"*The Intelligent Wet Mine*

Towards a risk-based decision framework to support an optimal transition of resources to reserves in marine mining

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1. Marine mining – RBM Example

2. Current market and future growth

Product Portfolio
- Mining dredger
- Slurry transport system
- Mineral separation plant
- Automation and control
- System integration

From dry to dredge mining
- Potential cost reduction by avoiding de-watering

Dredge mining project
- Millenium Brasil
- RBM, South Africa
- Iluka, Australia

Mineral sands

2. Current market and future growth

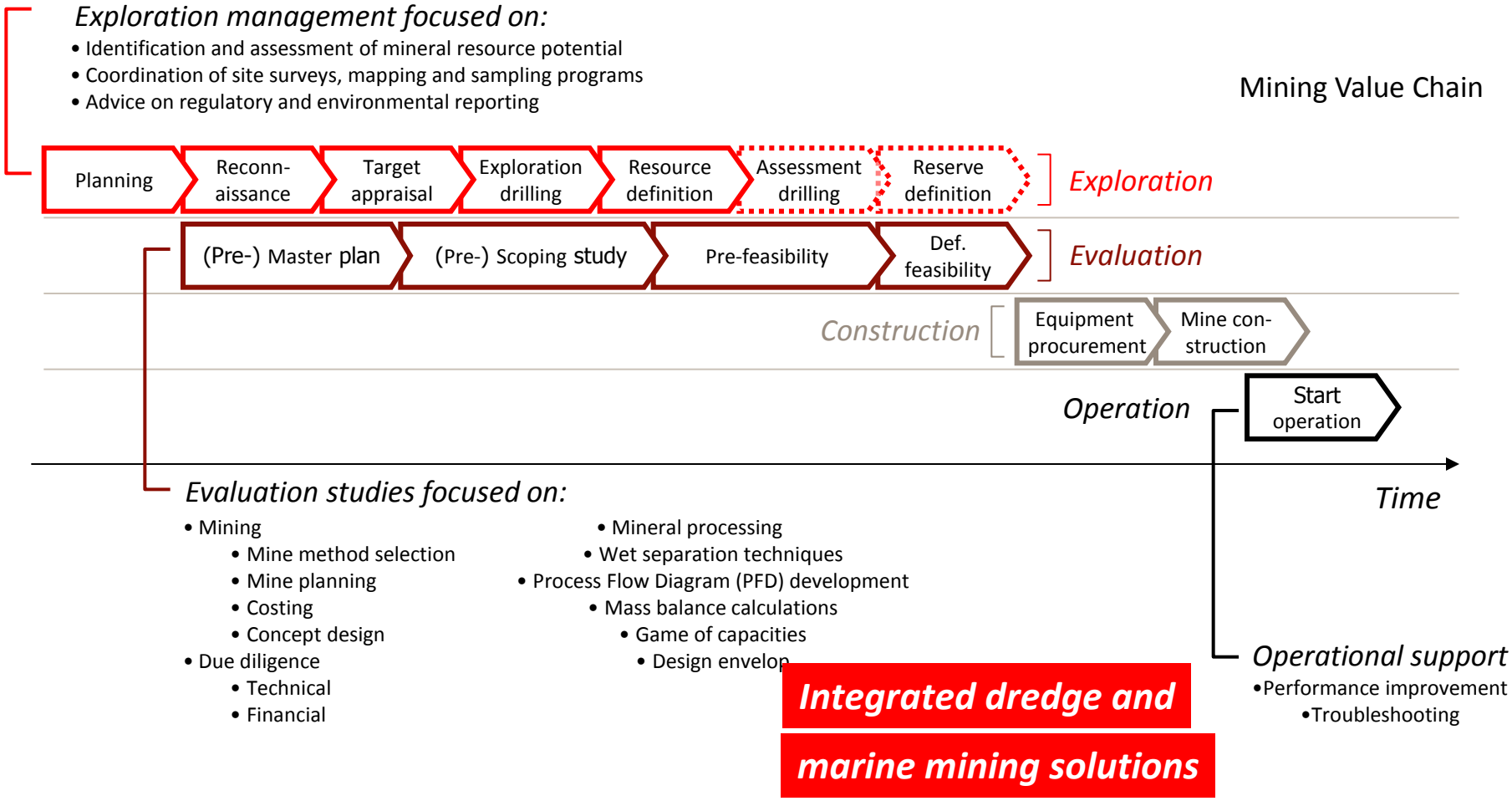
Product portfolio

- Mining support vessel
- Launch and recovery system
- Vertical transport system
- Seafloor mining tool
- System integration

Marine mining project

- De Beers Marine, Namibia
- Diamond mining
- Water depth up to 200m

2. Current market and future growth



3. Problem Statement

Paradox of seabed exploration

- For deep sea deposits, the level of information is scarce and data gathering is difficult and expensive!

How to reconcile?

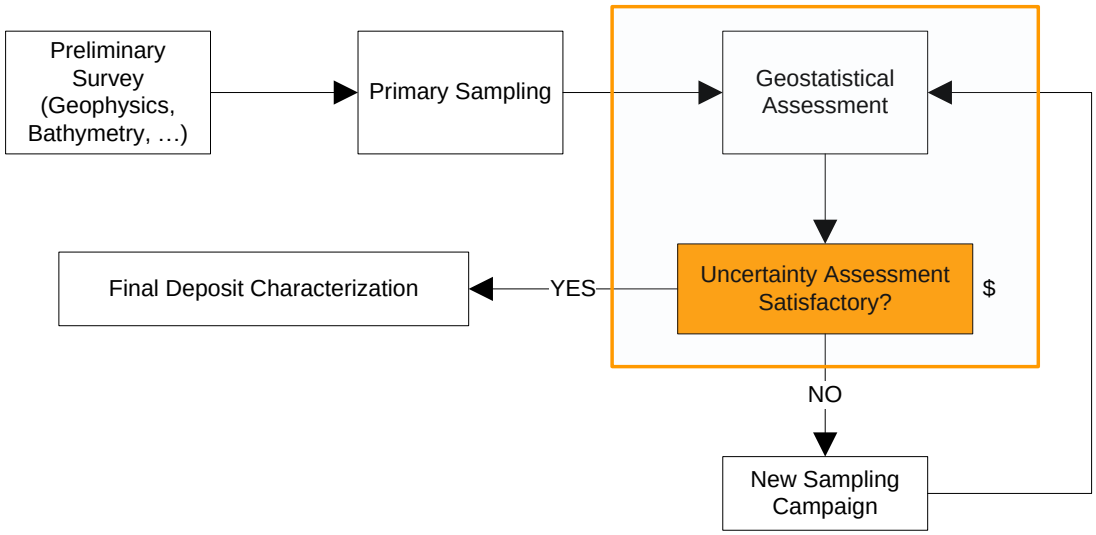
- Investors in seabed mineral exploitation require project information in terms of resources/reserves linked to the level of confidence

Obtain very expensive data in strategic stages to mitigate the risk!


Nautilus

3. Problem Statement

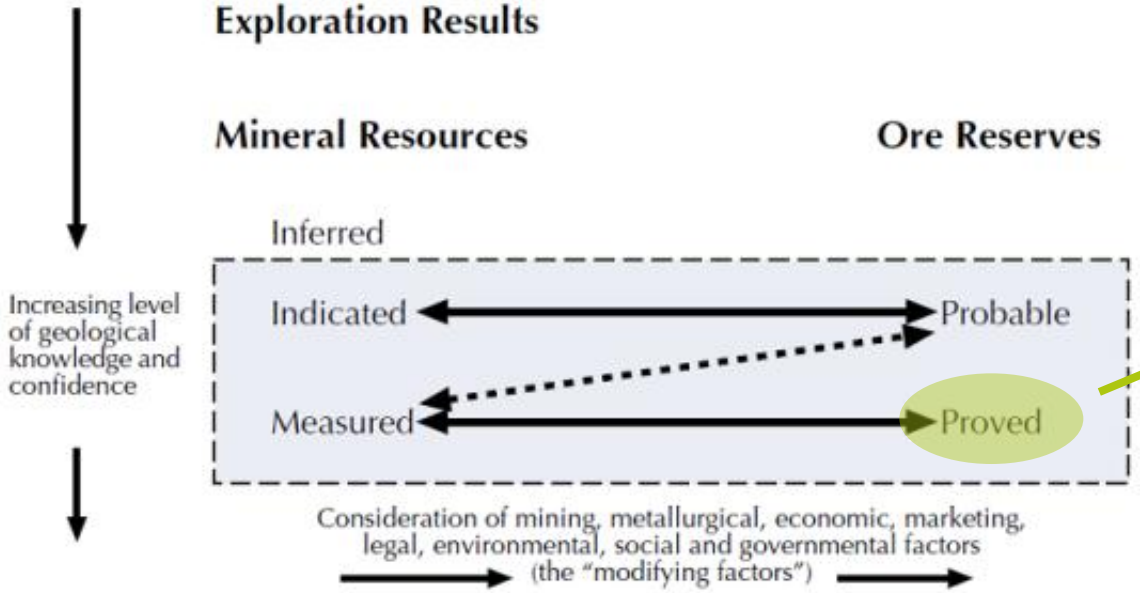
Towards a closed loop?



Obtain very expensive data in strategic stages to mitigate the risk!

3. Problem Statement

One step further?



Obtain very expensive data in strategic stages to mitigate the risk!

4. Research Objective

"*develop a new and innovative closed-loop management framework for the exploitation of marine mineral resources*

Development phase:

- large financial investment when knowledge is limited (data = scarce, exploration = expensive)
- Flexible decisions to account for residual uncertainty

Operational phase:

- Operational data = cheap + large amount
- Decision options can be narrowed down

TRANSPARENT RISK-ORIENTED FRAMEWORK!
> TOWARD OPTIMAL EQUIPMENT SELECTION + PLANNING

5. Research approach

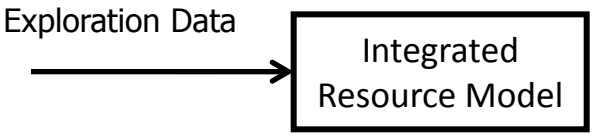
Towards an "Intelligent Wet Mine"

Input:

- Indirect/direct measurements
- Level of information
- Accuracies
- support

Output: G³U Model

1. Geological facies
2. Geotechnical and metallurgical
3. Grade distribution

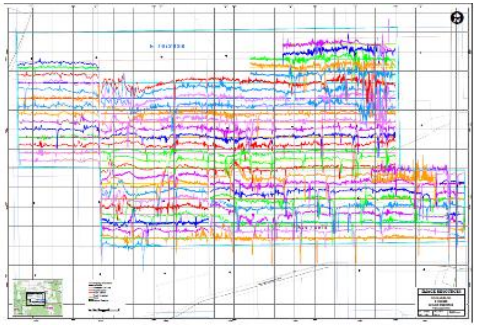


Spatial variability and uncertainty of the key properties impacting the resource recovery

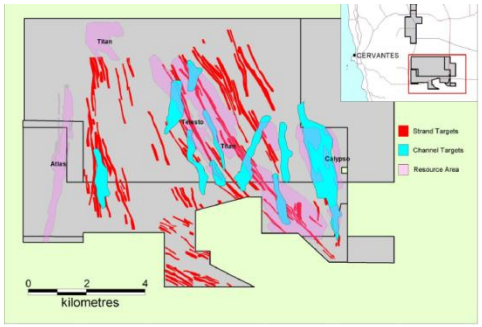
5. Research approach

Exploration Data

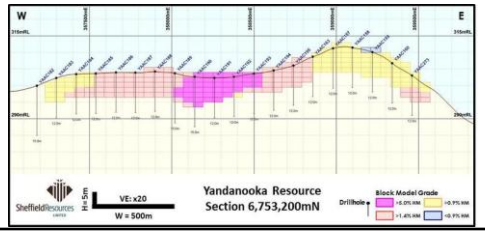
Magnetics



Expert knowledge



drillholes



Model

Integrated Resource Model

+

Transfer Function

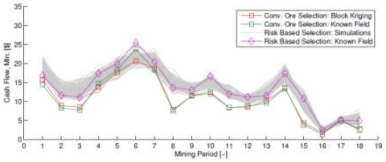
+

Development Decisions

PKI's

Excavation Recovery (Bucket Wheel)

Product Recovery (Jigs)



Cash Flow

5. Research approach

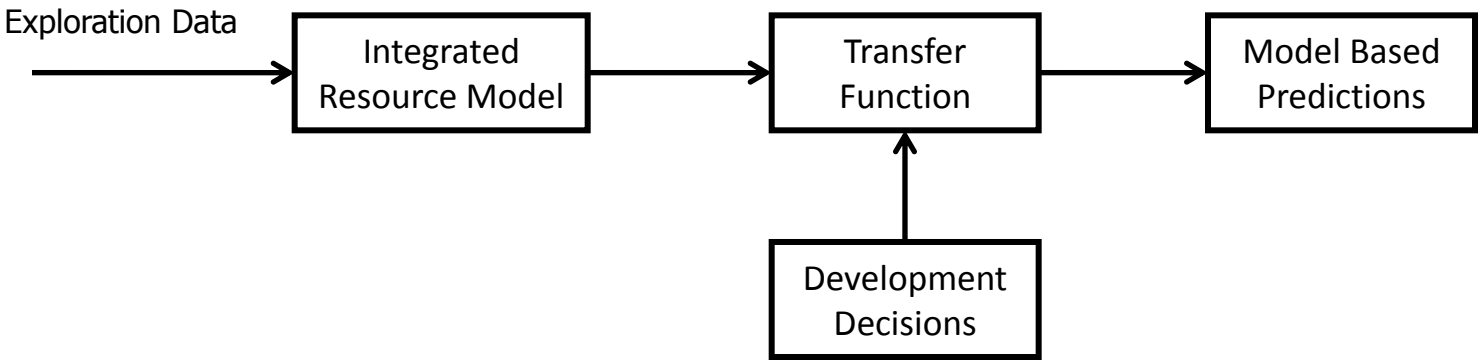
Towards an "Intelligent Wet Mine"

Transfer Function

- Excavation recovery
- Product recovery
- Financial returns

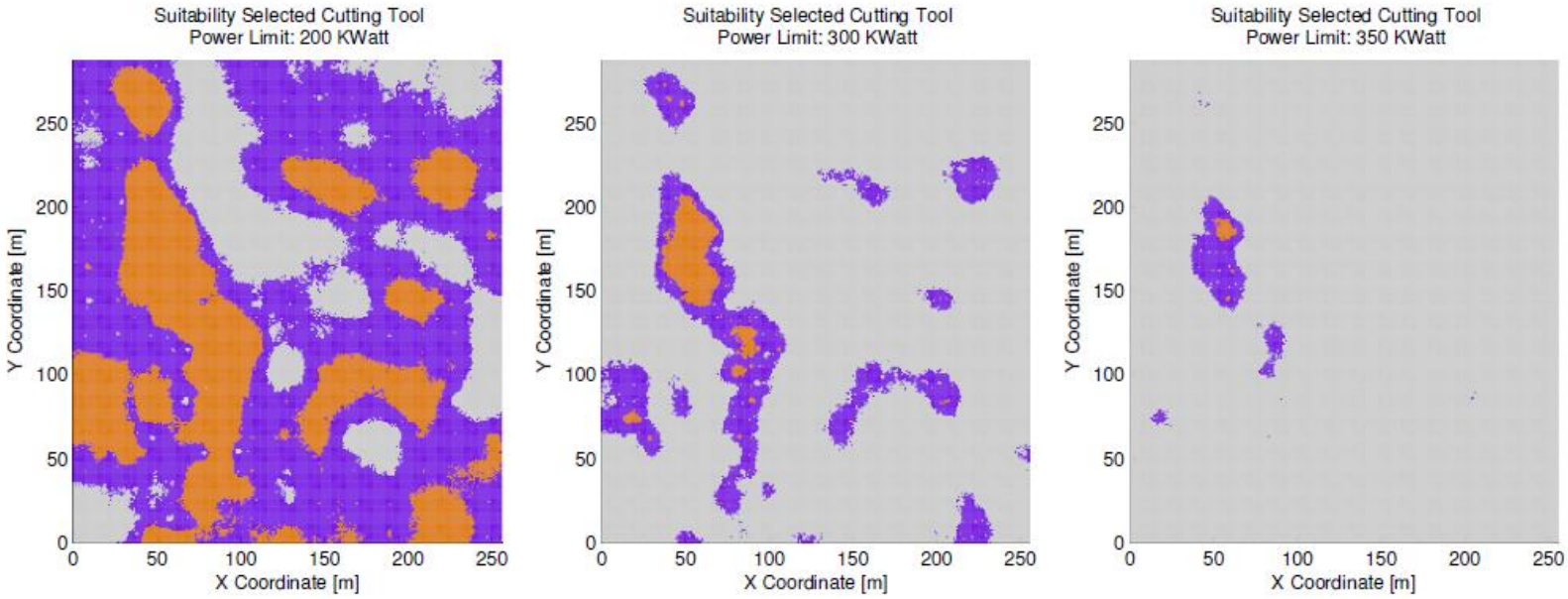
Development decisions

- Yearly production & cut-off
- Equipment selection
- Mine design & LT planning



5. Research Proposal

- ORANGE: > 80% chance that installed cutting power is not sufficient
- GRAY: > 80% chance that the tool can cut the material
- PURPLE: intermediate scenario, additional drilling will most likely provide useful information



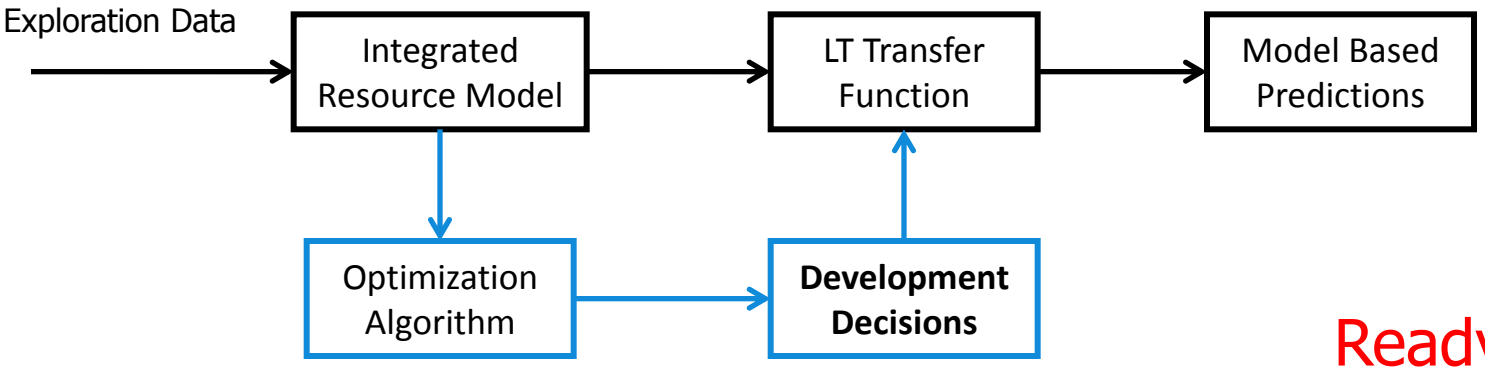
(a) 200 $kWatt$ (b) 300 $kWatt$ (c) 350 $kWatt$

5. Research approach

Towards an "Intelligent Wet Mine"

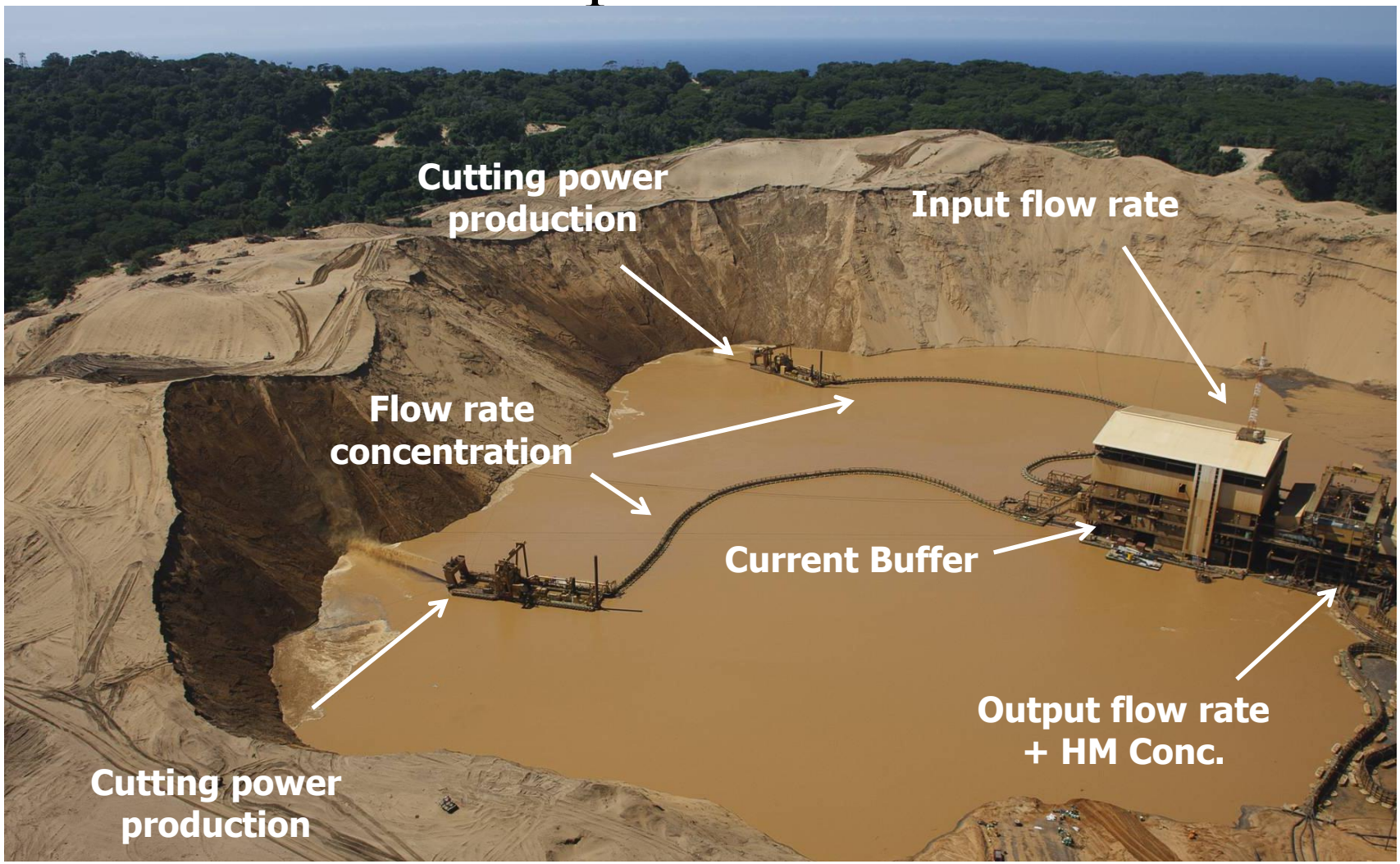
LT Optimization

- Flexible development option to mitigate risk!
- Maximizes monetary value
- Minimizes environmental impact (Selective vs. Bulk?)



Ready =
START OPERATION

5.Research Proposal



5. Research objective

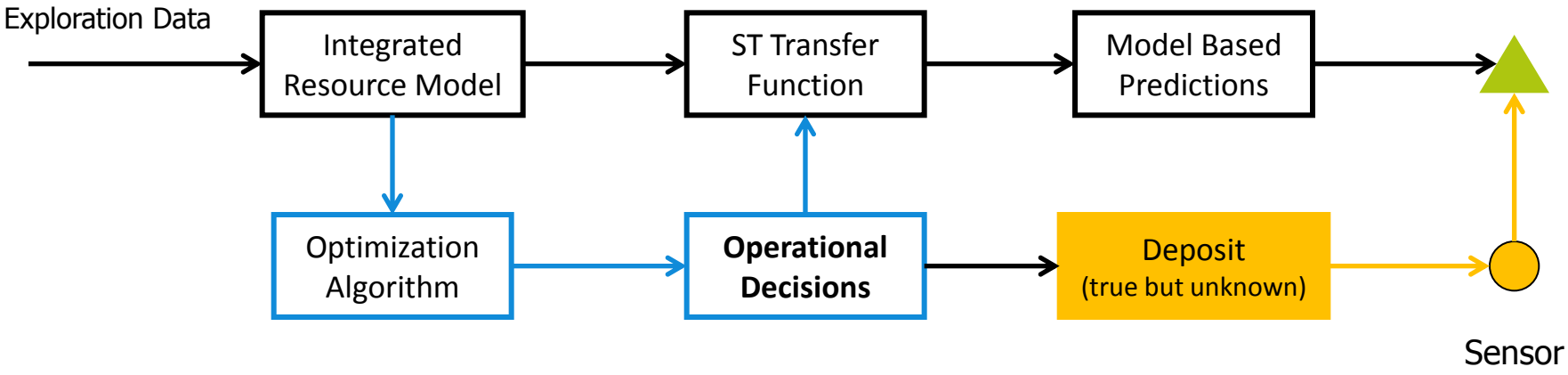
Towards an "Intelligent Wet Mine"

ST Optimization

- Short-term scheduling: comply with LT production targets

Operational data acquisition

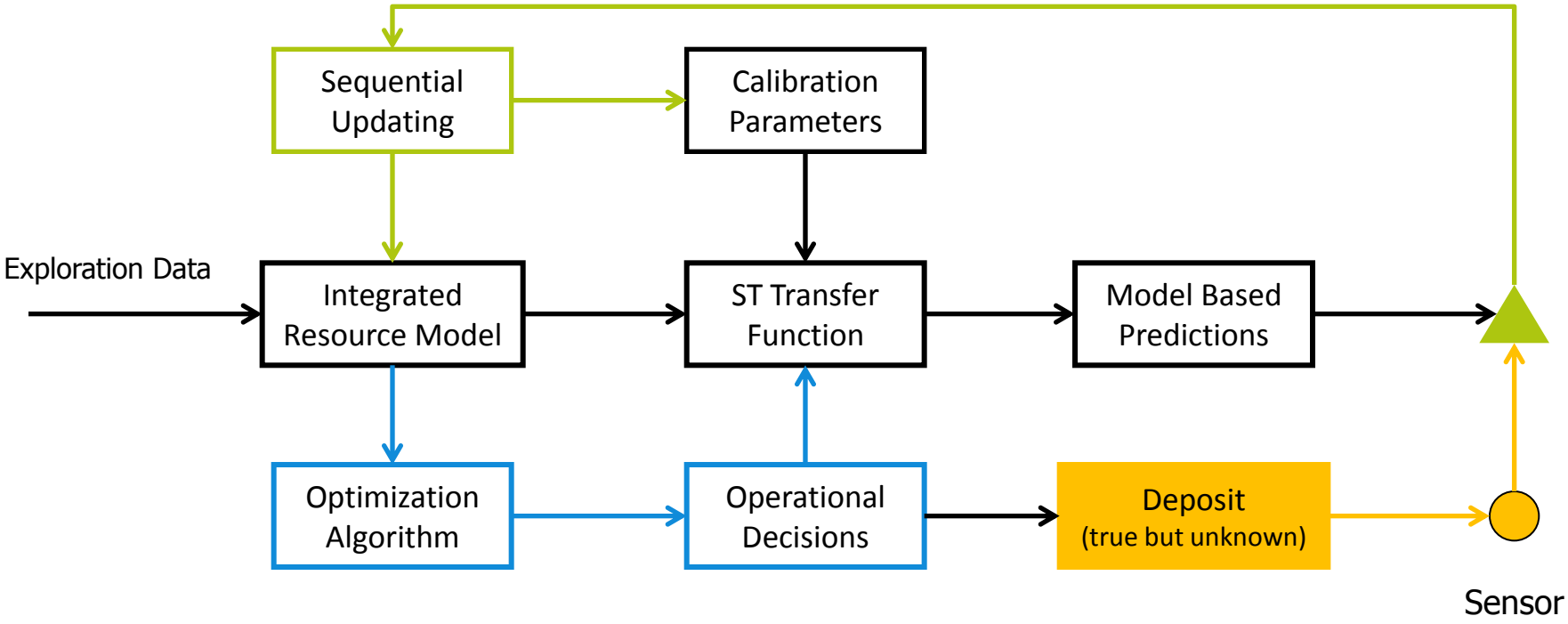
- Efficient & economically justifiable monitoring network



5. Research objective

Towards an "Intelligent Wet Mine"

Self-learning techniques to update resource model



Real-Time optimize ST scheduling (+ LT planning)

6. Conclusion

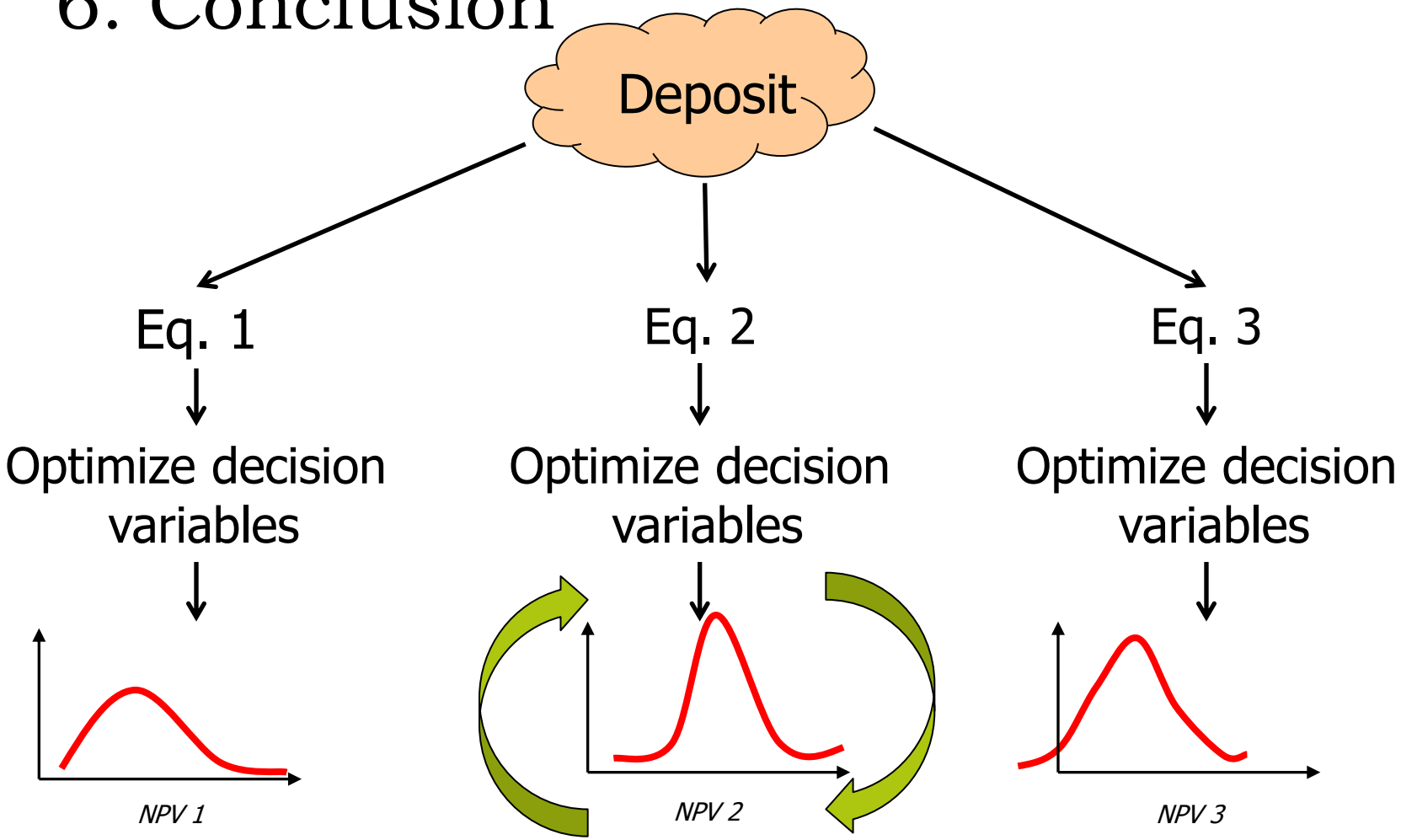
Development decisions

1. Integrated deposit model
2. Insert LT planning in transfer function > predict output
3. Optimize

Operational decisions

1. Development decisions are further detailed > ST scheduling
2. Optimize
3. Start Production & Collect data
4. Update resource model (Real-time)
5. Optimize decisions (Real-time)

6. Conclusion



Real-Time Reconciliation & Optimization

Thank you for your attention!