



Modeling for concentrator design and optimisation

Casper Steenkamp

Introduction

- Process modeling applications
 - Circuit design
 - Circuit optimisation through APC
- Ease of application
 - Complexity of model configuration
 - Large systems
 - Skilled user required
- Current modeling work
 - Milling Simulator
 - Flotation Modeling Framework





Milling Simulator

MillStar Simulator

Overview

- Dynamic simulator integrated with StarCS control platform
- Simulate nonlinear models described as ordinary differential equations
- Allow discrete process units to be connected arbitrarily to form any required process
- Ability to use model as a soft-sensor on industrial plant



MillStar Simulator

Technical Background

- Framework for easily adding new models to the simulator
 - Flexibility (only calculate states and outputs)
 - Can accurately simulate time-delays
 - Each input, output, state and parameter can have a variable number of entries (e.g. arbitrary number of size classes)
- Automatically determine solution order of process units to ensure valid results
- Internal Kalman filter
 - Use as soft sensor soft-sensor on industrial plant
 - Fitting model parameters to a plant online



MillStar Simulator

Applications – Circuit Design

- Enable rapid investigation of various flow-sheet options, such as
 - Sizing of mills, cyclones and sumps,
 - Flow-sheet changes, such as
 - Secondary sump-cyclone,
 - Pebble crusher,
 - etc
 - Operating conditions, such as mill ball loads and mill volumetric charge filling.



MillStar Simulator

Applications – APC Design

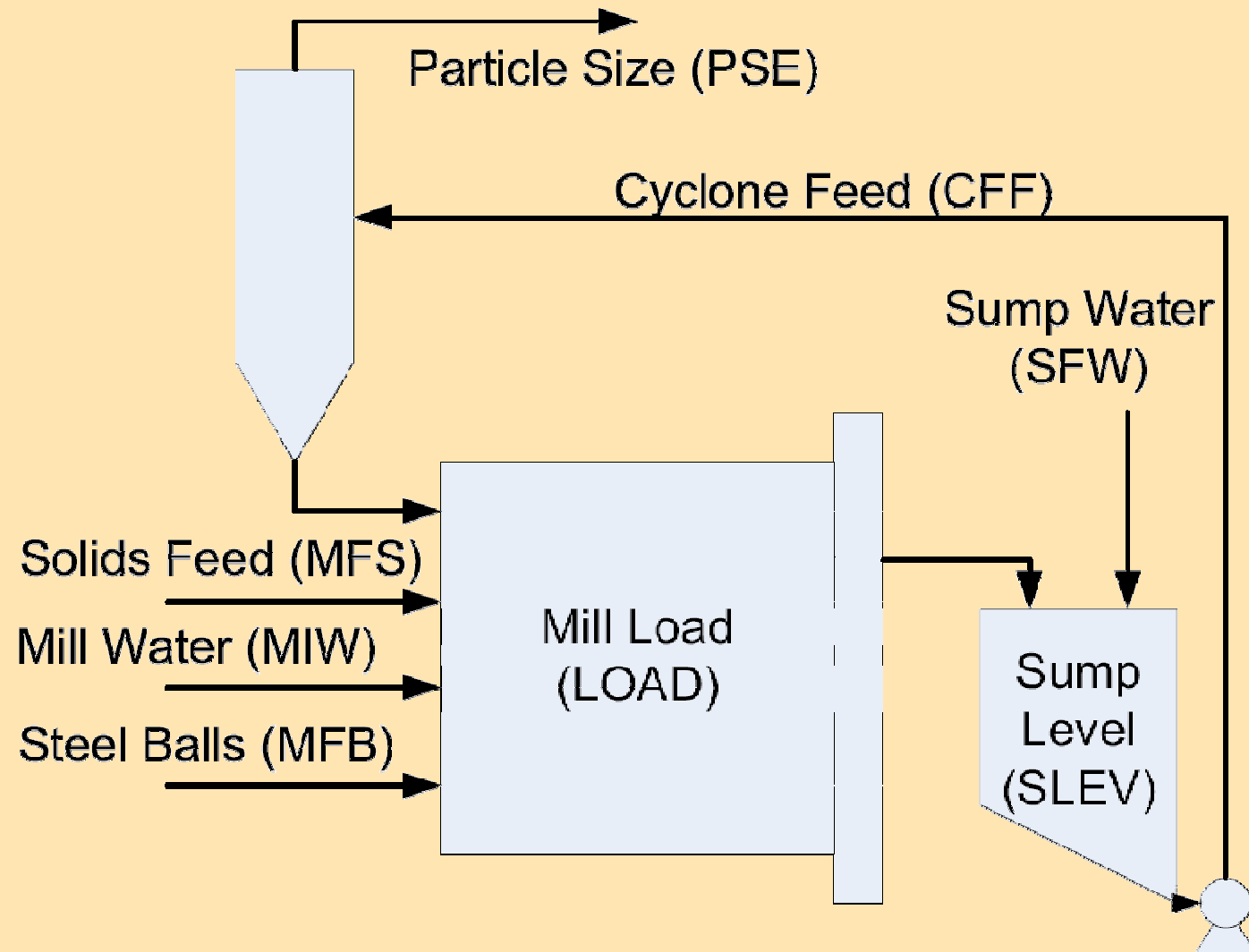
- APC design based on a model of a client's plant.
 - Setup controller configuration before actual controller commissioning.
 - Testing various control strategies.
 - Testing loop times for MPC control.
 - Preliminary tuning of controllers based on the model.
 - Quantifying possible performance gains.





MillStar Simulator

Example





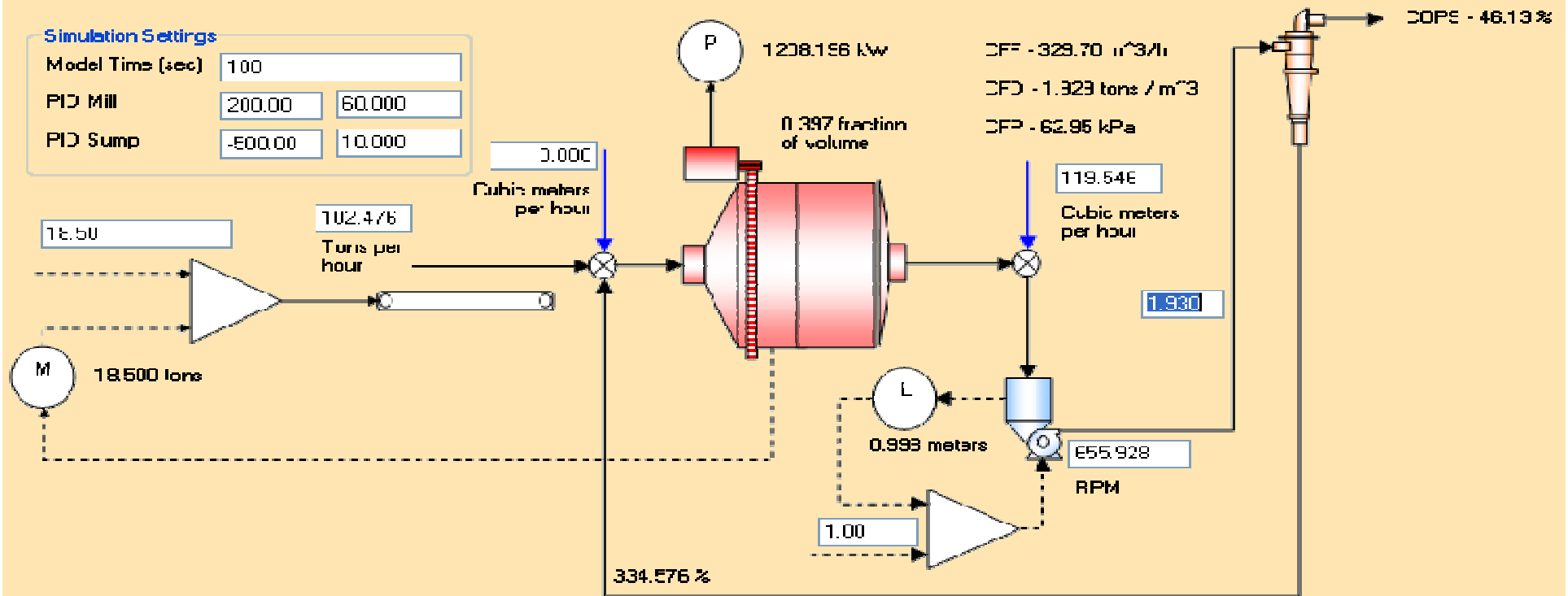
MillStar Simulator

Example

	Baseline	Target
Throughput	93 tons / hour	102 tons / hour (increase of 10%)
Ball Filling	24% of Mill volume	-
Total Charge Filling	33% of Mill Volume	-
Cyclone Overflow Volume Percentage Solids	58%	Maintain > 45%.
Grind	58% < 75 μ m	Maintain at 58%

MillStar Simulator

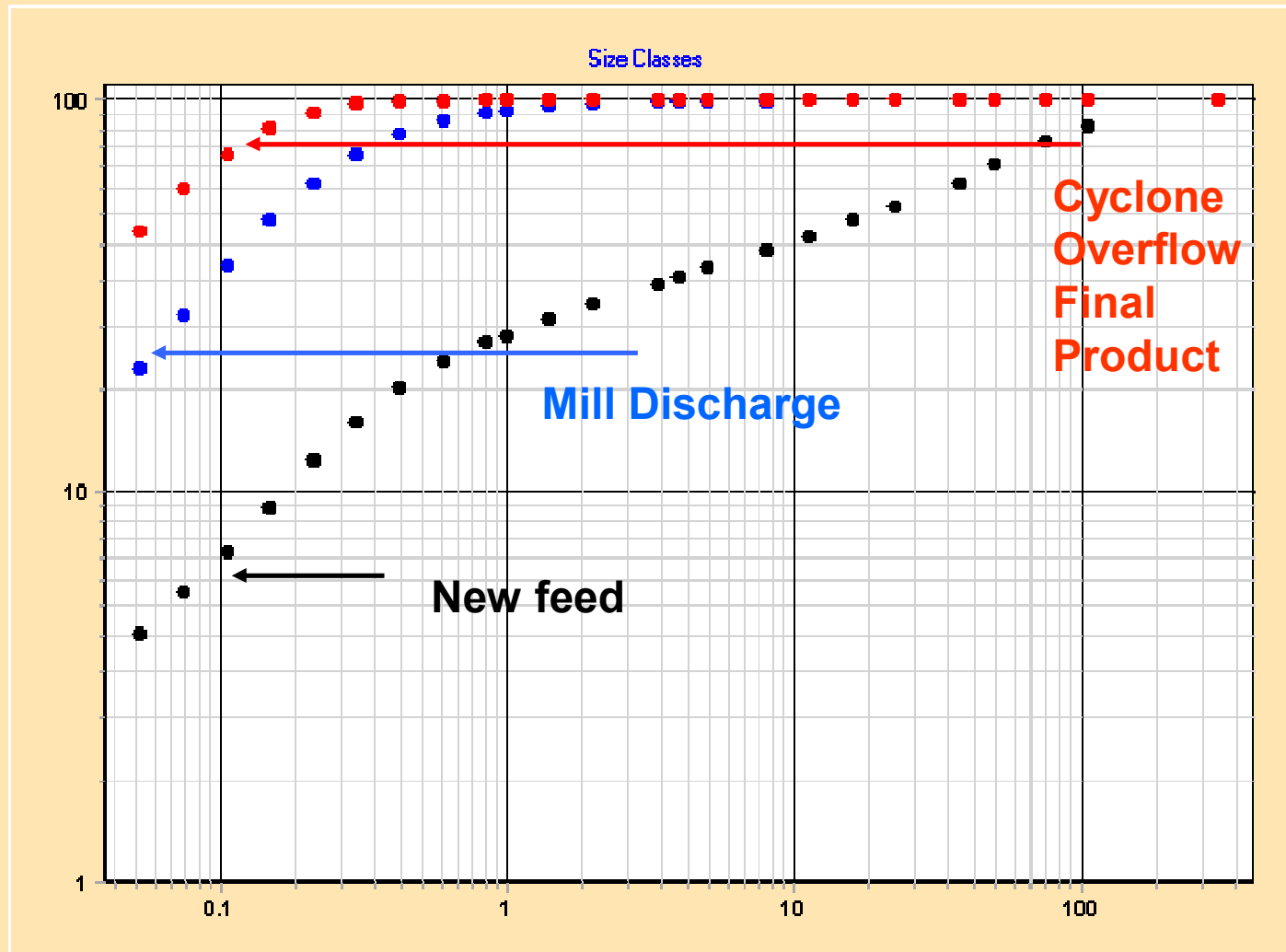
Example





MillStar Simulator

Example





MillStar Simulator

Example

	Baseline	Target	Final
Throughput (tons / hour)	93	102 (10% increase)	102
Ball Filling (% of Mill Volume)	24%	-	30%
Total Charge Filling (% of Mill Volume)	33%	-	39.7%
Cyclone Overflow Volume Percentage Solids	58%	$\geq 45\%$	46%
Grind (% < 75 μm)	58%	$\geq 58\%$	59%



Flotation Circuit Model Framework



Flotation Circuit Model Framework

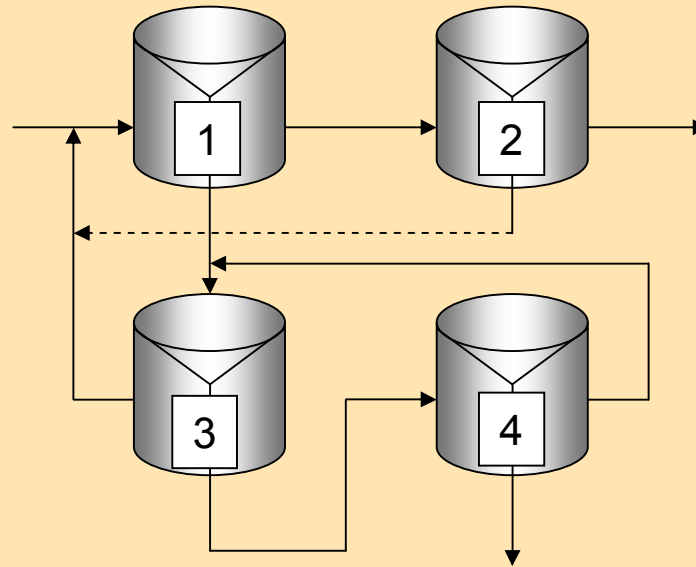
Overview

- A robust and accurate flotation circuit model will be very useful for
 - exploring flowsheet options
 - assisting in the correction of operational issues
 - comparing the performance of pilot- and full-sized plants
 - optimisation and control
 - plant design
- The framework is capable of
 - fitting rate parameters
 - solving circuit mass- and volume balances
 - simulating the behavior of a specific ore in different circuits



Flotation Circuit Model Framework

Defining the Circuit



External Feed Matrix

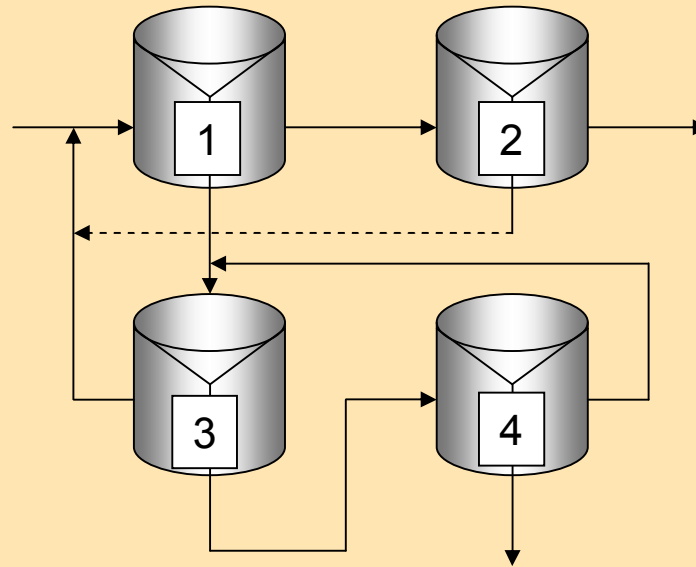
	Bank 1	Bank 2	Bank 3	Bank 4
Specie 1	0.2	0	0	0
Specie 2	0.25	0	0	0
Specie 3	1.4	0	0	0





Flotation Circuit Model Framework

Defining the Circuit



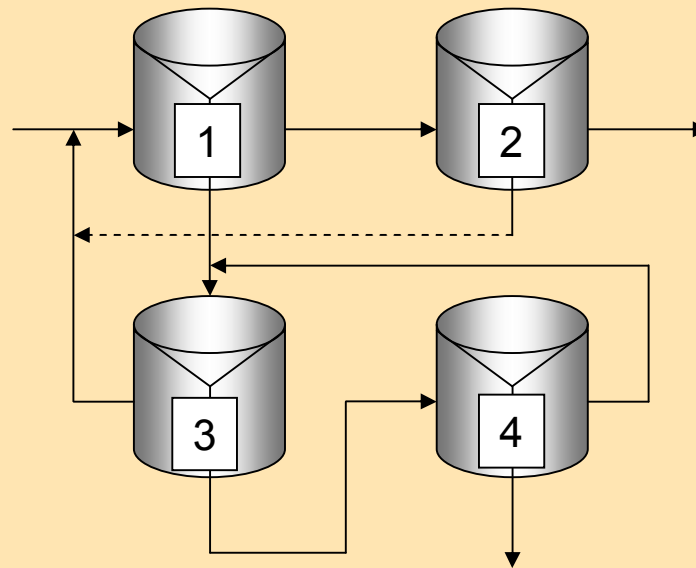
Tailings Config Matrix

		FROM			
		Bank 1	Bank 2	Bank 3	Bank 4
TO	Bank 1	0	0	1	0
	Bank 2	1	0	0	0
	Bank 3	0	0	0	1
	Bank 4	0	0	0	0



Flotation Circuit Model Framework

Defining the Circuit



Concentrate Config Matrix

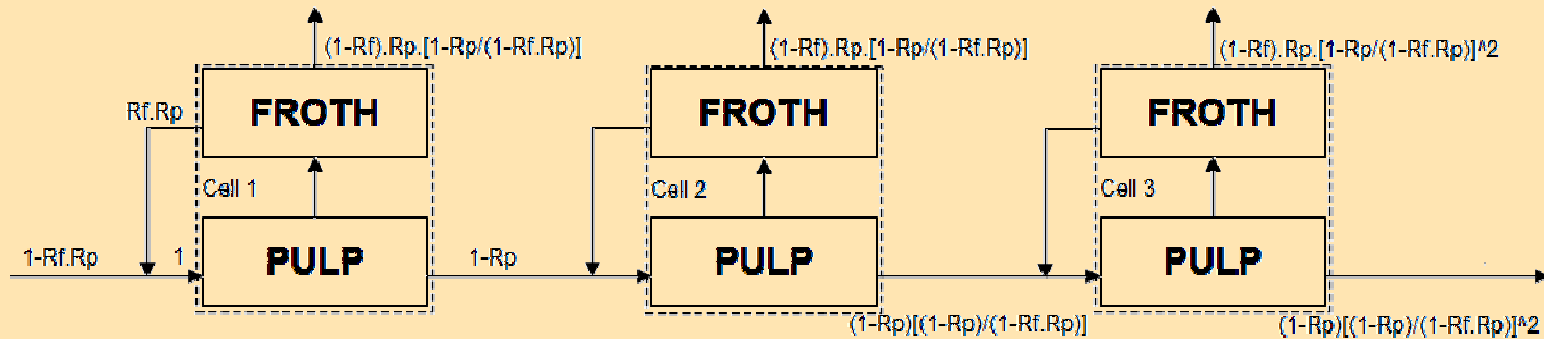
		FROM			
		Bank 1	Bank 2	Bank 3	Bank 4
TO	Bank 1	0	1	0	0
	Bank 2	0	0	0	0
	Bank 3	1	0	0	0
	Bank 4	0	0	1	0

Flotation Circuit Model Framework

Models

- True Flotation
 - First order (pulp/froth) flotation model
 - Derived for multiple cells per bank

$$\text{Bank Recovery} = 1 - \left(\frac{(1 - R_p)}{1 - R_p R_F} \right)^n$$



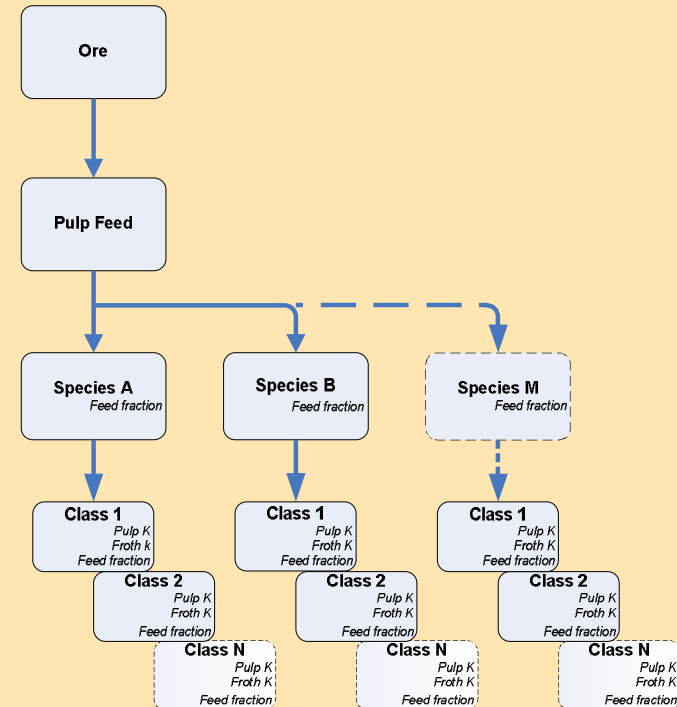
- Entrainment
 - Moys entrainment model
 - Derived for multiple cells per bank



Flotation Circuit Model Framework

Regression

- Inputs
 - 1 Circuit mass balance
 - 2 Layout
 - 3 Sizing
 - 4 Flow Rates
 - 5 Ore composition
 - 6 Operating conditions



- Parameters are regressed by running the algorithm on experimental pilot-plant data
- Recovery calculated from rate parameters and mass balance is solved



Flotation Circuit Model Framework

Applications – Circuit Design

- Circuit Simulation
- The regressed parameters can be used to simulate:
 - the same circuit, with different operational parameters
 - a differently configured circuit
- Intermediate step in a double pilot plant run
- Quantify the implications of small design alterations



Flotation Circuit Model Framework

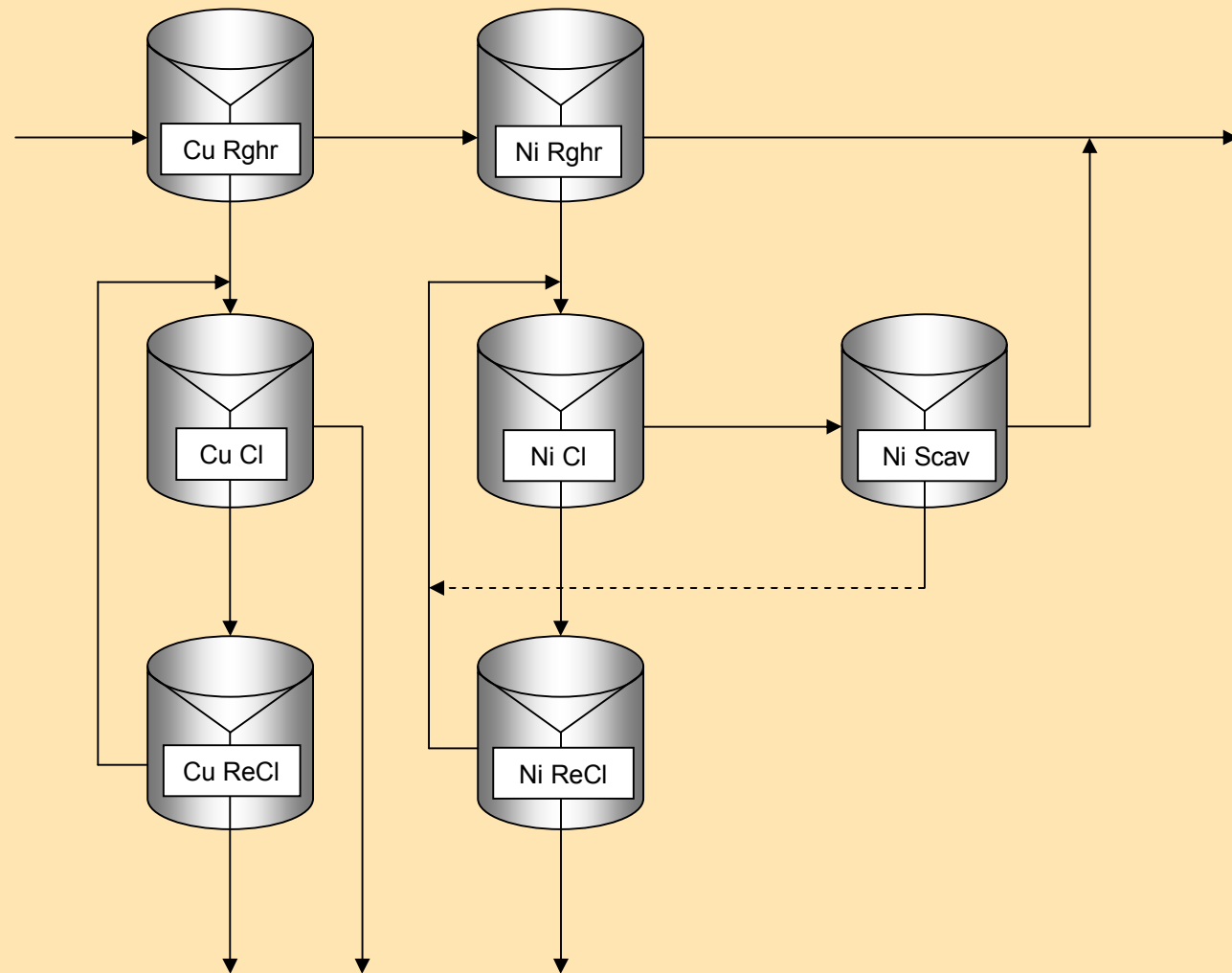
Applications – APC Design

- Quantify the implications of small changes in operational parameters
 - Determine effect on residence time, recirculating loads
- Soft-sensor
 - Use the model to provide more regular online grade measurements
 - Provide an indicative value if an online instrument should fail



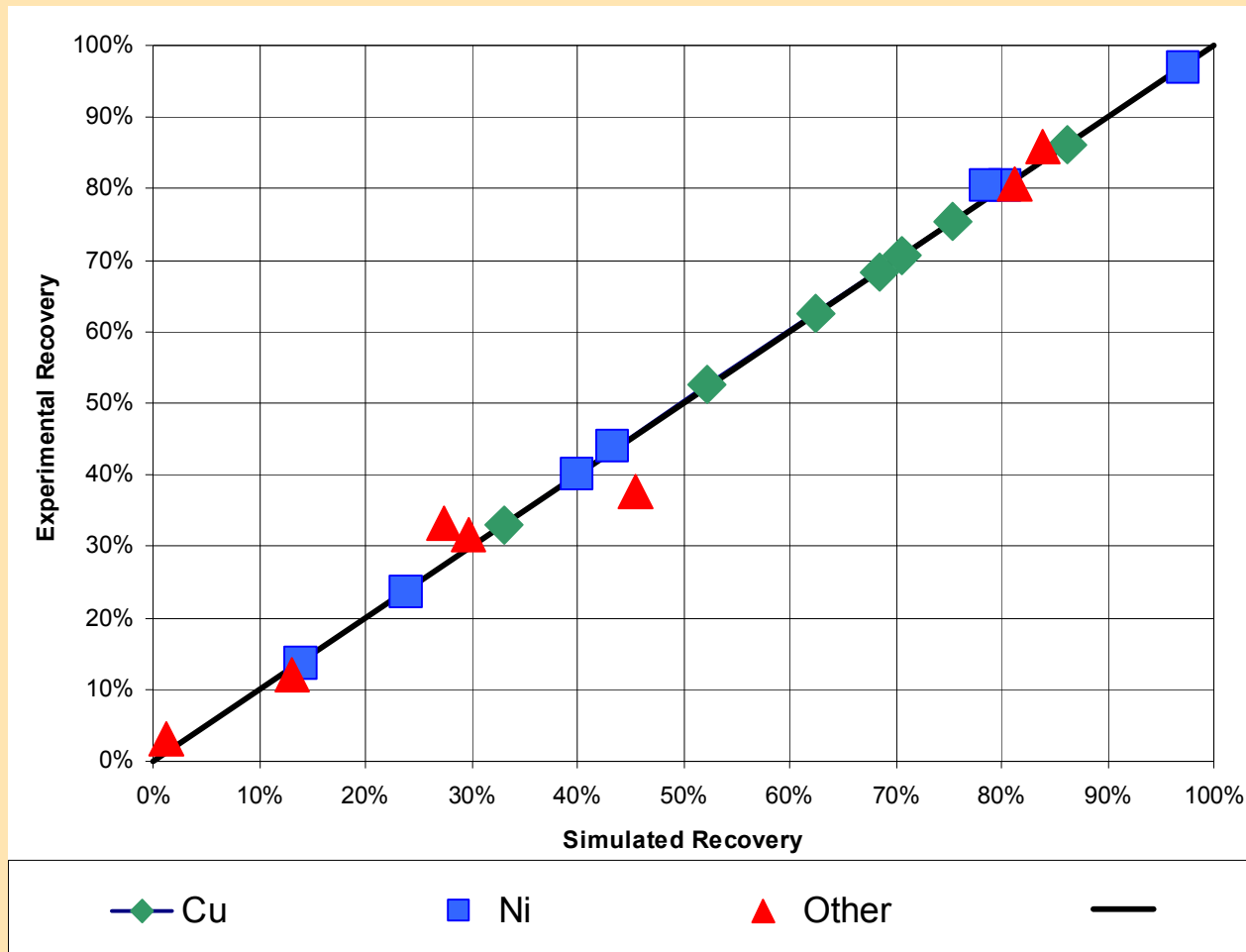
Flotation Circuit Model Framework

Example: Cu-Ni



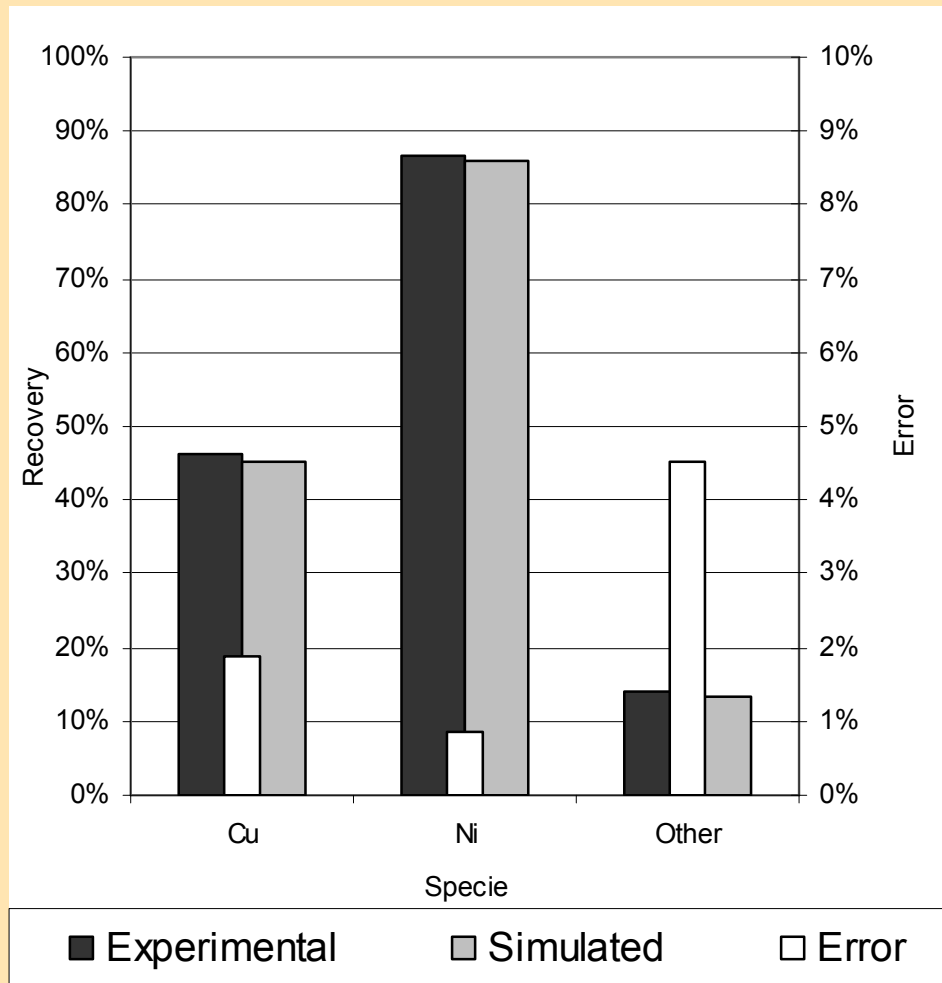
Flotation Circuit Model Framework

Example: Cu-Ni



Flotation Circuit Model Framework

Example: Cu-Ni



Flotation Circuit Model Framework

Example: Cu-Ni

SIMULATED SCENARIOS

SCENARIO	RECOVERY		
	Cu	Ni	Other
No Change	[45.23]	[85.92]	[13.25]
Cu-Rougher Volume increase by 10%	1.7%	0.4%	0.1%
Cu-Cleaner tails back to Cu-Rougher feed	-13.6%	-50.3%	0.6%
Reduce feed flow rate by 10%	11.1%	3.7%	2.0%
Increase feed flow rate by 10%	-10.9%	-4.7%	-2.6%
Extra Ni cleaning stage (30L, 1 cell)	0.0%	-6.9%	-10.8%



Conclusions

- Model frameworks and simulators
 - Useful for design and optimisation
- Future work
 - Milling Simulator
 - GUI
 - Flotation Circuit Modeling Framework
 - Model refinements
 - GUI





Questions