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Asia Downstream Summit 2025

From Pilot to Plant:
When Scale Breaks Your Digital Twin

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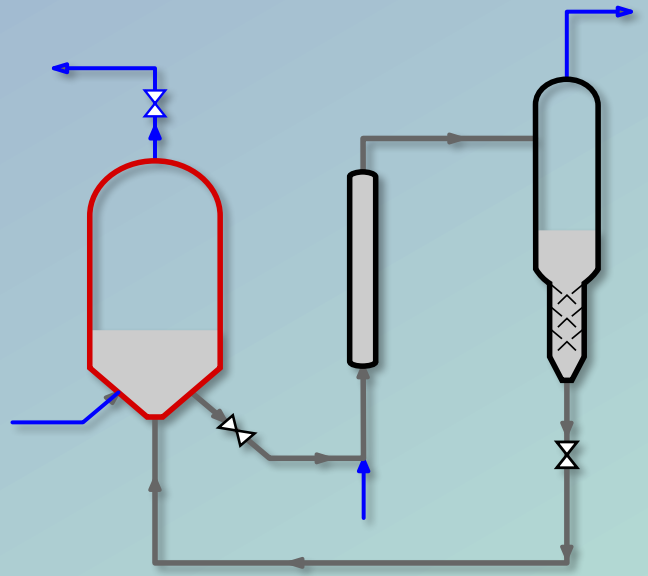
When Pilot Success Guarantees Nothing
Understanding Scale & Complexity in FCCUs

PILOT SCALE REGENERATOR:

- Catalyst inventory: ~50 kg
- Height: ~3m
- Diameter: ~0.3m



COMMERCIAL SCALE REGENERATOR:

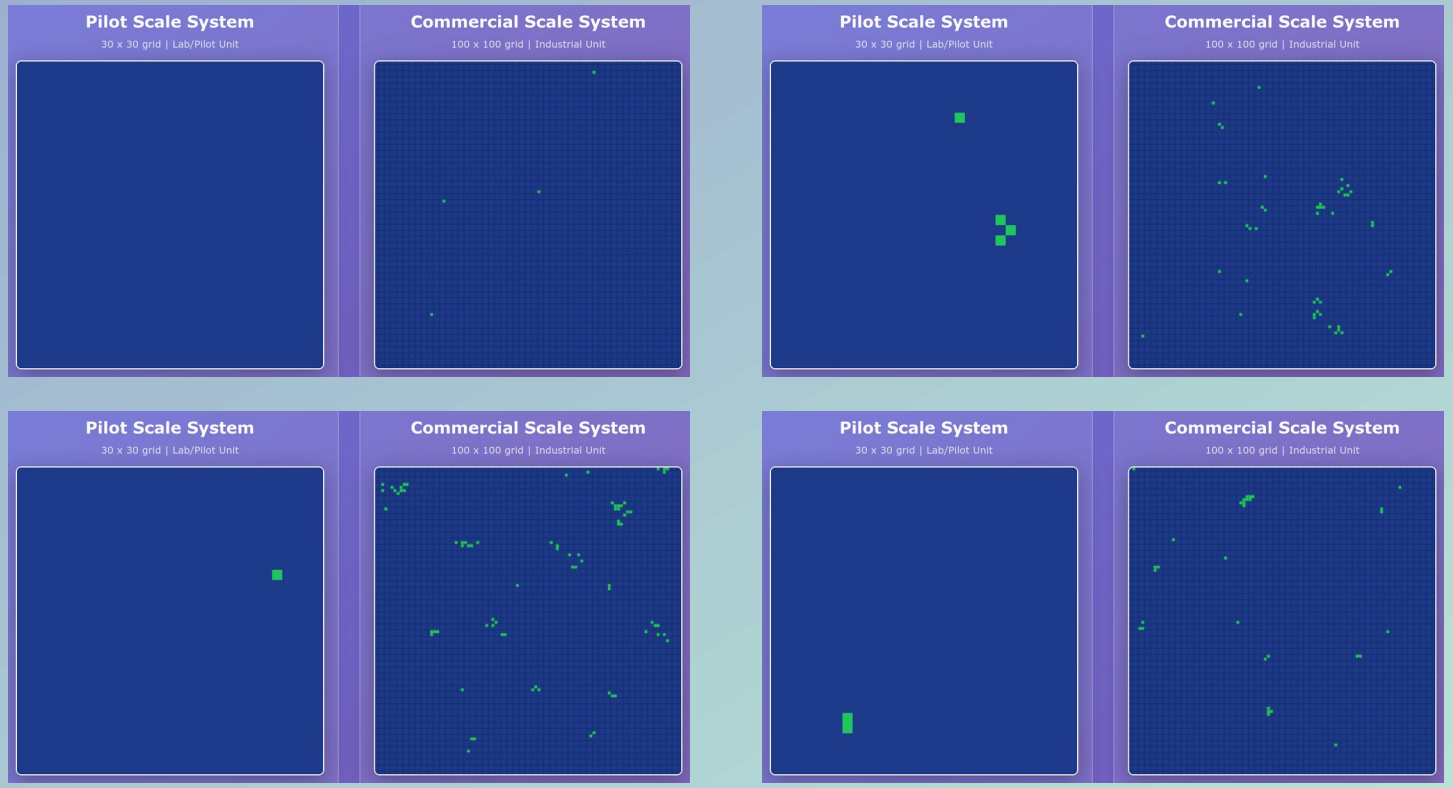
- Catalyst inventory: ~100,000 kg (100 tons)
- Height: ~20-30m
- Diameter: ~8-10m

Scale Ratio: 1:2000
Same Design • Same Chemistry • Behavior?

Following demonstrations use simplified CA models to illustrate complexity principles

Simulation – Both Systems Under Moderate Stress

Operating Margin: 97% | Disturbance: 2% | Initial Variation: 2%



- Normal Operation
- Hot zone
- Recovering
- Critical / Failure

Same conditions

- Pilot (left) handles easily
- Commercial (right) struggles but survives

Operating Margin:
How close to ideal operating conditions

- 100% = optimal
- 90% = stressed

The Threshold: Small Change, Catastrophic Difference

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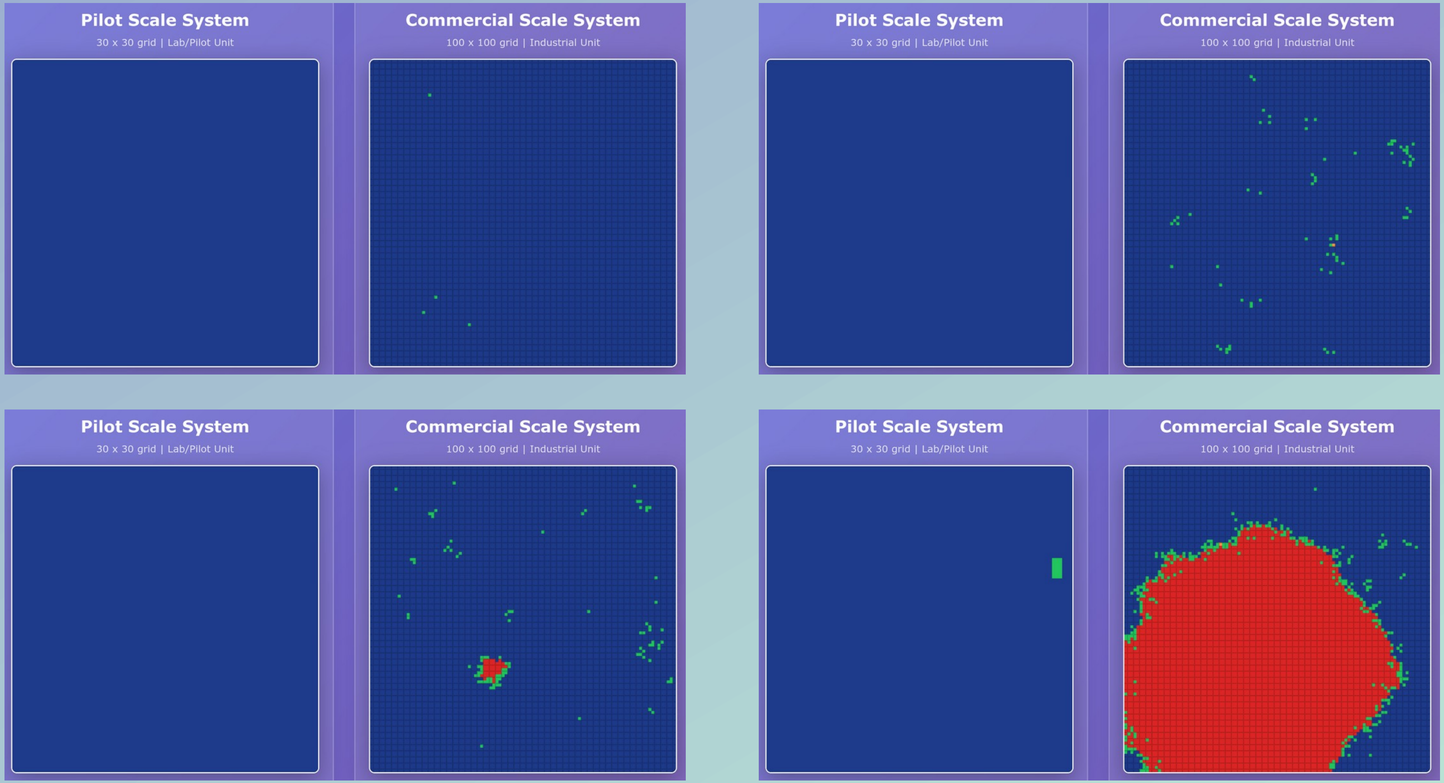

- Normal Operation
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<u>Just 1% margin reduction - Pilot survives, Commercial fails catastrophically</u>

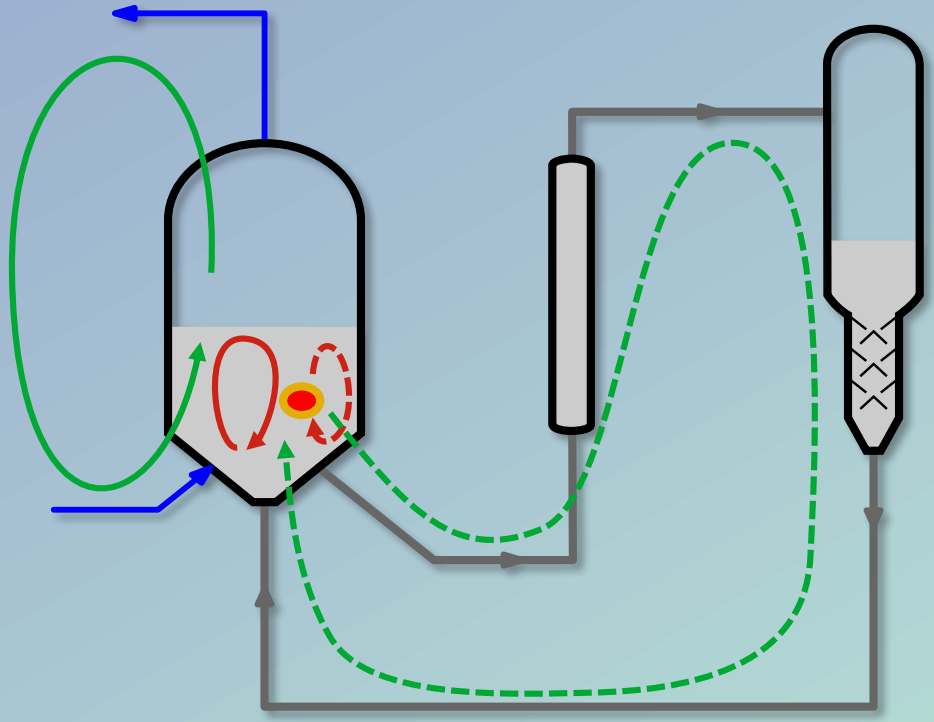
WHY?

FCCU Is a Complex System

What Makes a System Complex?

- Many interacting components
- Non-linear behavior
- Feedback loops (reinforcing - destabilizing & balancing - stabilizing)
- Emergent properties that cannot be predicted from parts

Competing Feedback Loops in the Regenerator



REINFORCING LOOPS (Vicious Cycles):

→ Coke combustion → Heat → Faster combustion → Thermal runaway

⇢ Hot spot → Poor fluidization → Agglomeration → Defluidization cascade

BALANCING LOOPS (Stabilizing):

→ Heat generation → Air flow removes heat → Temperature control

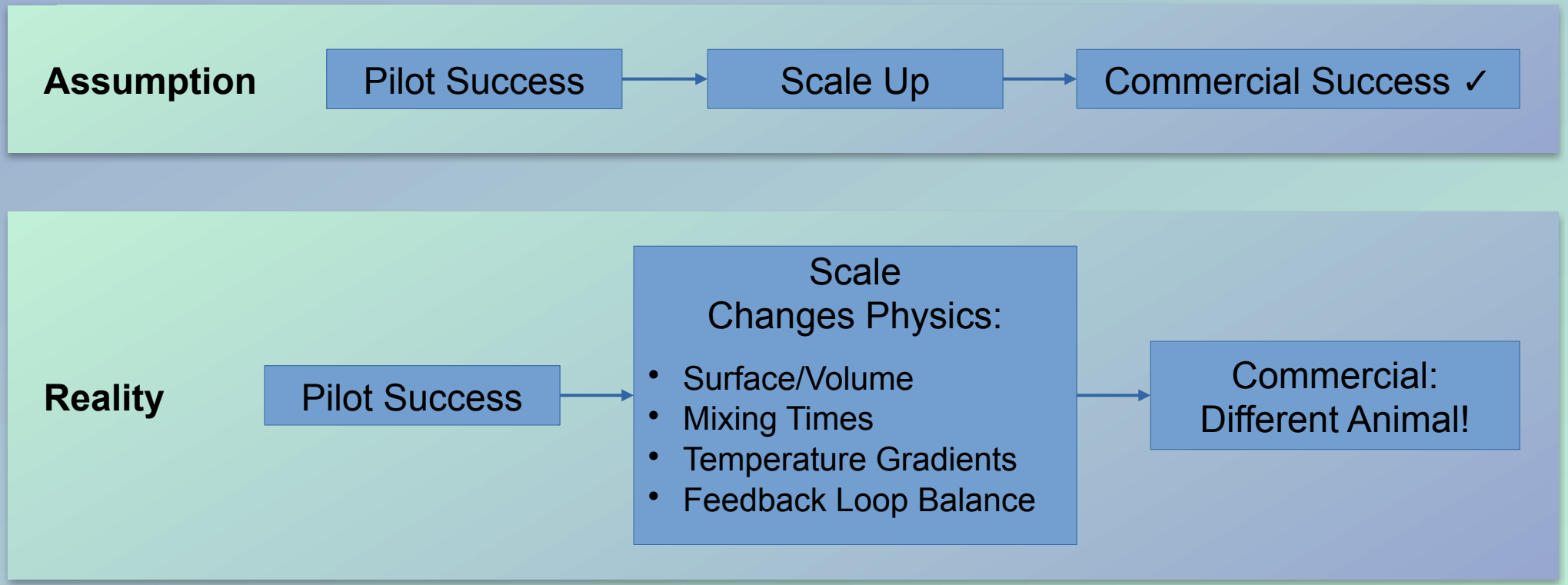
⇢ Hot spot → Catalyst circulation → Heat distribution

Which loops dominate → Stable vs. Catastrophic failure"

Scale Changes Which Loops Dominate

PILOT SCALE	COMMERCIAL SCALE
High surface-to-volume ratio → Heat dissipates	Low surface-to-volume ratio → Heat accumulates
Short distances → Fast mixing	Long distances → Gradients form
Small bed → Uniform distribution	Deep bed → Maldistribution
Balancing loops WIN	Reinforcing loops can WIN
Stable, forgiving	Sensitive, unforgiving

What This Means for Scale-Up



Key Takeaways

PILOT PLANTS ✓ (What They Tell Us)	PILOT PLANTS ✗ (What They Hide)	WHAT WE NEED ✓ (How to Bridge)
• Kinetics	• Scale-dependent stability	• Systems thinking
• Thermodynamics	• Emergent failure modes	• Multi-scale modeling
• Material properties	• Sensitivity thresholds	• Computational exploration
• Reaction mechanisms	• Operational resilience	• Operational experience

PILOT PLANTS: Essential but Limited

Visit us at Booth B8

Check Out Our Interactive Demo(*)

Explore scenarios • Adjust parameters • See emergence in action!

(*) **Note: Simplified CA model for demonstration**

Resources and Contact Info:

https://aprocesr.com/ADS2025

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