

OPERATOR TRAINING SYSTEM

UREA PLANT OTS

First-Principles Dynamic Simulation
for Advanced Operator Competency

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Optimize 2026



Presentation Agenda

Urea Operator Training System — Overview



Introduction & Project Context



Urea Plant: Process Overview



Model Approach & Aspen Properties Advantage



Challenges: Emulated OTS Approach



Training Scenarios & Value Demonstration



Economic Impact & Investment Justification



Conclusions

Company overview

- Agro-industrial company focused on nitrogen fertilizers, mainly **granular urea**.
- Operating since **2001** at Ingeniero White, Bahia Blanca; it is **Argentina's only granular urea plant**.
- Nominal capacity: **1.32 Mt/y of granular urea** and **790 kt/y of ammonia**.
- Integrated complex with a **2,350 t/d ammonia train** (Haldor Topsoe/BASF) and a **3,950 t/d urea train** using **Saipem/Snamprogetti** technology.

Why the OTS matters: Large-scale continuous operation integrating ammonia, urea and utilities; a strong use case for operator training focused on reliability, safety and operational excellence.



Production complex in Ingeniero White, Bahia Blanca

Since 2006 helping the processing industries in solving design and operational issues by applying process simulation



our **core business** is Process Simulation

enthusiastic about **sharing our knowledge** with our clients

all technologies (process simulator and control system)



2006

est. in Barcelona by domain experts



65 countries

worldwide footprint



160+ / 120+

employees / process simulation engineers



600+

executed projects



110+

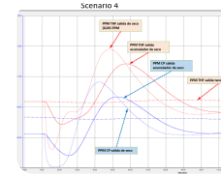
OTS / MPDS Projects



400+

Training courses

Inprocess Solutions and Services



Engineering Studies

- Dynamic Simulation Studies (compressors, control,...)
- Flare Systems Analysis
- Flow Assurance Studies



Operators Training Simulators

- Multi-Purpose Dynamic Simulator / ICSS Emulators
- 3D Virtual Reality
- Foundation Training Courses



Process Digital Twins

- Real-Time Simulators
- What-if Analysis
- Anomaly Detection



Engineers Simulation Training

- Steady State, Dynamics
- Introductory, Intermediate, Advanced
- Upstream, Natural Gas, Refinery, ...

Project Background

Profertil S.A. operates one of the largest fertilizer complexes in South America, producing ammonia and urea for agricultural markets.

An Operator Training System (OTS) based on first principles models is being developed for existing ammonia and urea plants to enhance operator skills and improve safety, availability, and overall plant performance.

Based on Aspen HYSYS® Dynamics and integrated with Aspen Properties, the OTS employs high-fidelity first-principles models with embedded DCS and SIS logic for realistic training.



1st-Principles

Dynamic Model
Engine: HYSYS Dynamics



DCS + SIS

Logic Embedded
Inside the Simulation



Operator Training

Emulation Platform

Urea Plant: Process Overview

Typical Industrial Urea Production Facility



Design Capacity

- 1,500–3,500 MTPD urea
- Typical world-scale plant
- Profertil: 3,950 MTPD



Process Technology

- Saipem NH₃-stripping
- Total-recycle processes



Key Operating Cond.

- HP loop: 140–175 bar
- Reactor temp: 120–190°C
- N/C molar ratio: 1.065 – 1.200

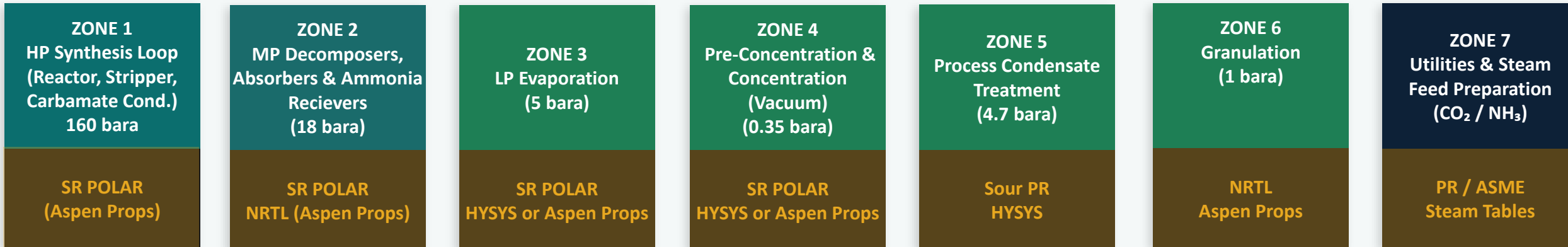


Main Products

- Granular urea (46% N)
- Urea for industry/agr
- By-product: MP steam

Model Approach & Aspen Properties Advantage

Hybrid Multi-Fluid Package Architecture



Why Aspen Properties?



Properties Model

- HCO₃⁻, NH₂COO⁻ ionic species correctly handled
- Pre-validated parameter databank for NH₃-CO₂-H₂O
- Accurate VLE/SLE across full P-T range of urea process



Built-in Data Regression (DRS)

- Regress binary parameters against plant/literature data
- Fit NH₃-urea-H₂O NRTL to observed evaporator data
- No equivalent tool in native HYSYS packages



Steady-State / Dynamic Consistency

- Same .aprbkp fluid package used in Aspen Plus AND HYSYS
- Validated SS balance transfers directly as OTS init. point
- Thermodynamic continuity guaranteed across platforms



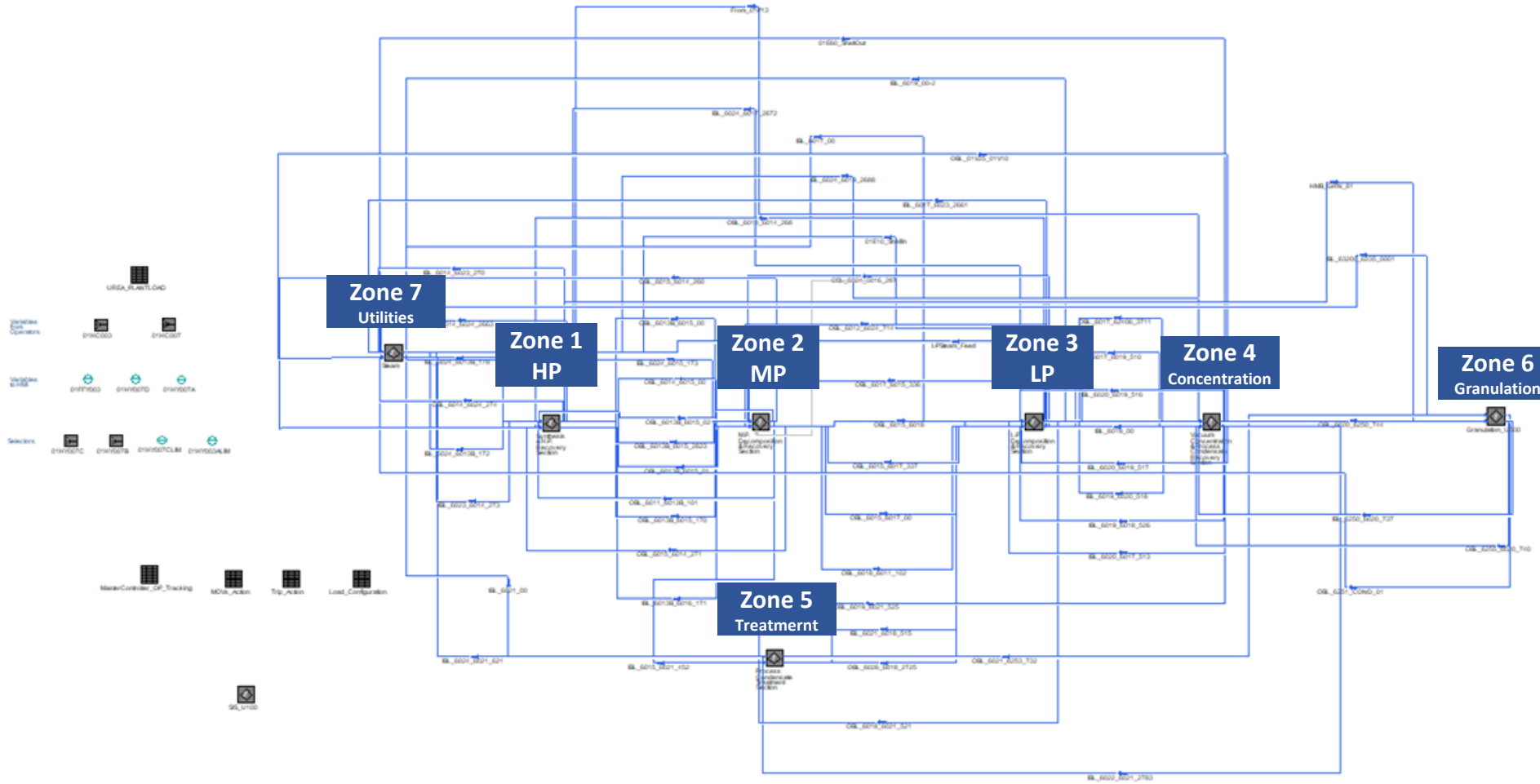
Solid-Phase & Crystallization

- Carbamate solidification curve (3-phase SLE-VLE)
- Urea crystallization onset in evaporators
- Drives alarm and interlock logic in HYSYS via lookup tables

Urea Plant: Model Overview

GRANULATED_UO

GRANULATED_UO



Main Challenges: Emulated OTS Approach

DCS & SIS Logic Embedded Inside the Process Simulation

Unlike traditional emulated OTS solutions, all control and safety logic (DCS and SIS) are directly embedded into the dynamic model — delivering consistent, realistic training without additional software layers.



Thermodynamic Complexity

- Multiple equilibria: NH_3 , CO_2 , H_2O , carbamate
- Highly non-ideal, reactive electrolyte system
- Standard EOS (Peng-Robinson) inadequate for synthesis loop
- Requires ElecNRTL / specialized packages per section



Computational Performance

- Thermo flash calls: 5–50× slower than typical cubic EOS
- Must achieve $\geq 1\times$ real-time simulation speed
- Property table interpolation as optimization strategy



DCS/SIS Logic Embedding

- All PID controllers, interlocks embedded in HYSYS
- Thousands of logic tags replicated inside simulation
- Ensures 1:1 fidelity with plant control behavior
- Eliminates interface lag between OTS and external DCS emulator



IIS Screen Emulation

- Operator HMI screens emulated with external IIS software
- Graphical fidelity must replicate real DCS screens
- Communication interface: OPC/COM data exchange



Solid Phase & Carbamate Risk

- Ammonium carbamate solidifies at $\sim 58^\circ\text{C}$
- Three-phase VLE-SLE behavior in synthesis loop
- Hysys not natively handling solids in dynamic mode
- Requires custom logic blocks and lookup tables



Model Validation & Tuning

- Kinetic parameters from literature show scatter
- Must be regressed against plant step-test data
- DCS historian data used for dynamic validation
- Continuous model maintenance over 15–20 yr lifecycle



OTS Architecture — Emulated Approach

DCS & SIS Logic Fully Embedded Inside the Dynamic Simulation

OTS System Architecture

Fully Emulated Approach: No Separate DCS Emulator — Simulation IS the Control System



OPERATOR LAYER — Inprocess Infrastructure Suite Screen Emulation

DCS Mimic Screens | Alarm Management | Trend Displays | Faceplate Controllers | Motor Control Views

OPC/DA



Inprocess Infrastructure Suite

Support the OPC emulation and Process Simulator Communication and Commands

Simulation & Communication
Manager

Instructor Station
Scenarios / IC
Malfunction Inj.



SIMULATION ENGINE — Aspen HYSYS® Dynamics

First-Principles Dynamic Model | Mass & Energy Balances | Equipment Hydraulics | Runs at $\geq 1 \times$ Real Time

DCS Logic
PID / Cascade
Override / Ratio

SIS Logic
Trips / Timers
Shutdown Seq.

Aspen Properties
Zones 1 & 2

Process Model
HP Loop · Decomp.
Evap · Granulator

Instructor Stn
Scenarios / IC
Malfunction Inj.



KEY DISTINCTION: Unlike direct connect systems, every PID loop, function block, cascade controller, and SIS interlock is replicated INSIDE HYSYS Dynamics. The control system is in the process simulation — no OPC latency between control and process, no separate DCS emulator license, single-system maintenance.

DCS & SIS Logic — Embedded Architecture Detail

Thousands of Control Tags Replicated Inside HYSYS Dynamics

DCS — Control Logic

- 600 PID control loops embedded in HYSYS
- Cascade, ratio & override controllers
- Anti-windup, output limits & bumpless transfer
- N/C ratio controller (reactor feed management)
- HP pressure control (synthesis loop)
- HP stripper steam flow control
- Granulator moisture & biuret control loops
- Alarm setpoints matching real DCS values

SIS — Safety Logic

- Emergency Shutdown (ESD) full sequences
- HP loop high-high pressure trips (PAHH)
- Loss of passivation air alarm & interlock
- CO₂ compressor protection logic
- Reactor temperature TAHH trip
- Steam supply failure interlock chains
- Post-trip restart permissive sequences
- SIS bypass management & trip voting logic

Instructor Station

- Scenario initialise / freeze / run / rewind
- Malfunction injection at any process tag
- Selectable upset severity & timing
- Speed factor: 1× to 3× real time
- Snapshot save & restore (any plant state)
- Trainee performance logging & scoring
- Remote monitoring of all trainee actions
- Debrief replay with full trend history

IIS Operator Screen Interface

DCS-Replica Graphical Environment — High-Fidelity Screen Emulation via OPC

IIS Platform — Key Features

DCS Screen Replication

Replicates identical to real DCS — same colors, navigation, alarm indicators. Eliminates negative training transfer.

Alarm Management

Full rationalization: priorities, suppression, shelving — trains real alarm response & decision-making.

OPC Communication

Bidirectional real-time exchange between IIS & HYSYS (100–500 ms cycle). Tag mapping: 2,000+ I/O.

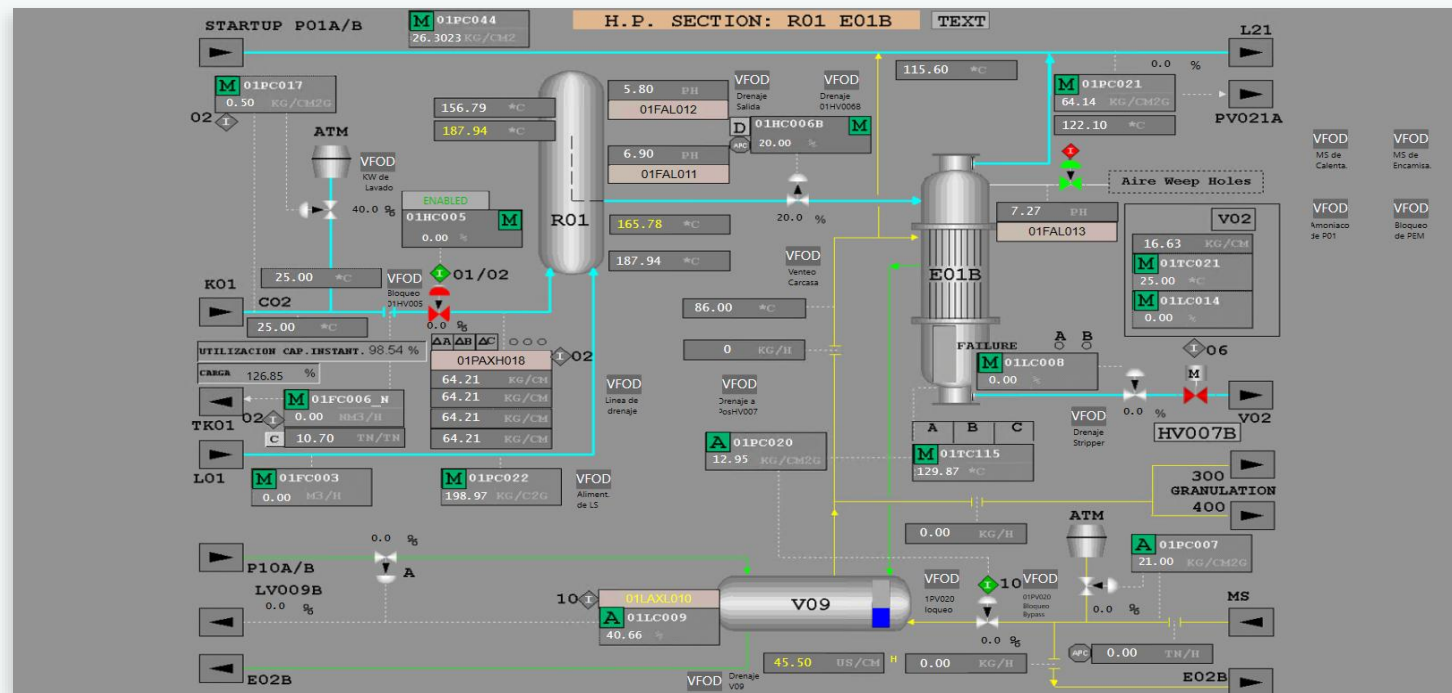
Multi-Station

Instructor + multiple trainee consoles. Supports coordinated field/console exercises.

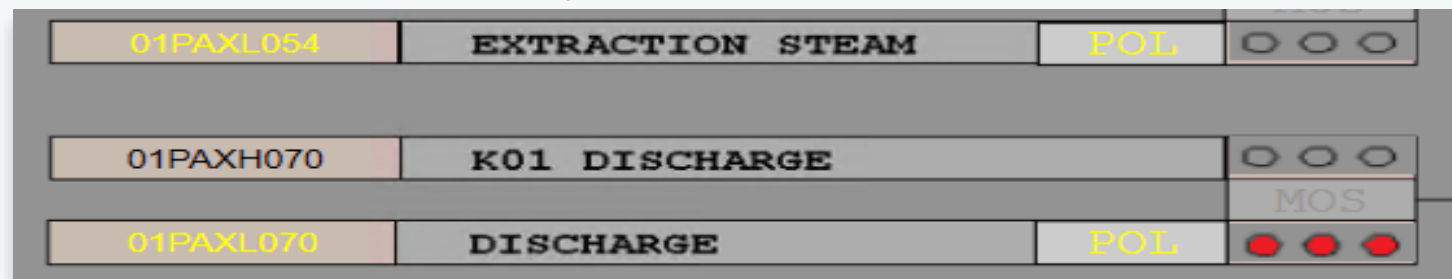
Trends & Historian

Real-time trends and session historian for post-debrief performance review & competency scoring.

HP Synthesis Loop — DCS Screen Mockup



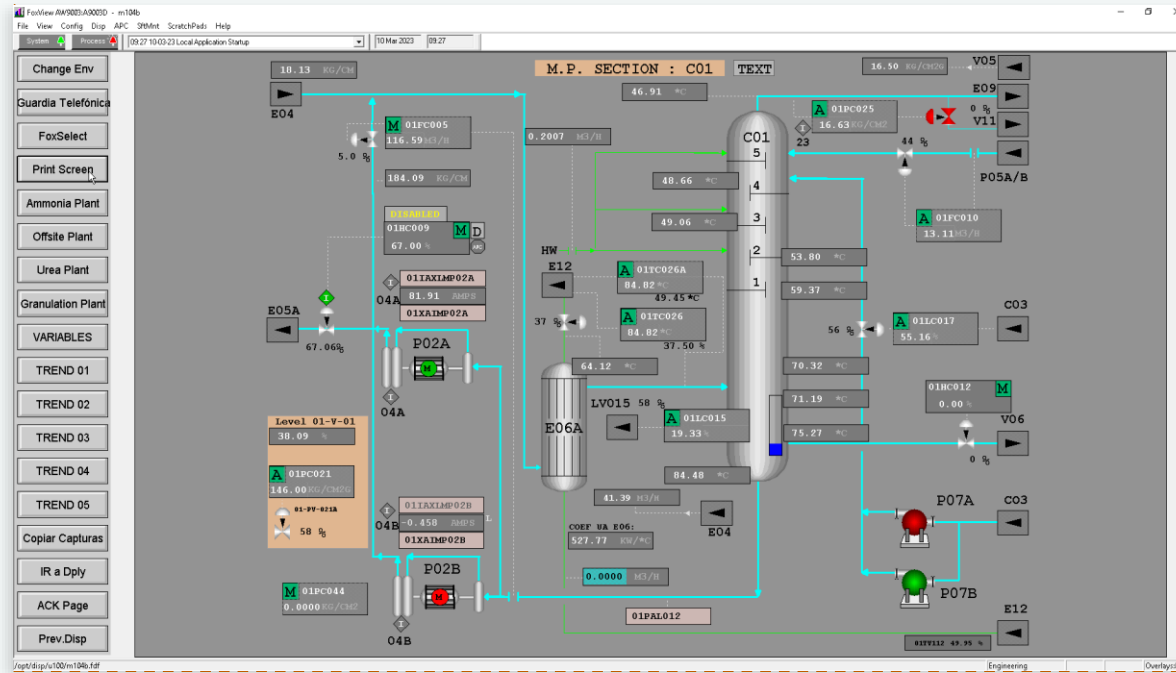
Active Alarm Screen — Scenario SC-1 Injected



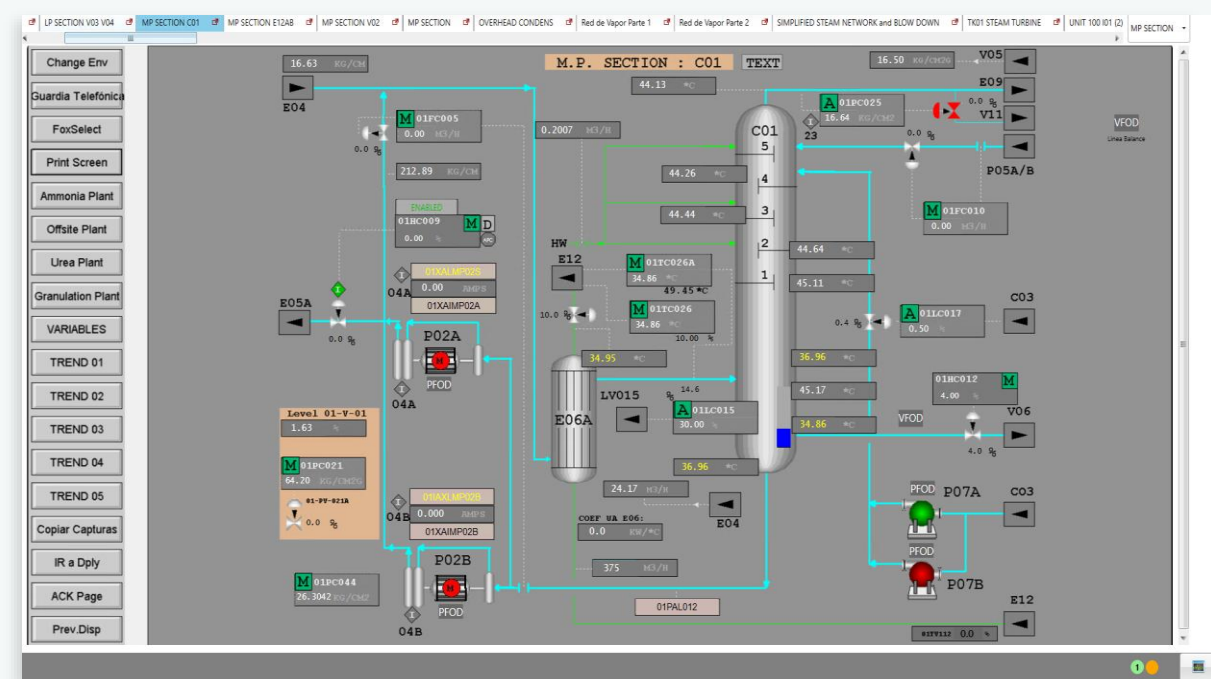
OTS Screen Layouts — Representative Views

Process Overview · Controller Detail · Process Trends

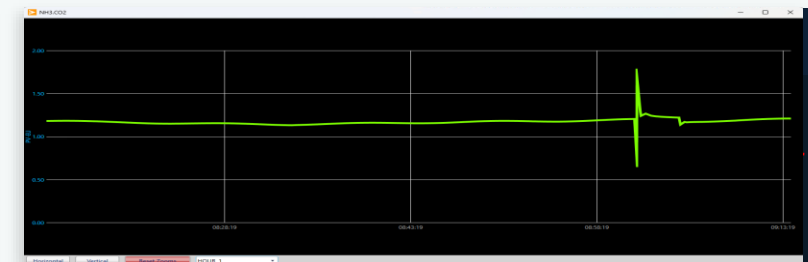
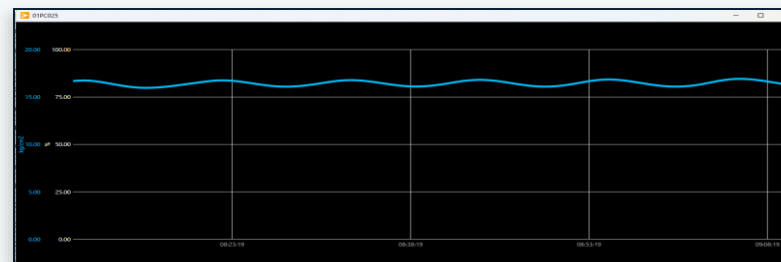
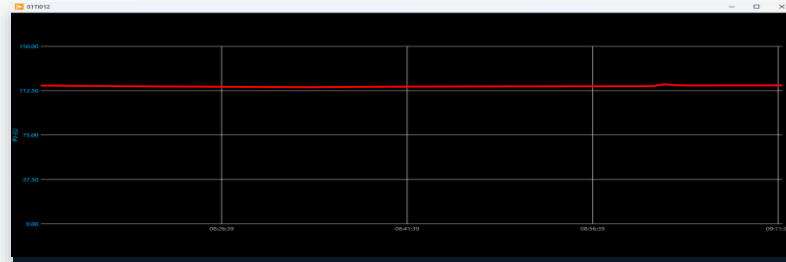
Screen — Plant DCS Screenshots



Screen — Synthesis Overview (OTS DCS Replica)



Screen — Process Trends





OTS Usage — Four Strategic Applications

Training · Process Optimization · Control Tuning · Debottlenecking

OTS Usage — Four Strategic Applications

A Lifetime Engineering Asset Beyond Initial Training



01

Training Program — Multiple Levels

- Level 1 — Novice: Plant orientation, steady-state normal ops, HMI navigation & basic alarm response
- Level 2 — Operator: Startup/shutdown sequences, abnormal ops management, first response
- Level 3 — Senior Operator: Emergency response (ESD, passivation loss), complex multi-unit upsets
- Level 4 — Supervisor/Certifier: High-consequence scenarios, post-event restart, certification delivery
- Continuous refresher training: 40–80 hrs/year structured curriculum per operator



02

Process Operation Improvement

- N/C ratio optimization: simulate conversion, energy consumption & biuret formation tradeoffs
- Production rate maximization within equipment and utility constraints
- Feed rate ramping strategies to minimize transient off-spec production
- Steam balance optimization: HP/MP/LP header interactions under variable load
- Evaporator and granulator condition optimization for product quality targets



03

Control Study & Controller Tuning

- PID tuning in dynamic model before implementation on real plant (zero process risk)
- Advanced Process Control (APC) strategy design and pre-commissioning testing
- Cascade and ratio controller interaction studies at full plant scale
- Override and selector controller logic validation including edge cases & saturation
- SIS modification testing: new trip logic, bypass management, timing changes



04

Debottlenecking Analysis

- Identify limiting constraints at production rates above design (dynamic pressure profiles)
- HP stripper flooding: steam-to-feed ratio limits vs. tube bundle capacity
- CO₂ compressor surge envelope mapping: safe ramp-rate limits
- Evaporator capacity limits: vacuum system performance at elevated throughput
- Granulator capacity and recycle ratio impact on maximum sustainable rate



Training Scenarios & Value Demonstration

Quantifying the Business Case Through Process Safety Incidents

Example Training Scenarios

Most Frequent Upsets & Disturbances in Urea Operations

SC-1 N/C Ratio Upset

- ⚡ **Trigger:** CO₂ compressor surge / NH₃ feed valve failure
- ⚠ **Impact:** Conversion drops from 68% → 55%; carbamate overload
- 💰 **Loss:** ~\$20K–\$30K per event **Freq:** High (monthly)

SC-2 HP Pressure Excursion

- ⚡ **Trigger:** Inert gas accumulation; loss of HP condenser cooling
- ⚠ **Impact:** Relief valve activation; forced slowdown / ESD
- 💰 **Loss:** ~\$230K–\$440K per event **Freq:** Medium (quarterly)

SC-3 HP Stripper Steam Loss

- ⚡ **Trigger:** Boiler trip; steam header pressure drop; wet steam
- ⚠ **Impact:** Carbamate solidification risk; 25–30% production cut
- 💰 **Loss:** ~\$145K–\$440K per event **Freq:** Medium-High

SC-4 Loss of Passivation Air

- ⚡ **Trigger:** Air compressor trip; O₂ analyzer malfunction
- ⚠ **Impact:** Accelerated corrosion — 0.05 → 2 mm/yr on 316L UG
- 💰 **Loss:** \$3.5M–\$9,2M per event **Freq:** Low (catastrophic)

SC-5 Tower Upset

- ⚡ **Trigger:** Melt moisture deviation; cooling fan trip; nozzle fouling
- ⚠ **Impact:** Off-spec product (biuret >1.5%); caking; rework
- 💰 **Loss:** ~\$12K–\$40K per event **Freq:** High (weekly)

Additional Scenario Categories

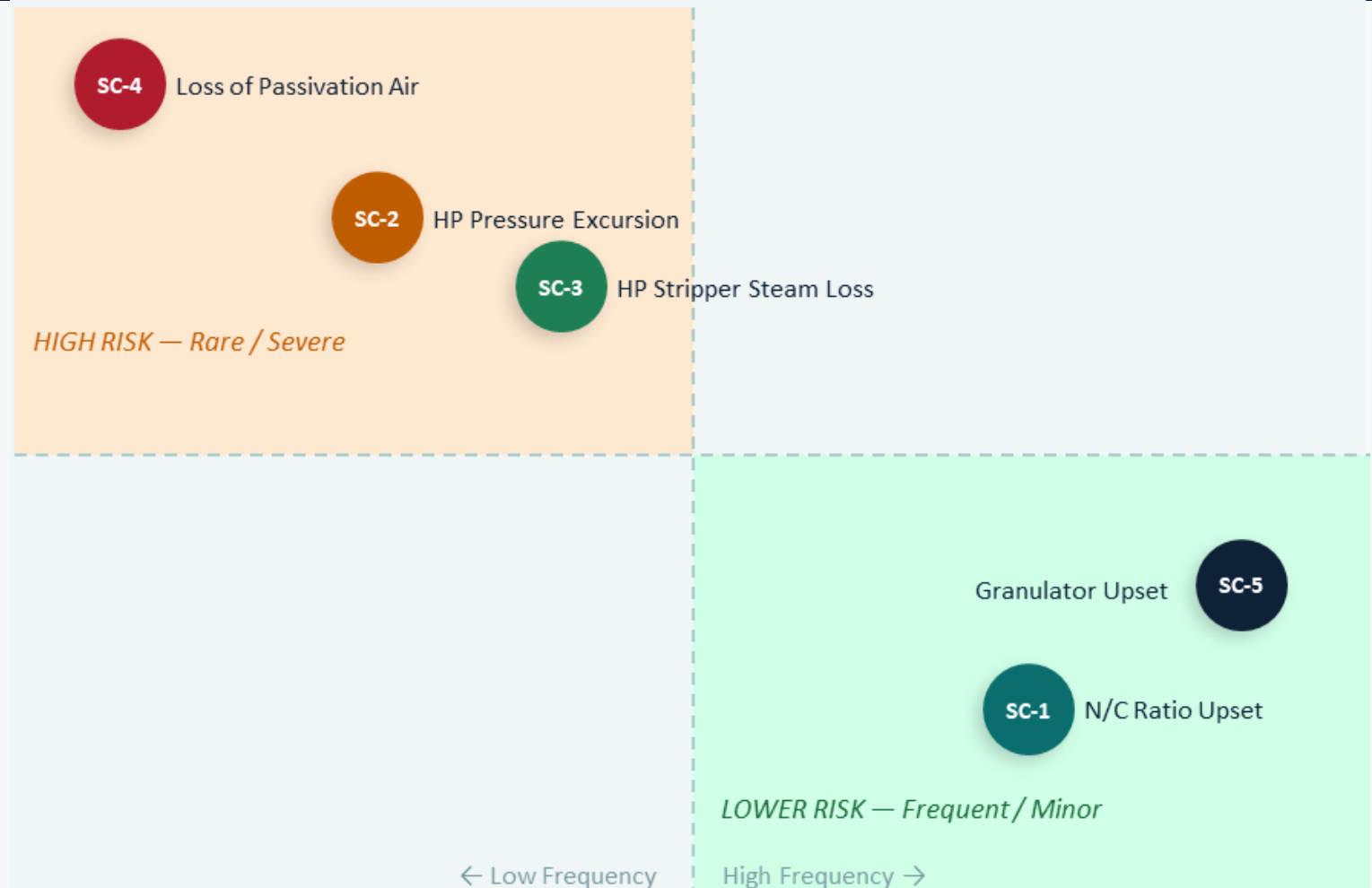
- Plant startup from cold conditions (full loop pressurization)
- Emergency shutdown with carbamate freeze-off
- Gradual feed rate optimization (N/C ratio controller tuning)

Training Scenario Portfolio — Risk Matrix Overview

Five Priority Scenarios Covering the Full Frequency–Consequence Spectrum

Scenario Summary

SC-4	Loss of Passivation Air \$3.2M–\$9.2M/event
SC-2	HP Pressure Excursion \$155K–\$320K/event
SC-3	HP Stripper Steam Loss \$155K–\$300K/event
SC-1	N/C Ratio Upset \$20K–\$30K/event
SC-5	Granulator Upset \$37K–\$86K/event



Note: SC-4 passivation loss shown in detail on following slides — single event recovers full OTS investment

Scenario SC-1 — N/C Ratio Upset: Training Value Demonstration

High-Frequency · \$20K–\$30K per Event · 8–12 Events/Year · Annual Exposure: \$160K–\$360K

Scenario Description & Training Value

Trigger: CO₂ compressor surge or NH₃ feed pump cavitation causes N/C ratio to drift below setpoint (3.70) toward ~2.8:1. DCS alarms at 3.50 (LOW).

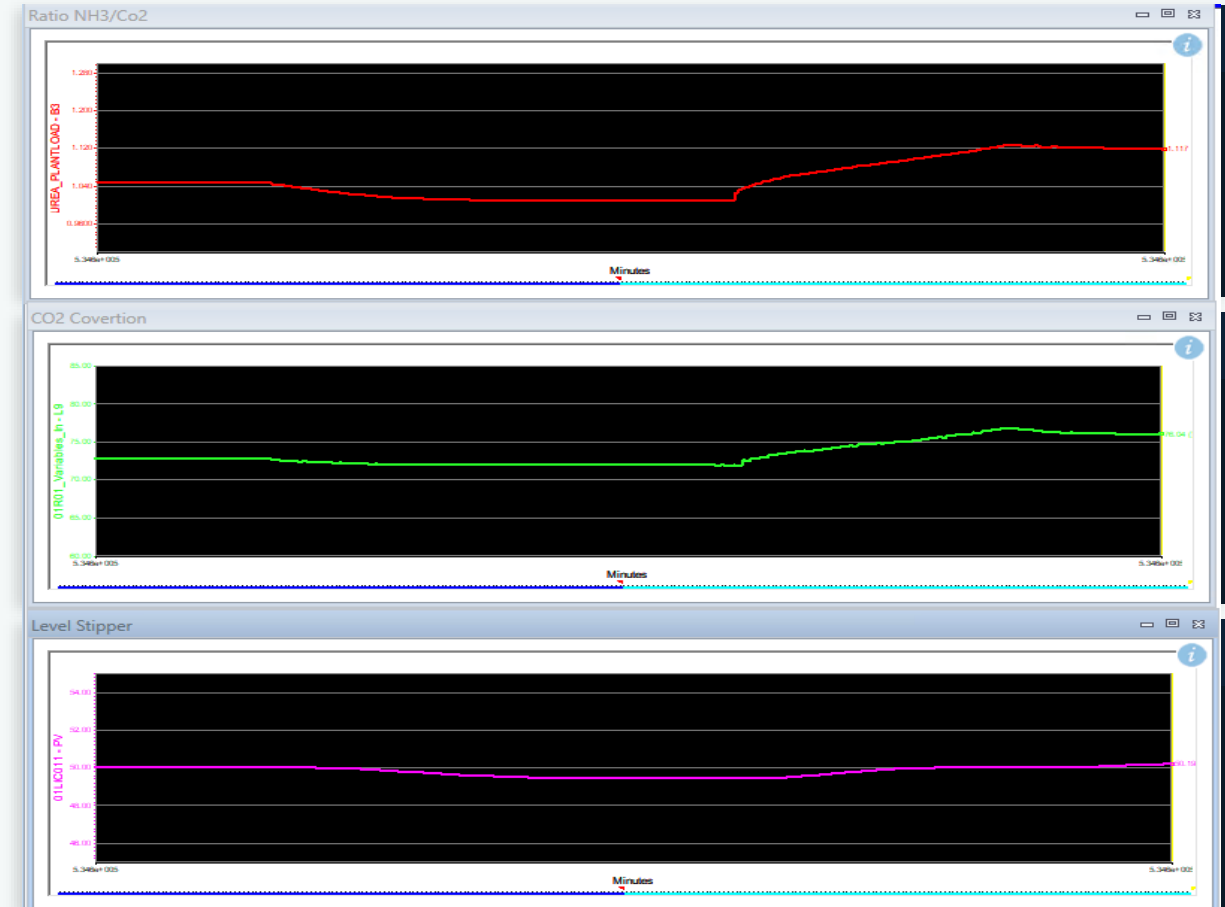
Process Impact: CO₂ conversion drops from 65% → 52%. Carbamate recirculation load on LP section increases. HP stripper duty rises. Production efficiency deteriorates.

Operator Challenge: Multiple interacting loops respond simultaneously — N/C ratio, reactor temperature, HP pressure, LP absorber level. Operators must diagnose root cause correctly before acting.

WITHOUT Training: Operator attempts wrong corrective action (adjusts wrong feed). Event duration: 8–12 hours. Lost production: 150–200 MT.

WITH OTS Training: Operator correctly identifies root cause from alarm pattern. Takes correct feed controller action. Recovery time: 2–3 hours. Lost production: 30–50 MT.

Simulated Dynamic Response — Instructor Injects CO₂ Compressor Surge @ t=10min



Training Value: Trained operator saves 6–9 hrs × 200 MT/hr × 50% margin = \$18K–\$27K per event × 10 events/yr = \$180K–\$270K/yr from this scenario alone

Scenario SC-4 — Loss of Passivation Air: The Catastrophic Scenario

Rare but Devastating · \$3.2M–\$9.2M per Event · Single Event = Full OTS Investment Recovered

Corrosion Rate — Passivated vs. Unpassivated 316L UG Steel

Passivated (normal O₂ > 0.25%): < 0.05 mm/yr

Unpassivated (O₂ < 0.05%): 0.5–2.0 mm/yr → 40× higher

Event Timeline — Without Trained Operator

- t = 0 hr** Air compressor trips. O₂ drops below 0.25%
- t = 0–2 hr** O₂ LOW alarm active — operator uncertain of action
- t = 2–4 hr** Continued operation. Corrosion rate rising sharply
- t > 4 hr** ESD activated — HP stripper tube inspection triggered
- t = 7–21d** Tube bundle replacement, plant idle, NDE campaign

Insurance Principle: OTS cost \$500K–\$1.5M total vs. event cost \$3.2M–\$9.2M.
5% annual probability → expected annual benefit = **\$64K–\$552K/yr from this scenario alone**

Event Cost Breakdown — Unmitigated

HP Stripper Tube Bundle Replacement	\$1.5M – \$4.0M
Lost Production (7–21 days downtime)	\$1.6M – \$4.7M
Inspection & NDE Campaign	\$0.1M – \$0.5M
TOTAL EVENT COST	\$3.2M – \$9.2M

What OTS Training Delivers for SC-4

- Early recognition**
Response within 30 min vs. 2–4 hrs untrained — prevents corrosion exposure
- Correct emergency action**
Practice of: air restore, manual O₂ control, and ESD decision timing
- Equipment protection**
Rapid correct response prevents tube damage → avoids \$1.5M–\$4M replacement
- Financial return**
One prevented event = \$3.2M–\$9.2M saved = 3–15× full OTS investment cost


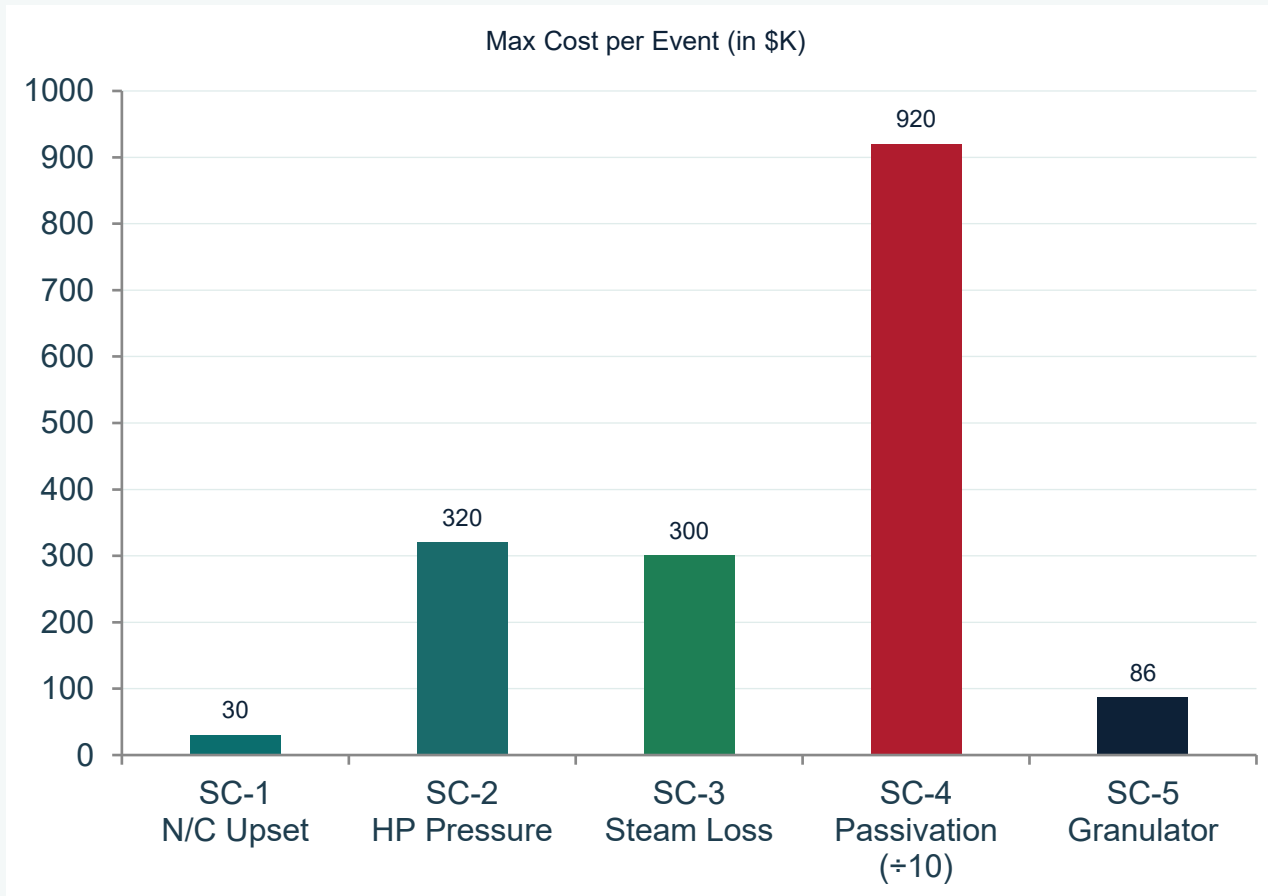


Economic Impact & Investment Justification


Three Complementary Methodologies

Economic Impact & Investment Justification

1,760 MTPD Reference Plant | Urea \$300/MT (World Bank 2023–24)



25–40%
Reduction in Upset Frequency



30–50%
Faster Operator Recovery



\$300–800K
Annual Avoided Losses (conserv.)



0.6–3 yr
OTS Investment Payback Period

 **Expected Annual Benefit**

 **Insurance Value**

 **Real Options**

Conclusions

Fully Emulated Architecture

DCS/SIS logic embedded inside HYSYS Dynamics — simulation IS the control system. No separate emulator, no latency.

Aspen Properties — Essential

The thermodynamics for $\text{NH}_3\text{-CO}_2\text{-H}_2\text{O}$ is critical. No native HYSYS package provides equivalent accuracy.

Four Strategic OTS Uses

Training (4 levels) + Process Optimization + Control Tuning + Debottlenecking — 15–20 yr engineering asset.

Scenario Training Delivers ROI

SC-1: \$180K–\$270K/yr. SC-4 (insurance): one event = \$3.2M–\$9.2M. Both independently justify OTS investment.

Investment Justified on 3 Levels

Expected value: \$300K–\$900K/yr. Insurance value: tail-risk elimination. Real options: APC, compliance, knowledge.

Profertil will Demonstrate Viability

First-principles OTS achievable and sustainable for existing world-scale urea plant. Payback: 0.6–3.5 years.

THANK YOU

Questions & Discussion

Aspen HYSYS® Dynamics | Aspen Properties

Profertil S.A. — Bahía Blanca, Argentina

Inprocess Technology — Barcelona, Spain

Optimize 2026 Conference

