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**MULTIVARIABLE PREDICTIVE CONTROL APPLIED TO
SECONDARY-TERTIARY CRUSHING LINES**

Honeywell

Agenda

- Introduction
- Process Features
- Crusher Processes - Control Challenge
- Control Implementation
- Results and Evaluation
- Future Applications
- Conclusion

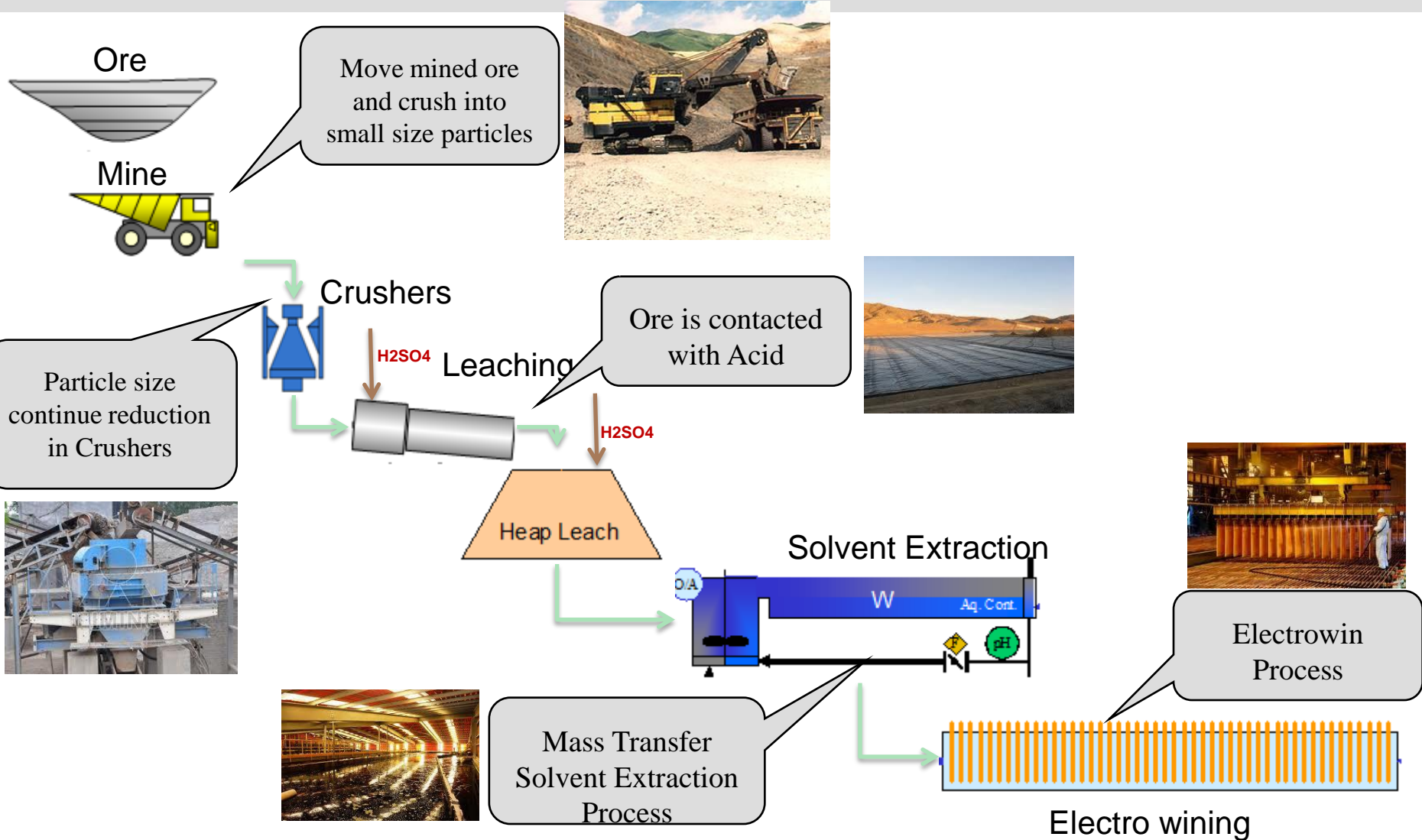
Introduction of Company

- The Company operates a copper open-pit mine and processing facility in El Loa province in northern Chile, Region II.
- The operation is Hydrometallurgical and includes a SX/EW facility, a 150,000 metric ton-per-day crushed leach circuit.



HYDROMETALURGIC OVERVIEW

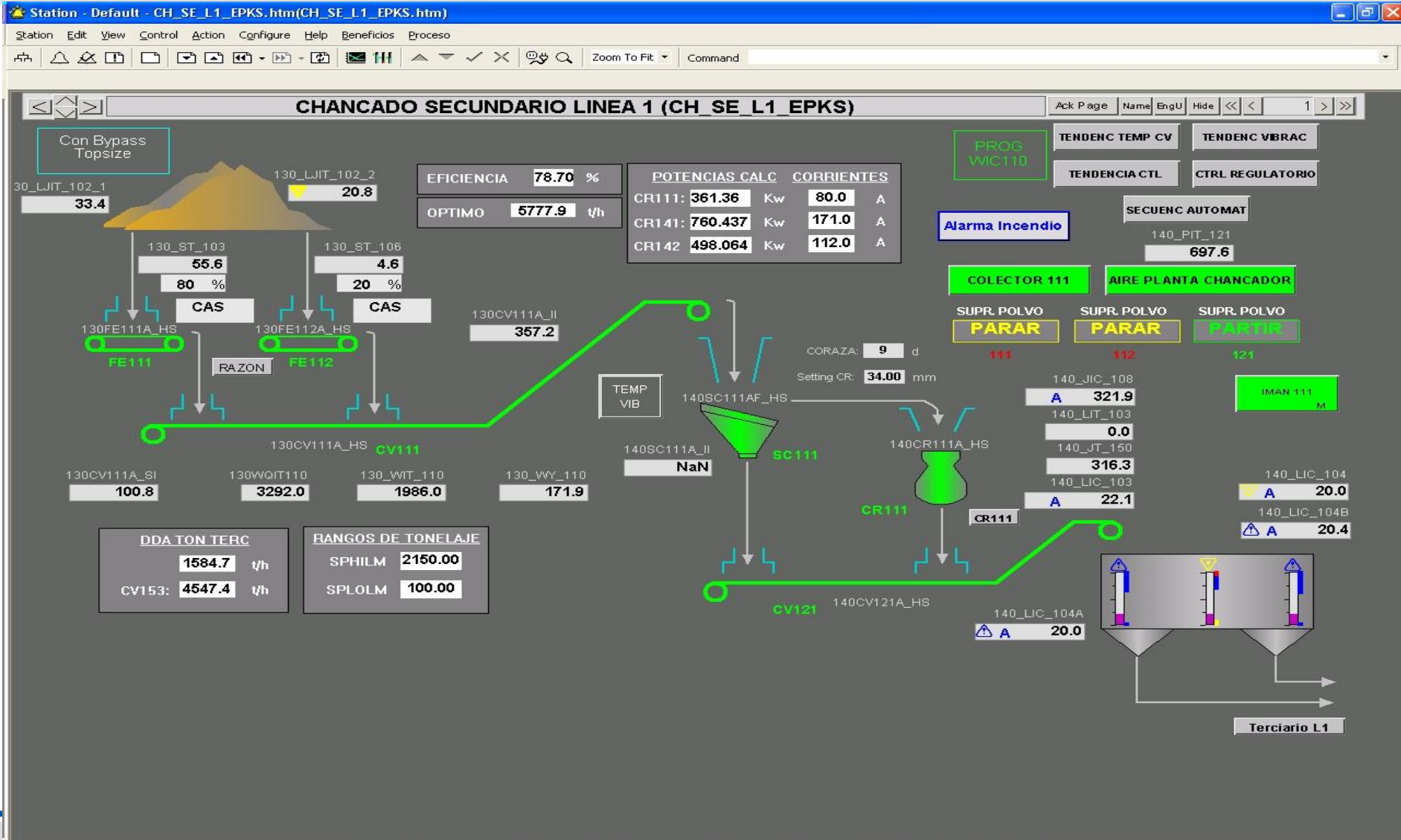
Hydrometallurgy Value Chain



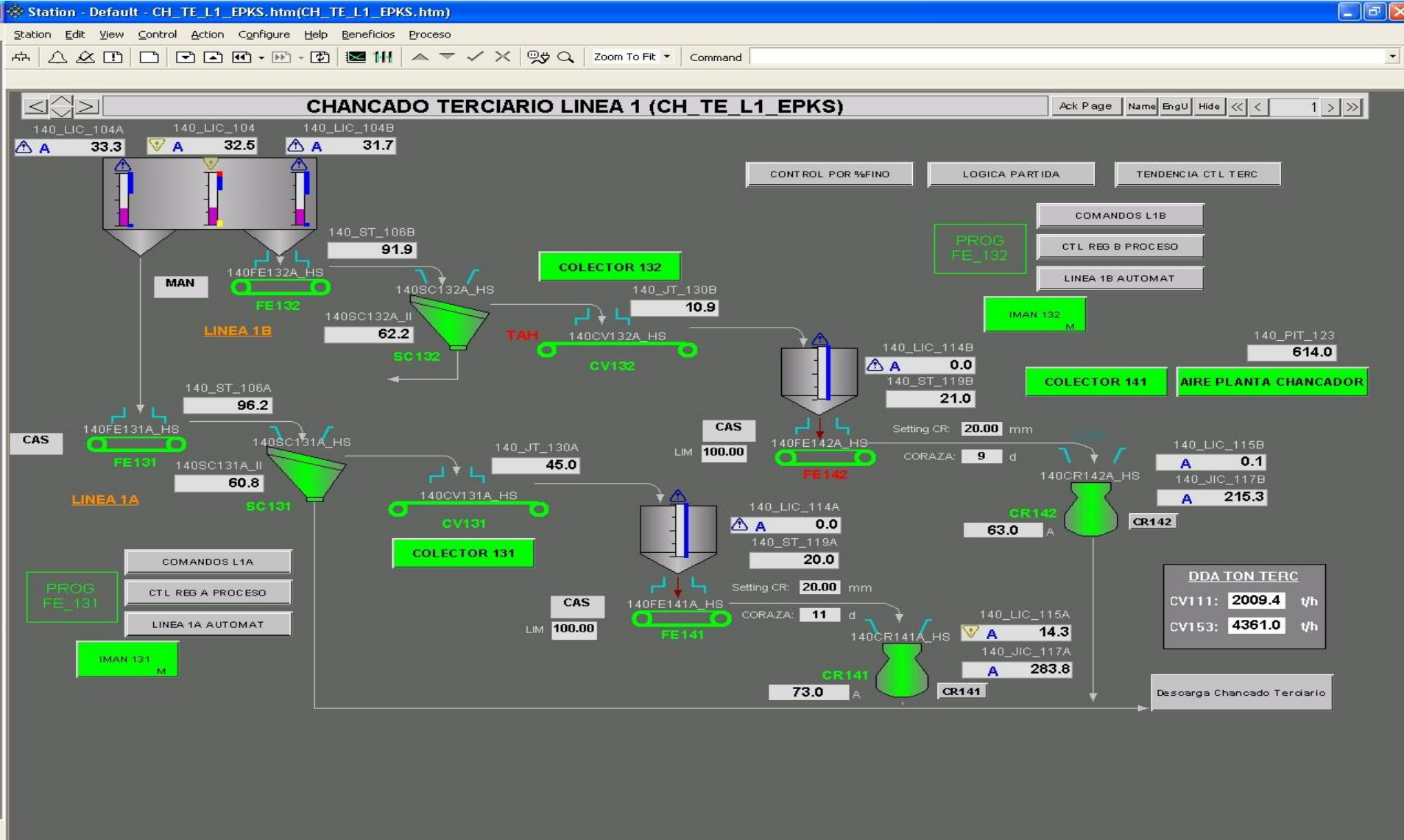
Process Features

- The company has three crunching lines ~2,600Tn/Hr each one. Each line is composed by Secondary and Tertiary crushers sub units.
- Process Goal: Keep in synch secondary and tertiary lines. “Tertiary line doesn’t have to consume faster that the Secondary line can feed” otherwise all line will shut down.
- Delays because long distance in conveyors.

Process Diagram - Secondary Crusher

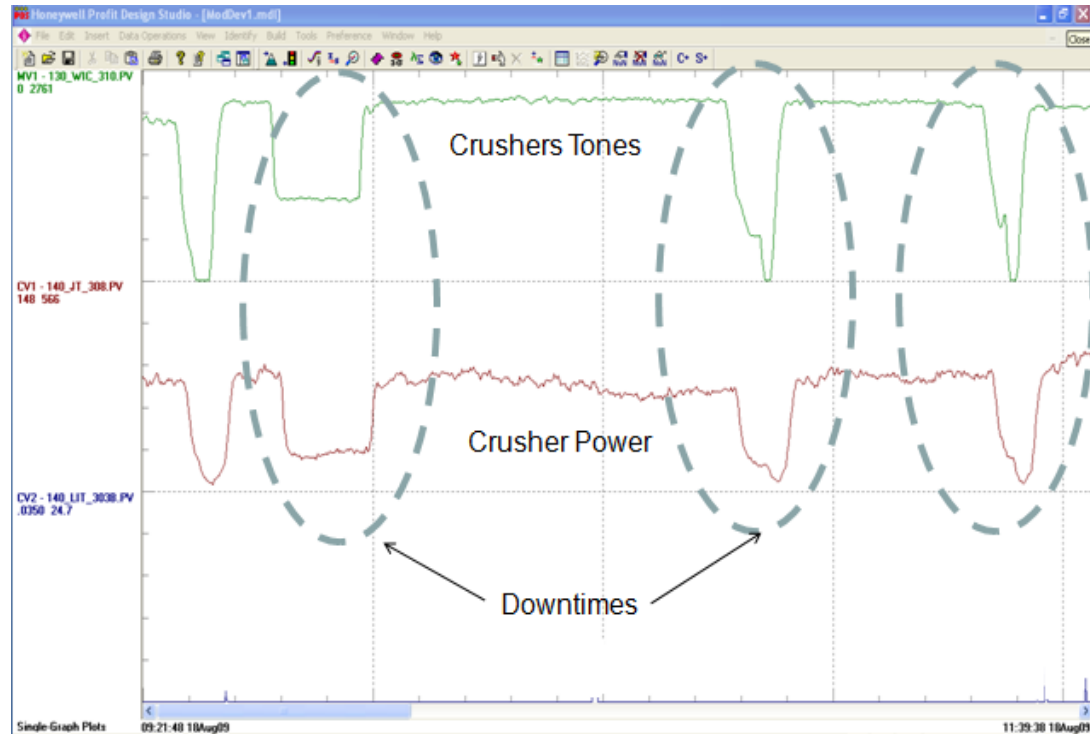


Process Diagram – Tertiary Crusher



Crusher Processes - Control Challenge

- Long Delays
- Changes in Ore condition
- Unplanned Downtimes
- Dynamic Optimization Criteria



CONTROL CHALLENGE



Controller Goals

- Increasing Throughput
- Stabilizing Crusher lines (secondary, and tertiary), considering the constraints imposed by the Hopper's levels.
- Compensating delay due to Feeder Conveyor distance in the secondary and tertiary crushers.
- Changing the Optimization criteria online, based on the state of the internal crusher shell.
- The Solution: Multivariable Predictive Control - MPC

What is MPC

*Complex Math?

Foreigner Language?

第三章 环境试验设备介绍及建模研究

3.1 环境试验设备介绍

二级标题小三黑体，上下空一行

3.1.1 简介

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环境试验设备是模拟人们所期望的一种自然环境而对某些工业产品进行环境试验的装置。温度、湿度环境试验是最常进行的环境试验之一（特别是对于电子产品来说）。为了达到人们预期的试验目的，要求该环境试验设备的温度、湿度能够被精确的控制在某设定值上。

3.1.2 环境试验设备的结构及硬件

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高精度温度、湿度环境试验设备系统的硬件结构框图如图 3-1 所示：

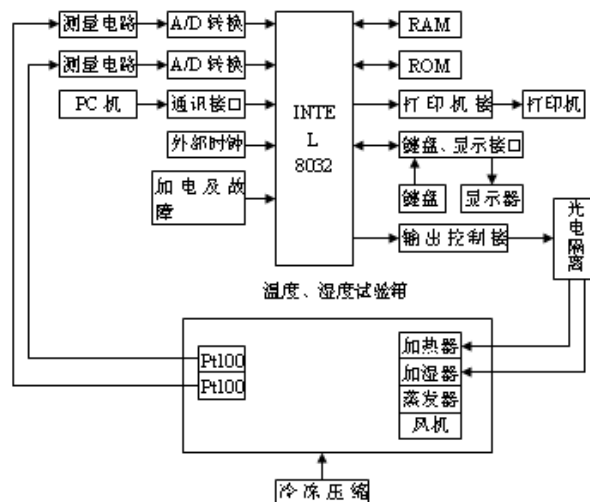
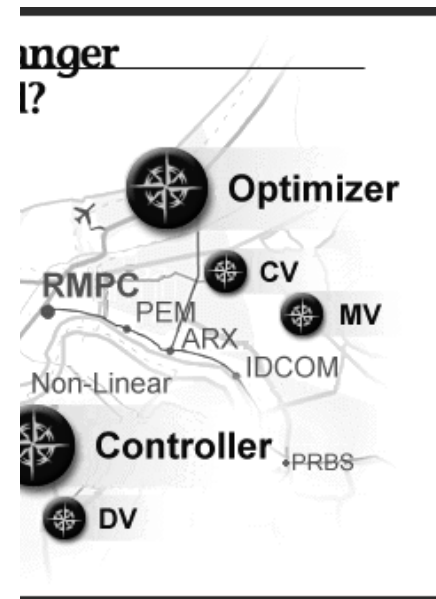


图 3-1 温度湿度控制系统的硬件结构图



$$J(\mathbf{u}^M) = \sum_{j=1}^P \left\{ \|\mathbf{e}_k^j\|^2 \right. \\ \left. + \sum_{j=0}^{M-1} \left\{ \|\mathbf{e}_k^j\|^2 \right\} \right.$$

$$\mathbf{x}_{k+j} = \mathbf{f}(\mathbf{x}_{k+j-1}, \mathbf{u})$$

$$\mathbf{y}_{k+j} = \mathbf{g}(\mathbf{x}_{k+j}, \mathbf{u}_{k+j})$$

$$\underline{\mathbf{y}} - \mathbf{s}_j \leq \mathbf{y}_{k+j} \leq \bar{\mathbf{y}}$$

$$\mathbf{s}_j \geq 0$$

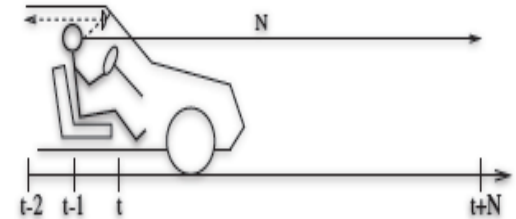
$$\underline{\mathbf{u}} \leq \mathbf{u}_{k+j} \leq \bar{\mathbf{u}}$$

$$\Delta \underline{\mathbf{u}} \leq \Delta \mathbf{u}_{k+j} \leq \Delta \bar{\mathbf{u}}$$

MPC = Multivariable Predictive Control

Fundamentals of MPC

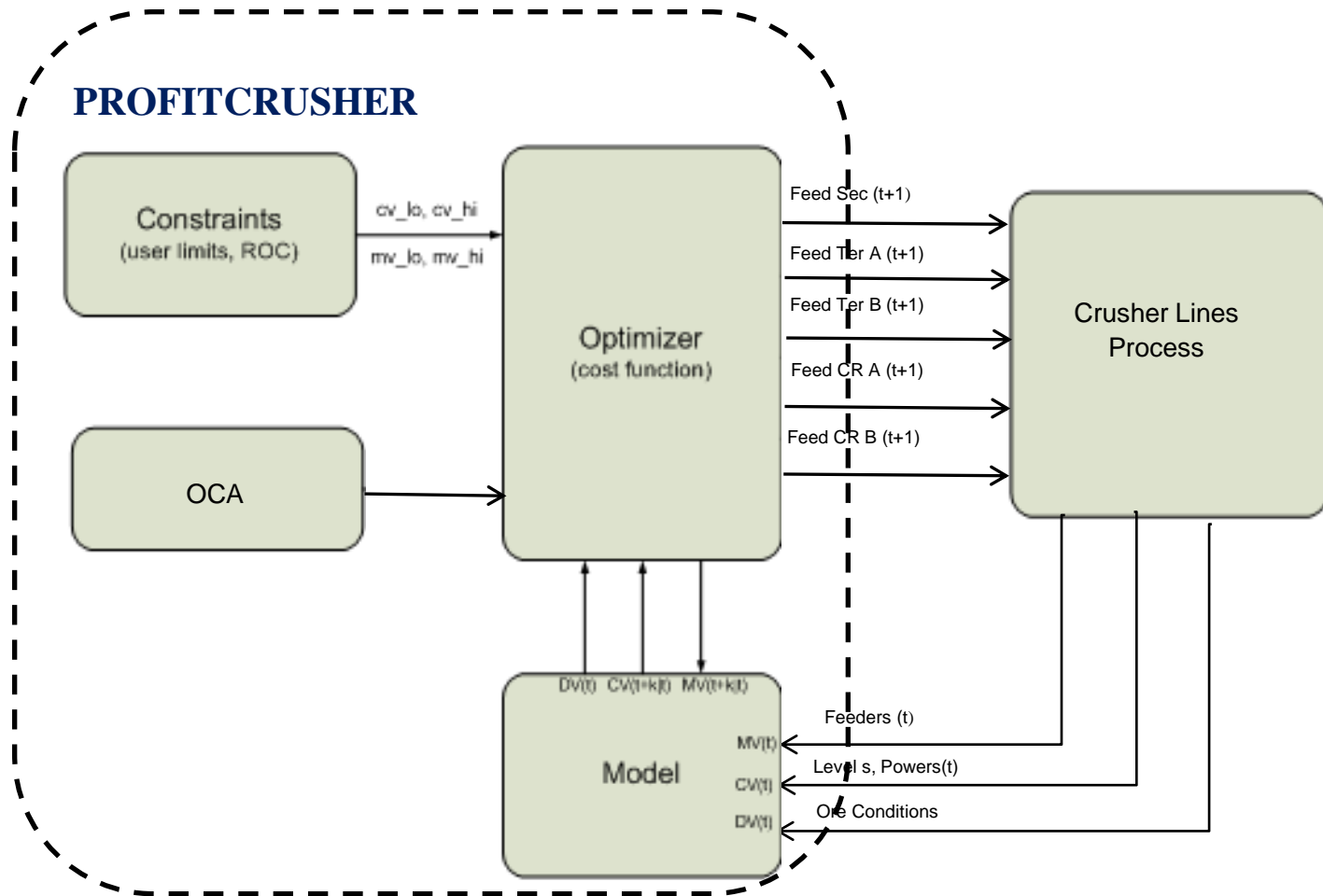
- Through the identification of a model predicts the process response.
- Control actions are calculated based on the predictions and the desired trajectory future
- Apply the first control action and the cycle is repeats.



MPC Honeywell Solution: Profit Controller

- ◆ **Honeywell Solution Based on MPC.** Matrix of Models including delays are used to generate predictions, and calculate the future control actions.
- ◆ **Robustness** Low sensitivity to modeling errors or non linearity.
- ◆ **Prioritize** the use of manipulated variables, according to the operational needs of the Process

The Solution -PROFIT CONTROLLER

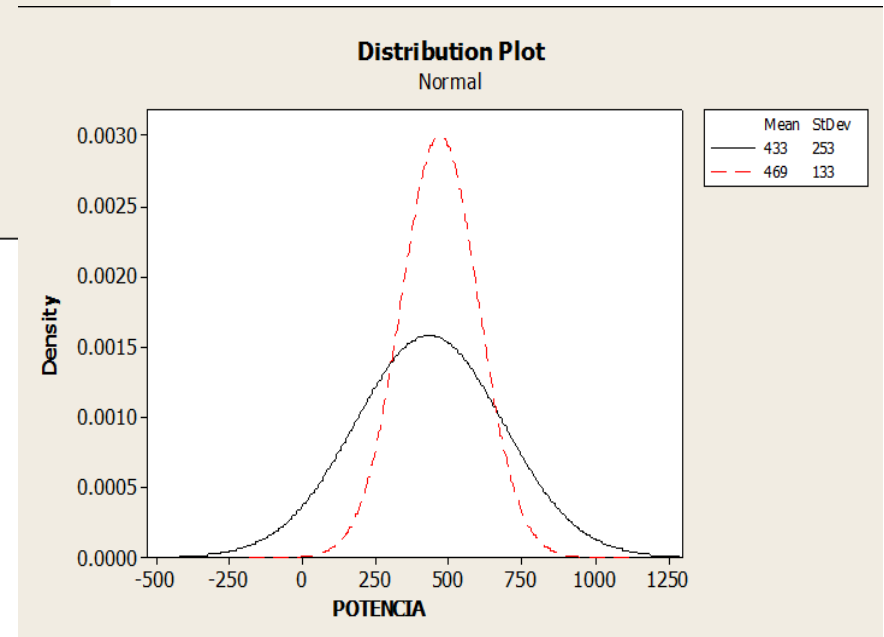
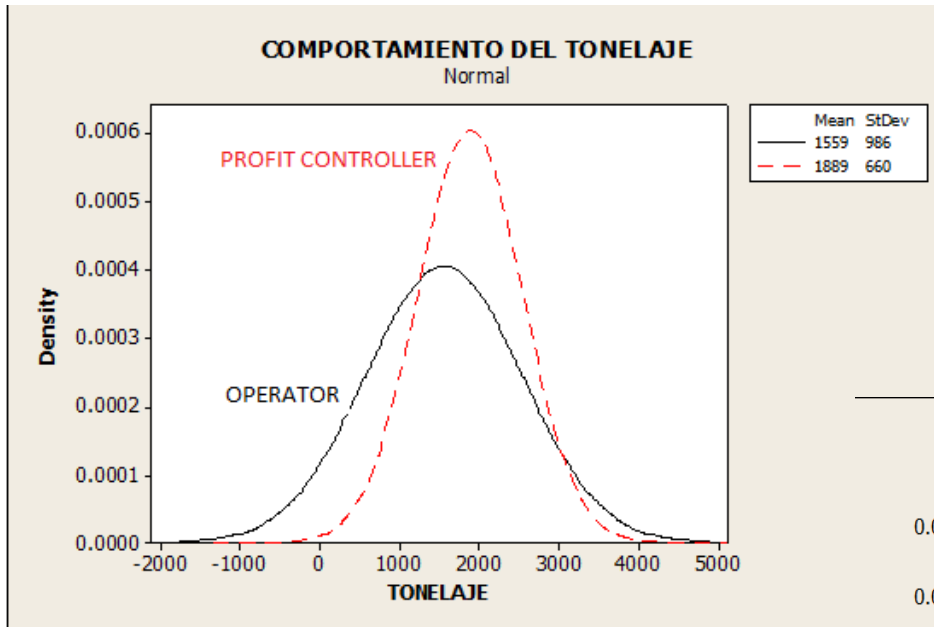


OCA: Optimization Criteria Adapter









EVALUATION



Results and Evaluation



Results and Evaluation

Variable	Benefits	Standard Deviation
Tonnage	 4 – 10 %	 ~ 33%
Power Secondary Crusher	 5 -15 %	 ~25%
Power Tertiary Crusher Line A	 5 – 8%	 ~ 40%
Power Tertiary Crusher Line B	 5 – 13%	 ~ 40%

APC in MMM Chile

- We have new applications in BHP.
 - APC for Tackiness : Tails and Concentrate
 - APC in Solvent Extraction – no reference in the past this is the first Reference.
- Customer is convinced that MPC technology is better than Expert Systems.
- We are in position to offer a integrated solution Simulation and APC in one platform.

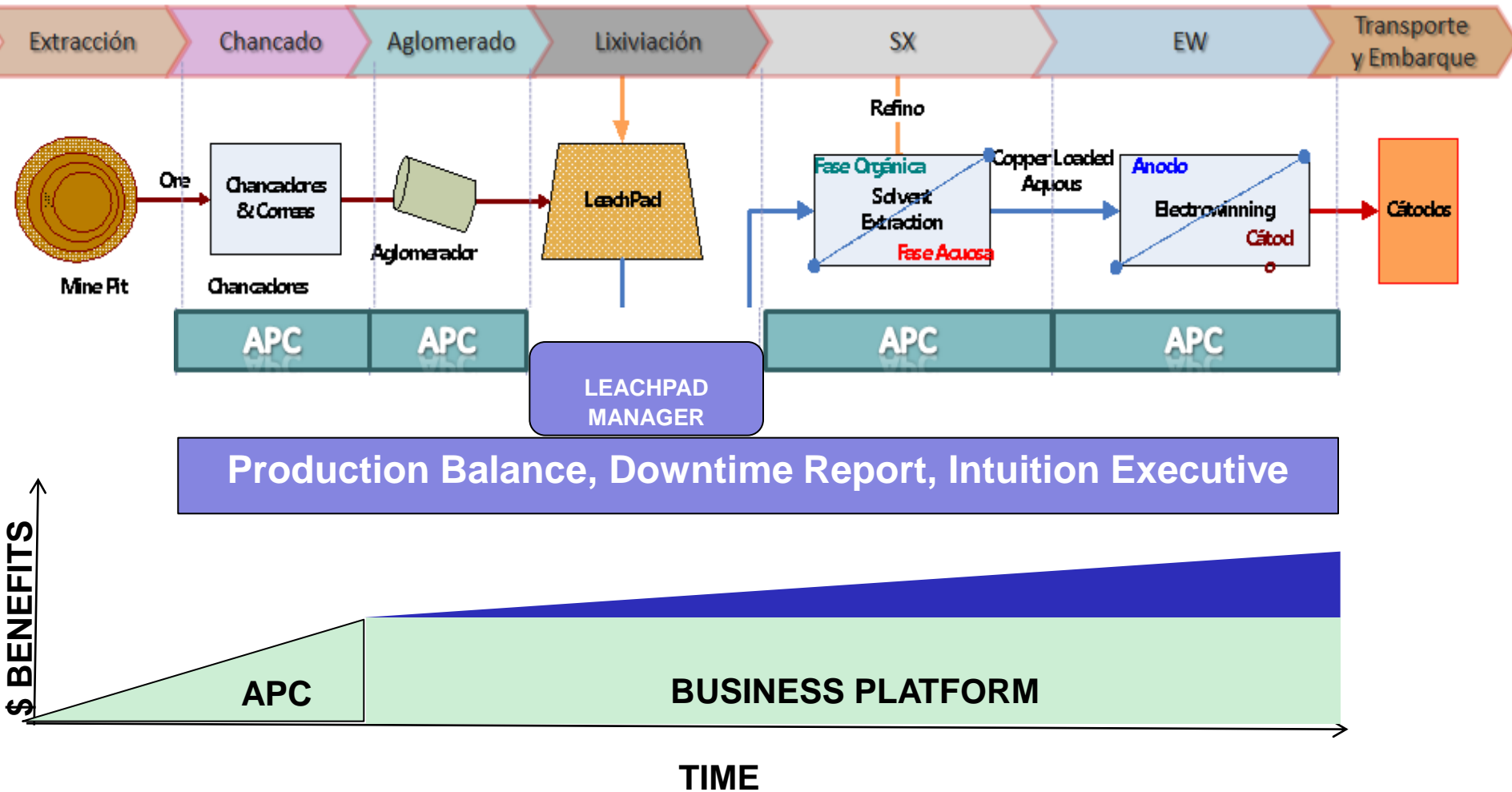
THE FUTURE



Next Applications

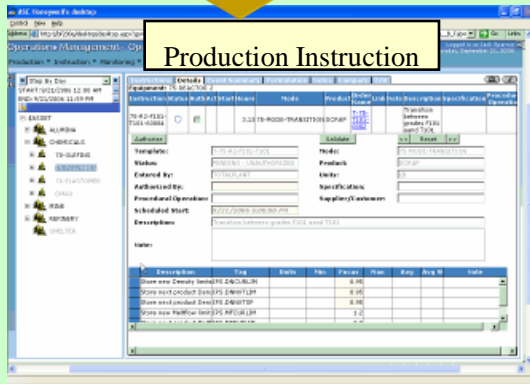
- Integrate Fixed Condition Monitoring with Profit Controller in order to detect changes in Operation Points or changes in Ore features.
- Incorporate particle size instrumentation in tertiary crushers
- Implement Profit Controller in Solvent Extraction (SX) Units.
- Push the **Smart Cathode Production** concept

Smart Cathode Production



Process & Business working together

Product Pacification - ERP



MES Platform INTUITION

TARGETS:
 • ENERGA
 • METALURGICOS

Process Deviations / Reasons

Summary | Deviations | Event Summary | View Config | View Events | View Trend

Drag a column header here to group by that column. And Drag column back on to Grid for Ungrouping.

Target	Type	Hours	Limit As	Equipment	Tag
75 R2 CATALYST FLOW	PLANNING	10.73	✓	75-REACTOR 2	75_R2_FIC100
75 R2 DENSITY	PLANNING	3.52	✓	75-REACTOR 2	75_R2_DIC140
75 R2 H2/MONOMER RATIO	PLANNING		✓	75-REACTOR 2	75_R2_RI101
75 R2 MELT INDEX	PLANNING	6.00	✓	75-REACTOR 2	75_R2_RI151
75 R2 PRESSURE					75_R2_RI120
75 R2 TEMPERATURE					75_R2_RI110
75 R2 VENT FLOW					75_R2_RI105

Target: 75 R2 CATALYST FLOW

Equipment: 75-REACTOR 2

Reason Description:

- Leaks
- Accident
- Cracked
- Damaged
- Blocked
- Feed Quality

Classification:

- Safety
- Environmental
- Planned
- Process-related
- Product yield/quality
- Product on cost and loss
- Rejection loss

Priority:

- Low
- Medium
- High

Comment: A planned incident

Station - Default - (CVSummaryPage.Mn)

Honeywell Profit Controller FCCU_Demo_PDI214RPV OPTIMIZING

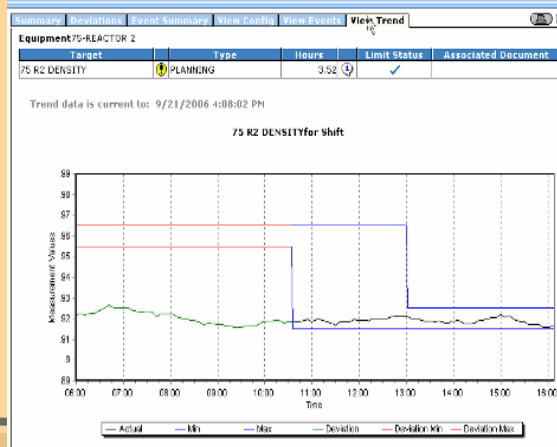
PV Pages | PV Tools | PV Themes | PV Configurations

CV#	DESC	STATUS	VALUE	FUTURE	SS VALUE	LO LIMIT	HI LIMIT	SETPOINT
1	Total Fresh Feed	GOOD	25.00	25.00	25.00	0.00	25.00	25.00
2	Regen Cat Slide Vw D	GOOD	4.49	4.50	4.50	0.00	4.49	4.49
3	Regen Cat Slide Vw D	GOOD	150.75	150.92	140.00	230.00	151.02	151.02
			5.14	5.14	4.50	6.50	5.15	5.15
			19.73	19.73	19.60	20.50	19.73	19.73
			0.00	0.00	5.00	50.00	49.97	49.97
			1270.00	1270.00	1330.00	1350.00	1269.99	1269.99
			4.77	4.77	1.50	5.00	4.68	4.68
			257	257	200.00	268.00	257.52	257.52
			9.96	45.87	20.00	55.00	15.99	15.99
			19.34	19.46	3.00	80.00	19.40	19.40
			62.47	62.40	55.00	70.00	62.47	62.47
			90.02	90.00	90.00	100.00	91.01	91.01
			699.75	699.75	695.00	707.00	699.75	699.75
			450.41	450.41	425.00	470.00	450.41	450.41
			900.40	900.42	895.00	915.00	900.40	900.40
			17.10	17.11	13.00	19.40	17.10	17.10
			430.00	430.00	420.00	430.00	430.00	430.00
			690.05	690.01	690.00	23.00	690.05	690.05
			19.91	19.91	13.50	23.00	19.91	19.91
			2.51	2.51	0.50	4.00	2.51	2.51
			1.61	1.61	0.50	1.61	1.61	1.61
			1.60	1.60	0.50	3.00	1.60	1.60
			47.25	47.26	0.00	92.00	47.24	47.24
			10.05	10.11	2.00	80.00	10.05	10.05

20-Oct-06 17:48:03 OPCADVNC OPCADVNC COMMS U 00 Server: Data from OPCADVNC UNAVAILABLE

21-Oct-05 22:08:03 Alarm System apcscr3 rtd02 Mng

Targets are converted as new operation points to MPC....



Advance Process Control Platform PROFIT CONTROLLER

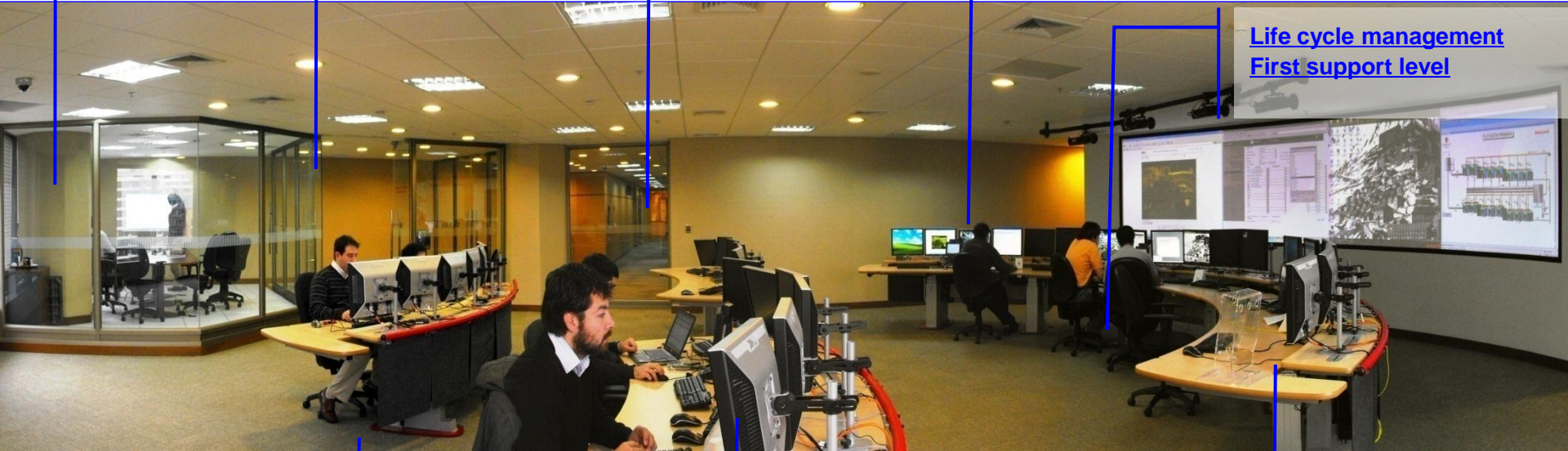
Remote Support Center

Management and contingency

Metallurgical analysis

Life cycle-management
Second support level

Life cycle management
First support level



Life cycle management
First support level

KPI's management

Advanced applications
monitoring

Life cycle management
First support level

QUESTIONS?