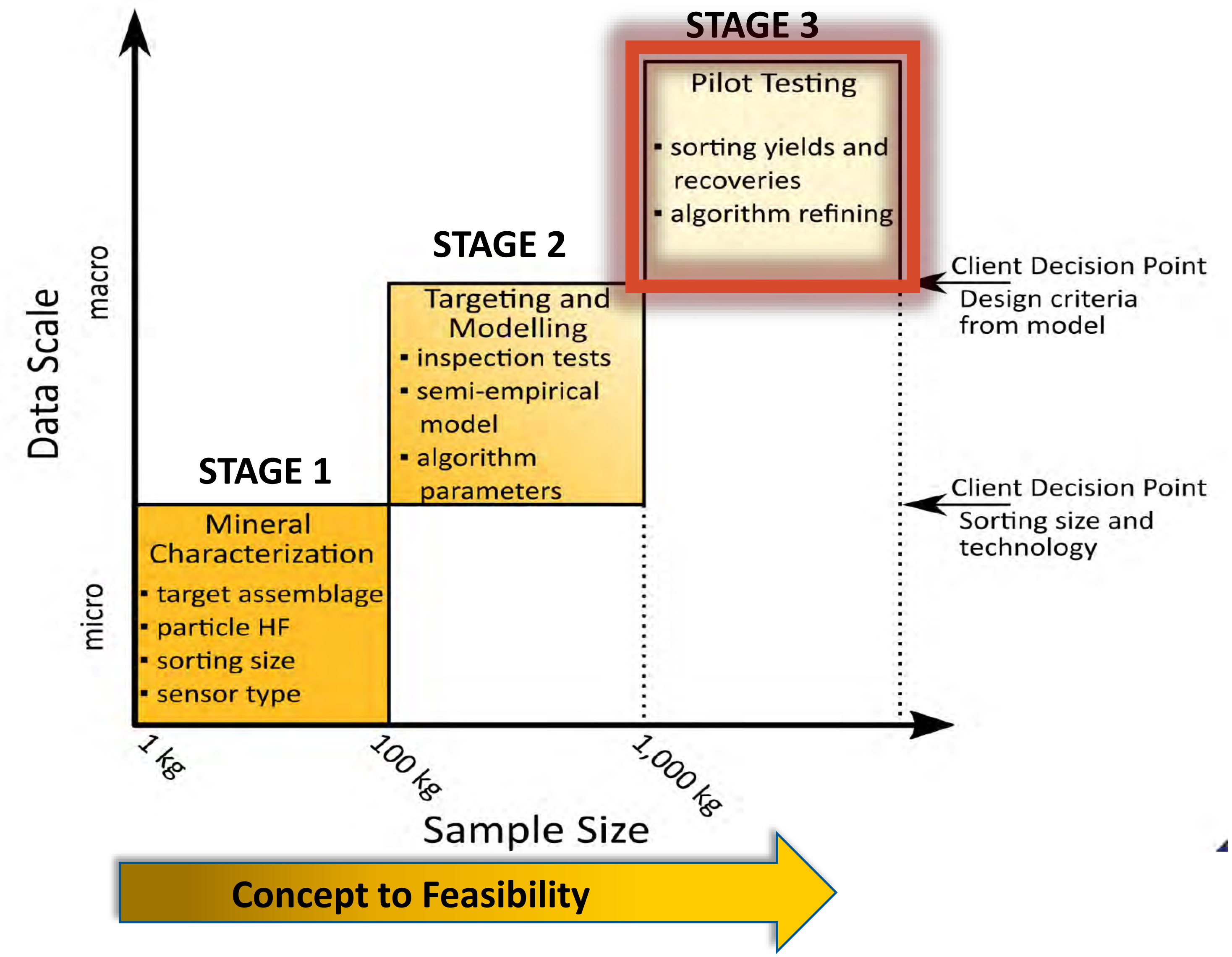
STAGE 3



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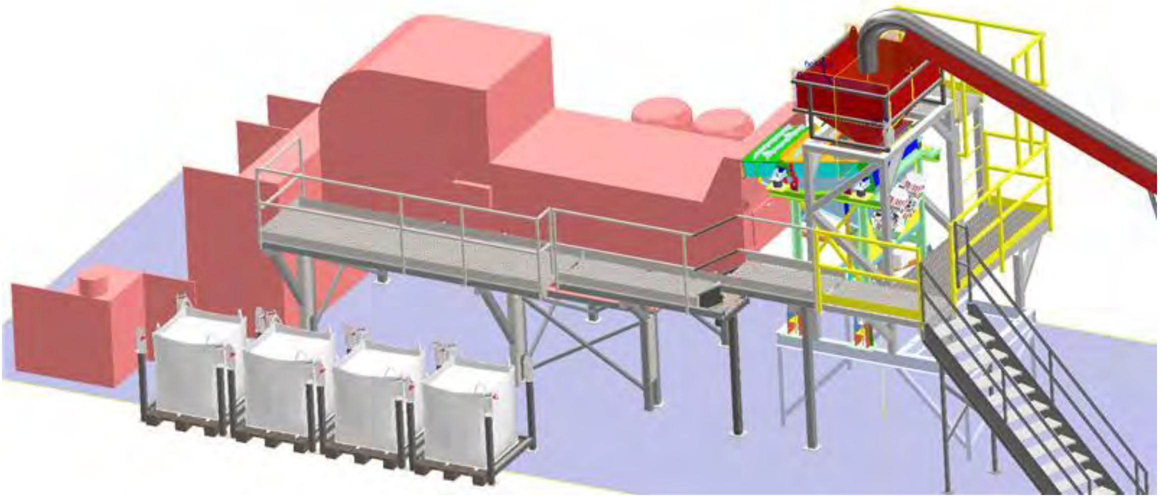
Pilot Testing

- Larger volume test work based on previous stages
- Verification of equipment specifications
  - Performance (real vs. semi empirical model)
  - Throughput
  - Yield
- Optimizes entire flow sheet
- 1,000 kg to 100,000 kg of material needed



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Key Points for Lithium Sorting

- Mineral characterization can provide first indications of sortability.
- Test work combined with assay can be used to develop a semi-empirical model.
- Scaled testing can provide validation of equipment for flow sheet design.
- Quantitative data and modelling might be used for feasibility studies and compliance reporting. (ex.NI 43-101)

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Sensor-Based Sorting at SRC

- Independent
  - Work with equipment suppliers
  - Work with contractors
- On-site analyses at SRC Geoanalytical Laboratories
- Mineral Processing Team
  - Crushing
  - Sizing
  - Hydrometallurgy

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