

twelve

# a world made from air™

From CO<sub>2</sub> to E-Jet® SAF: Dynamic Simulation, Control Validation and Operator Training

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# Agenda

- Twelve's mission
- Process overview and challenges
- Why dynamic simulation?
- Project Objectives
- Project Scope
- Key outcomes and value delivered
- Next steps – digital twin roadmap

# Twelve's mission

- Twelve is building a circular carbon economy by transforming CO<sub>2</sub> from a liability into a feedstock for fuels, chemicals, and materials.
- E-Jet® SAF uses captured CO<sub>2</sub>, water, and renewable energy to produce a drop-in jet fuel with up to 90% lower lifecycle emissions than conventional petroleum-based fuel.
- This project shows what it takes to move from promising lab scale climate technology to a commercial demonstration plant that operators can actually start up, run, and trust.



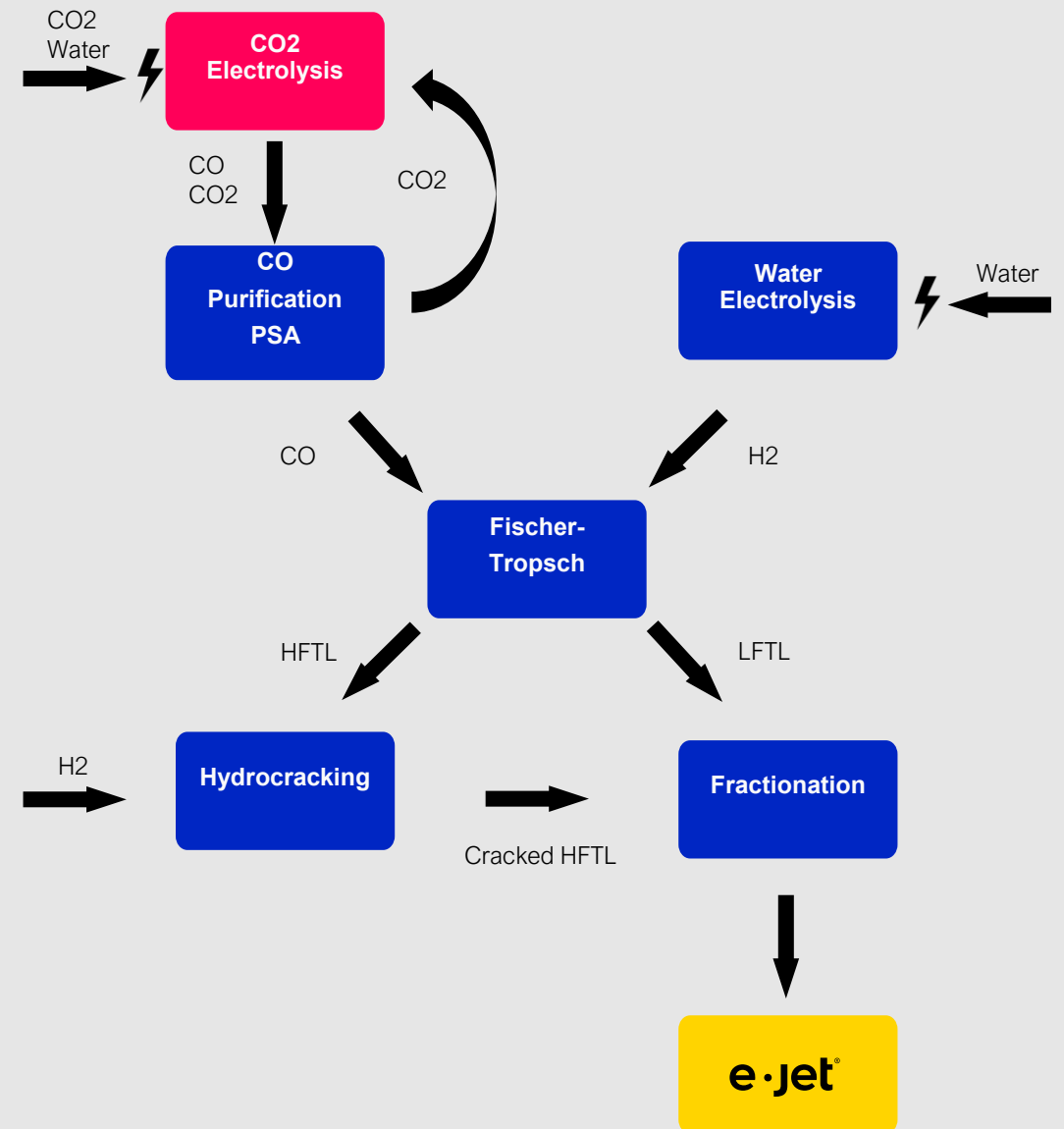
# De-risking a first-of-a-kind saf facility

- Twelve is converting captured CO<sub>2</sub> and renewable electricity into E-Jet® sustainable aviation fuel
- The process integrates electrolyzers, PSA purification, Fischer–Tropsch synthesis, hydrocracking, and fractionation in one tightly coupled operation.
- That creates significant startup and operational complexity, especially in a facility with limited industry precedent
- Aspen HYSYS® Dynamics and an emulated OTS were used to validate controls, train operators, and reduce commissioning risk before startup



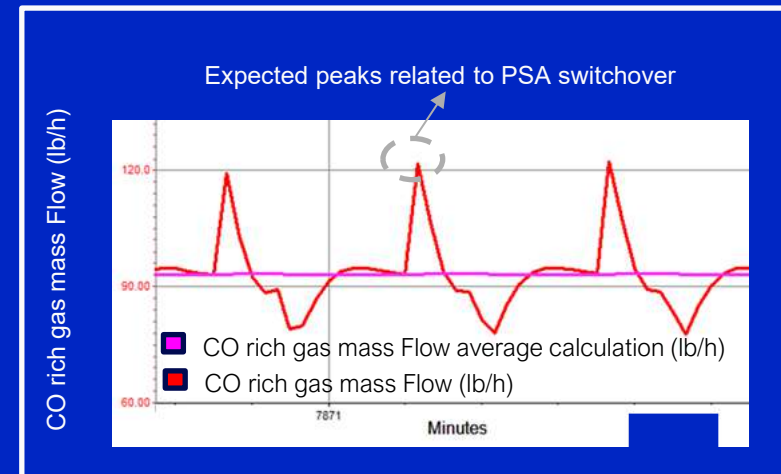
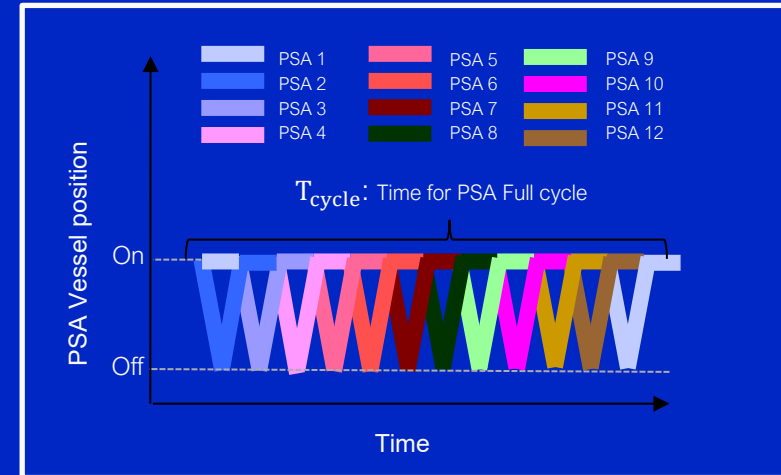
# Process overview

- $\text{CO}_2 + \text{Water} + \text{Power} = \text{eFuels}$
- Demonstration scale  $\neq$  Simplicity



# Process challenges

- Marrying cyclical and steady state process (e.g. PSA->FT)
- Small scale = small margins for error
- New process means no tribal knowledge



# Human challenges

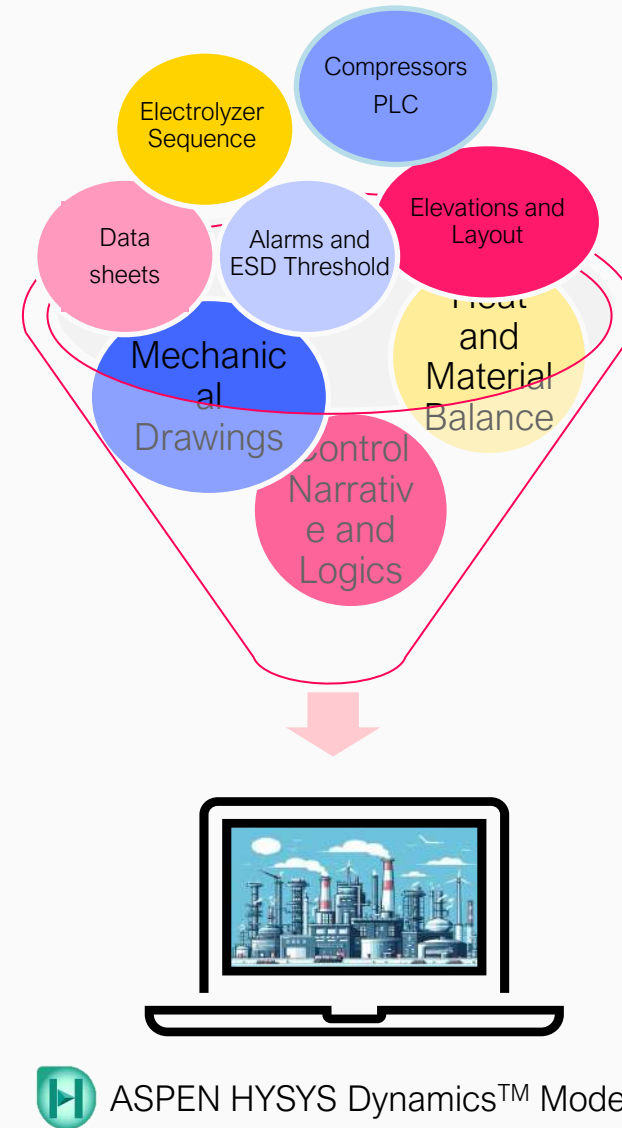
operators for a plant that doesn't yet exist

- Startup company creates production pressure
- Location drives workforce availability
- No procedures, no operations organization, no history



# The solution: dynamic simulation and operator training simulator

- Aspen HYSYS foundation
- Dynamic process model to bring the process together
- OTS overlay to train operators in their native environment



# Key Modelling Challenges

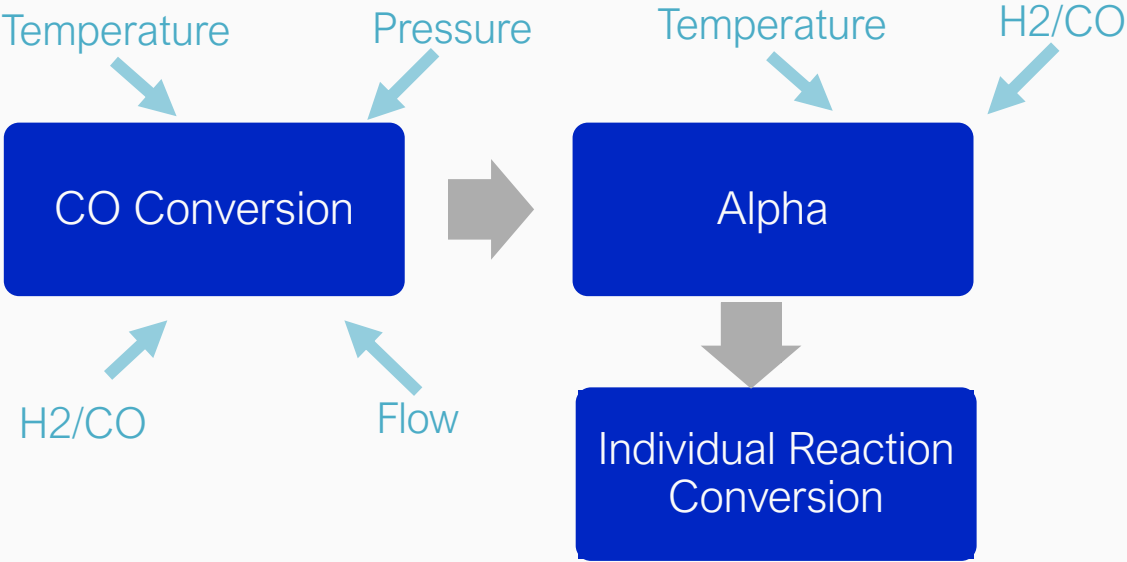
## Fischer-Tropsch

Desired reactions

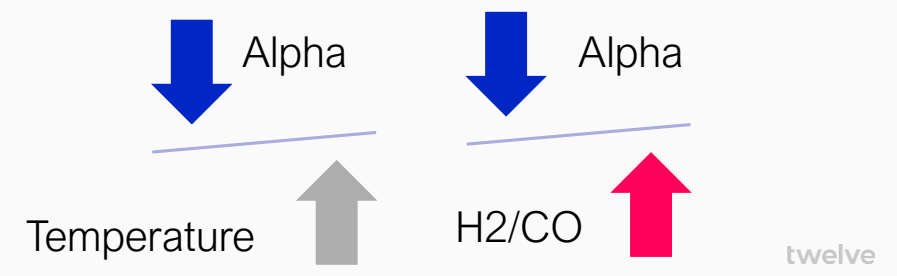
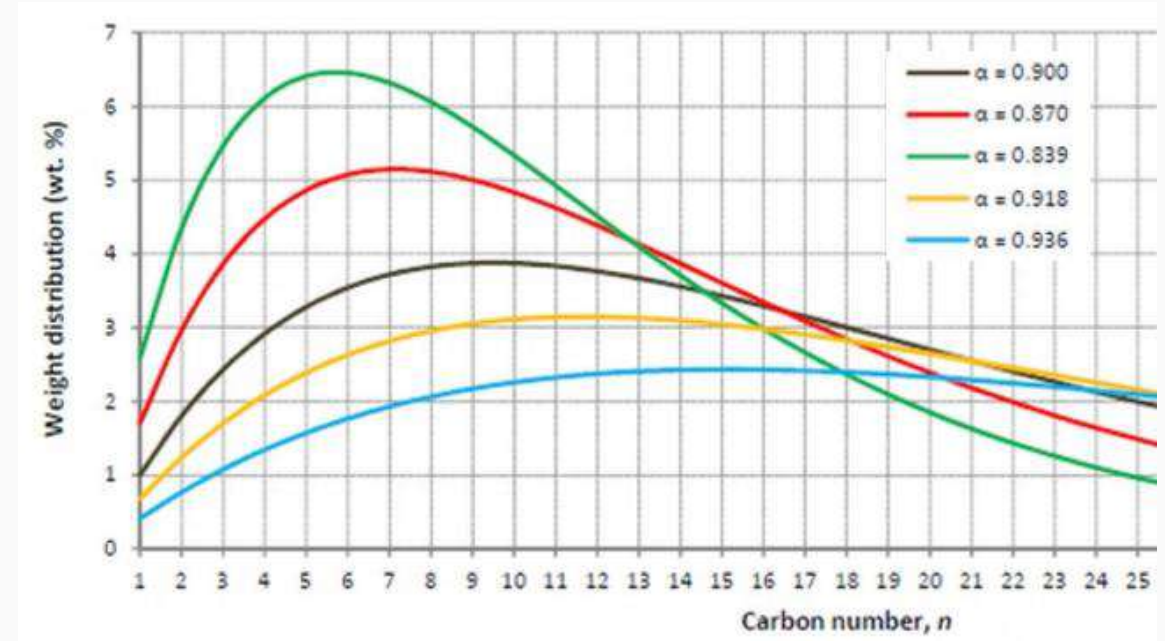
1. Formation of Paraffins (Alkanes) – Saturated Hydrocarbons  
 $(2n+1)H_2 + nCO \rightarrow C_nH_{2n+2} + nH_2O$
2. Formation of Olefins (Alkenes) – Unsaturated Hydrocarbons  
 $(2n)H_2 + nCO \rightarrow C_nH_{2n} + nH_2O$

Undesired reactions

3. Formation of Alcohol  
 $2nH_2 + nCO \rightarrow C_nH_{2n+1}OH + (n-1)H_2O$
4. Water Gas Shift  
 $H_2O + CO \rightarrow H_2 + CO_2$



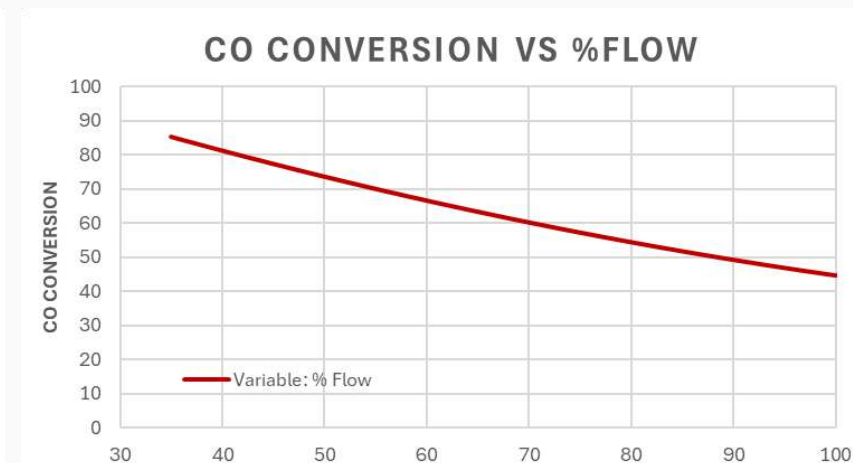
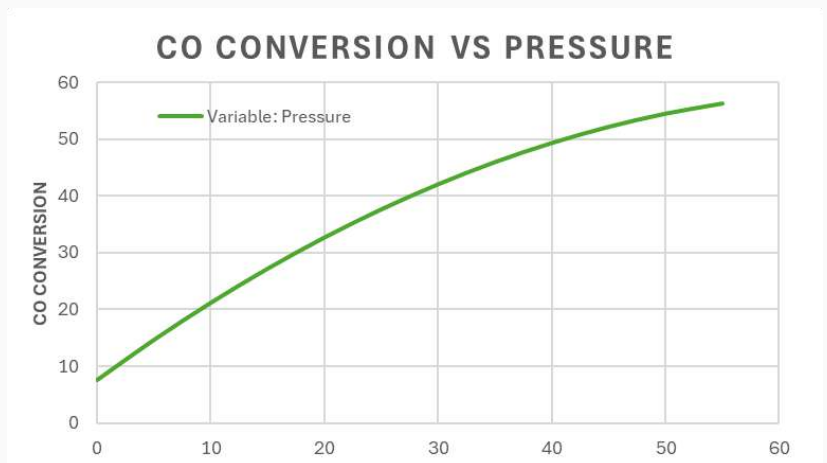
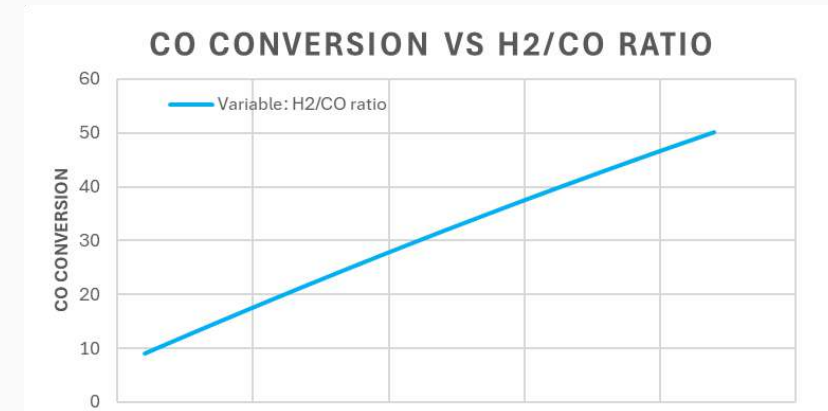
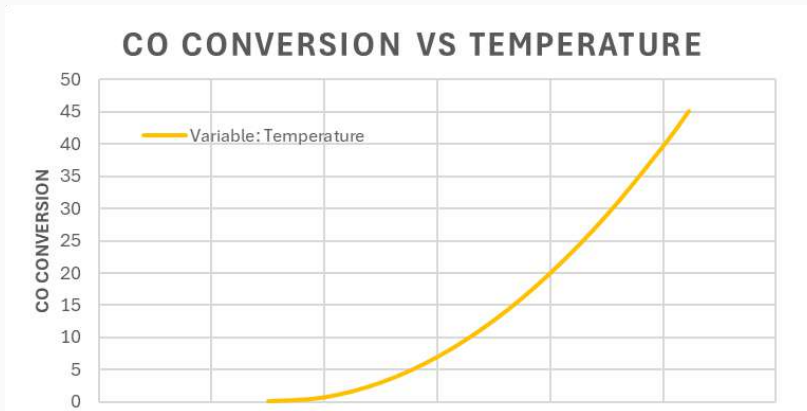
## Carbon Chain Distribution (Alpha)



# Key Modelling Challenges

Fischer-Tropsch

Units Operations Used in HYSYS



Connections Parameters Formulas Spreadsheet Calculation Order User Variables Notes					
Current Cell					
A1		Variable:		Export	
				Angles in	
	A	B	C	D	
1			CO conversion Eq		-43.03
2	CarbonNo		Alpha	Reaction	Rei
3	1.000	3.751e-002	0.9625		43.03
4	2.000	3.610e-002	0.9625		43.03
5	3.000	3.475e-002	0.9625		43.03
6	4.000	3.344e-002	0.9625		43.03
7	5.000	3.219e-002	0.9625		43.03

# Key Modelling Challenges

## Hydrocracker



**Bed 1**  
Heavier  
paraffins

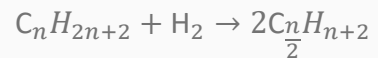


**Bed 2**  
Rest of paraffins  
Alcohols  
Water gas shift

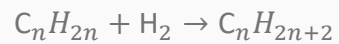


**Bed 3**  
Isomerization

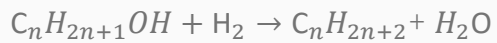
1. Cracking of Paraffins (Alkanes) – Saturated Hydrocarbons



2. Cracking of Olefins to Paraffins (Alkenes) (double bond C=C)



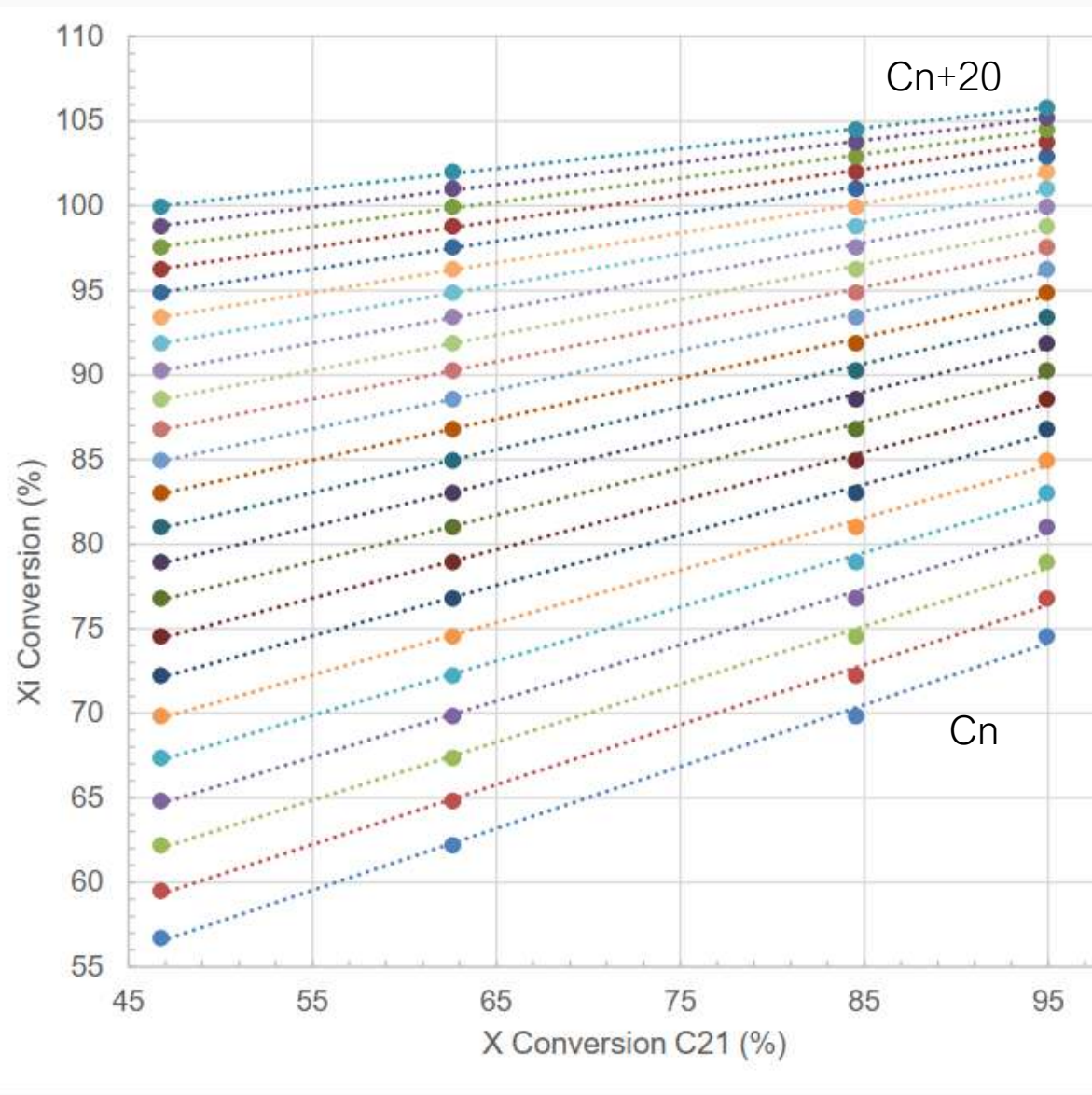
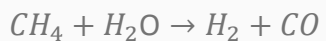
3. Cracking of Alcohol to Paraffins



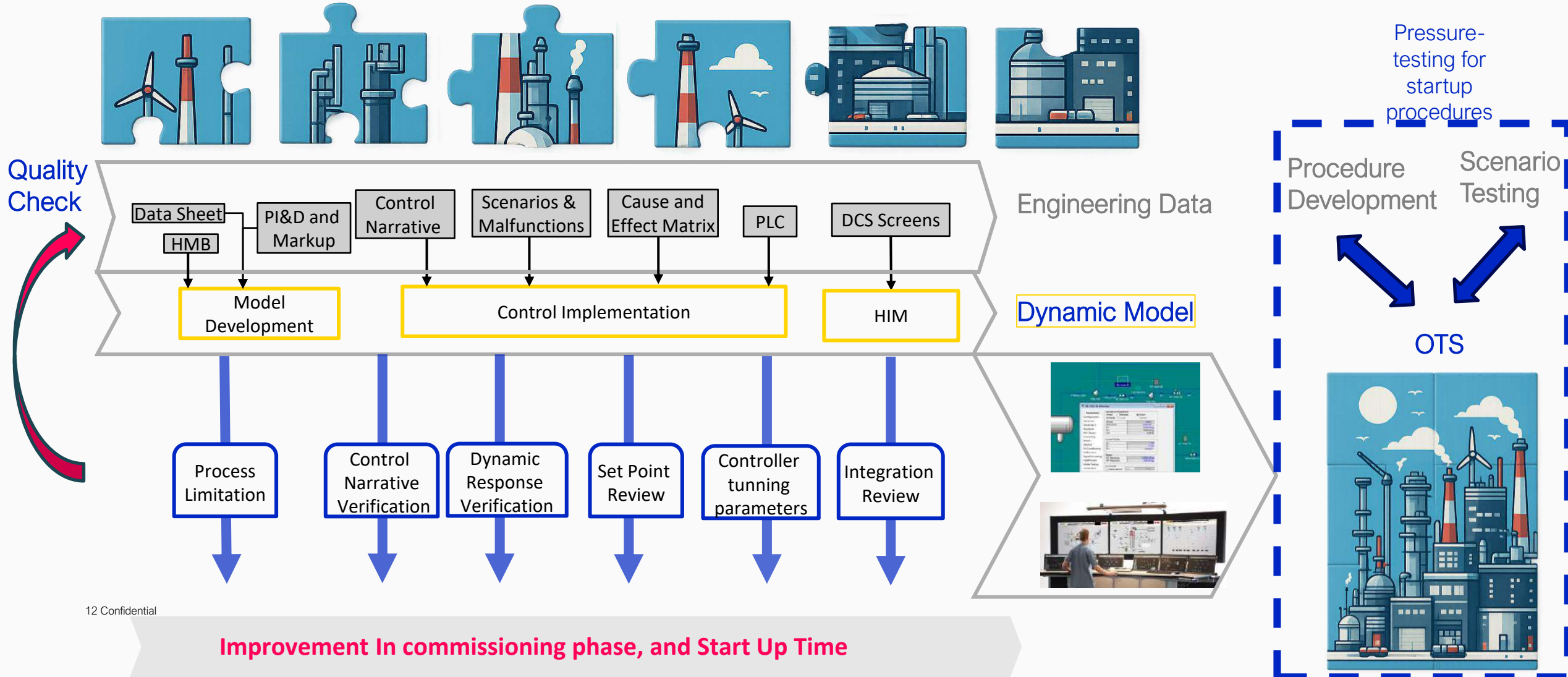
4. Isomerization



5. Water Gas Shift



# How the Dynamic Model was used



# OTS

## Training Scenarios

Equipment and Analyser Failure

SIS scenarios

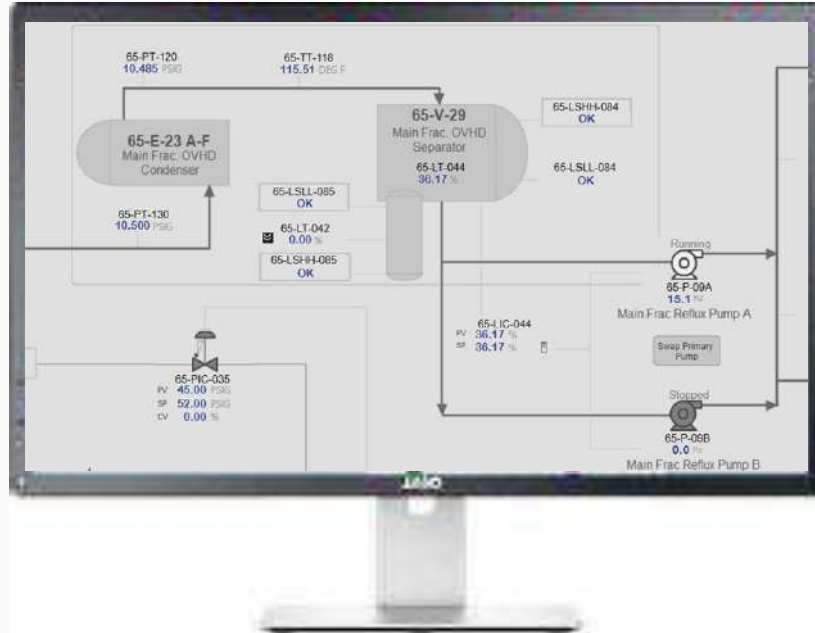
Changing in Load

Utilities Failure

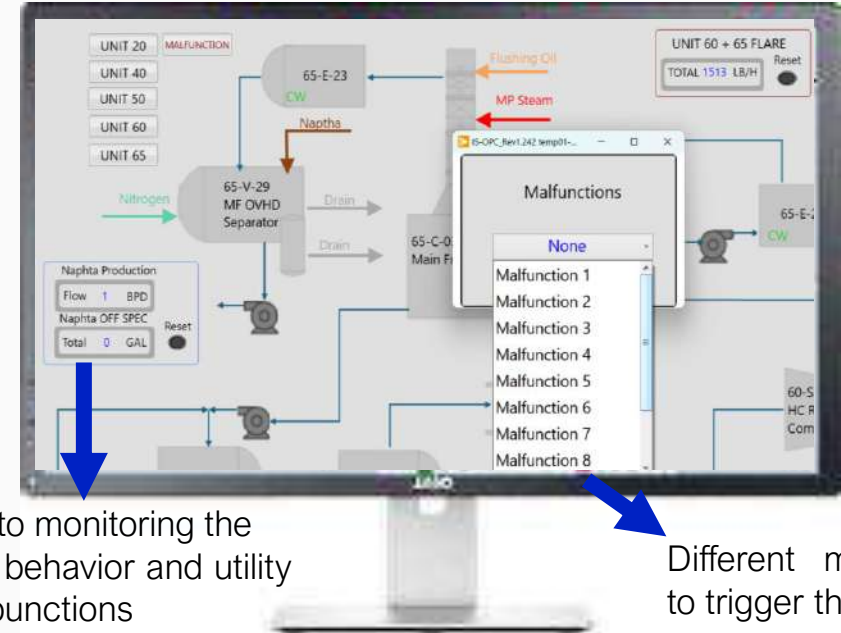
Shut down

Start Up

## Operator Station: DCS HMI



## Instructor Station



KPIs to monitoring the plant behavior and utility compunctions

Different malfunctions to trigger the operator

## Results

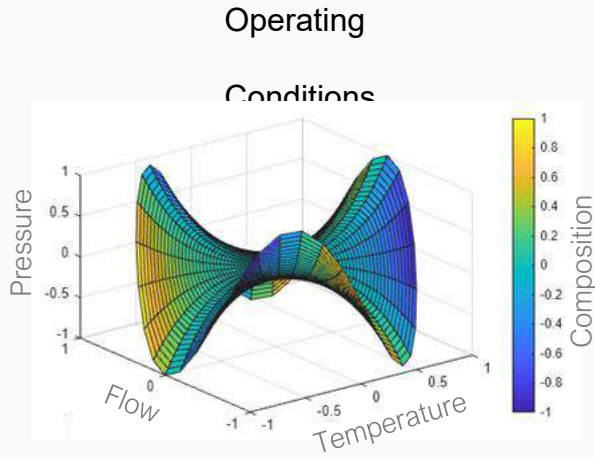
Operator Assessment



6 Operators trained  
 3 operators training at the same time  
 with Individual scenarios  
 8 weeks of Training

# Historical Link

HMB Conditions



Move the model to Different Condition



Working with CO Storage



Working at higher H<sub>2</sub>/CO ratio



Increasing the reactor recycle



Maximum Rate



Many Other scenarios.....



Explore Constrains of the process



Different Training Scenario



There are different operating conditions:

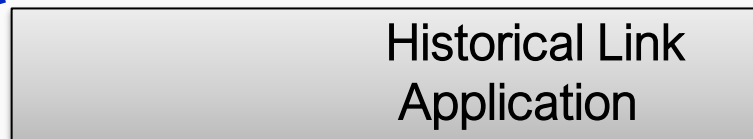
- Variations in CO concentration and flow (Due Sequences)
- Different operating conditions around the reactors
- Different production levels and rates of naphtha and jet fuel



Model Base



Inlet Data



Inlet Data Validation

Warnings about the process Constrains

Warnings about SIS

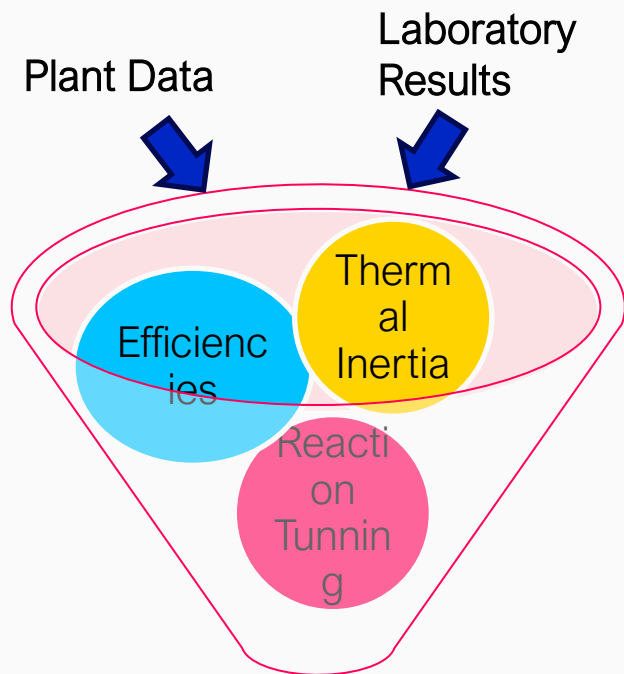


OTS snapshot ready to be use



Stable Model in current conditions

# Next Steps



Online KPIs used to:

- Predicts variables that are not measured online
- Acts as a virtual sensor for quality prediction
- Provides early warning of potential quality deviations
- Supports proactive operator actions before off-spec production

Current Model



ASPEN HYSYS Dynamics™ Model



Validation and More Realistic Model



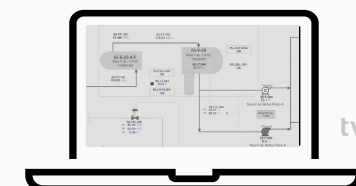
Online KPIs



Laboratory Data



Plant Data



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# Key value delivered

- 3 major control strategies identified with significant improvement opportunities during simulator-based testing
- System operated continuously for ~24 days before an intentional shutdown
- 0 unplanned shutdowns during extended run. Estimated cost avoidance of \$50k per avoided shutdown.
- Each unresolved control issue discovered at commercial startup typically drives days, not hours, of delay
- Resolving these major control challenges with simulator materially reduced startup uncertainty for first-of-a-kind commercial units
- Future data historian work will benefit schedule risk reduction at future scale where cost avoidances are exponentially higher

# Lessons learned

- Dynamic behavior must be understood early
- Integrated testing reduces operational risk
- Plantwide dynamics are where hidden risk lives
- Cross-unit interactions may drive many of the hardest scenarios
- OTS is as much an engineering tool as a training tool
- Digital readiness supports commercialization

For first-of-a-kind facilities, simulation helps close the gap between design intent and operational reality.

airplant™ one

