ADVANCED PROCESS MODELLING FORUM 2017
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ARRMO: new tools and approaches for Operational Excellence in Refining

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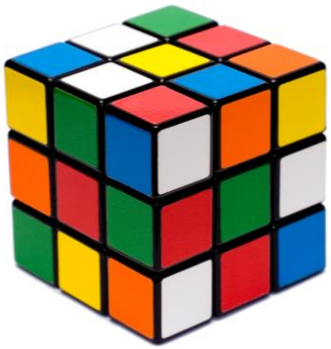
gPROMS

OUTLINE

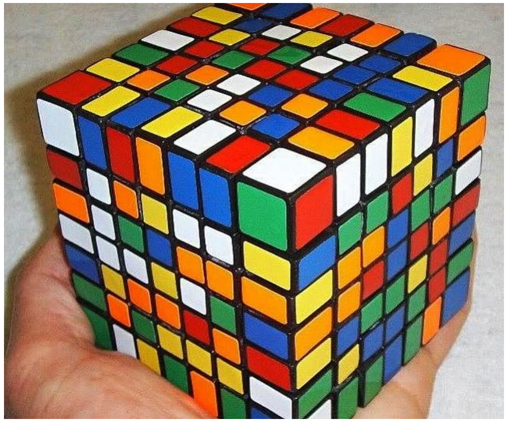
- Refining challenges and operational excellence
- Why APM and why now ?
- ARRMO project recap
- New gPROMS model library: Refining
- Modelling systems : Reactors, Distillation, HEN
- Modelling objectives: On-line applications, closed loop/advisory, focus
- Application example – fouling manager
- Conclusions

Refining challenges

- Increasing crude and feedstock variability
  - Evolving production techniques, new supply areas, enhanced oil recovery, transportation logistics
- Tightening environmental and product quality regulations
  - Air quality, CO2 emissions, VOCs
  - US EPA addressing refinery flaring directly from 2018
- Maintaining high equipment reliability
  - Minimising fouling, corrosion, integrity, risk



We thought it was bad –
it was actually worse !



Introduction to operational excellence

- What is operational excellence ?

  Focus is **Sustainable** Improvement

Why APM and why now?

- Success and observations with ARRMO & others
- The state of the 'State of the Art'
  - Computational complexity has pushed others to look at, for example

Short-cut models

Neural networks

Statistical data models

Artificial intelligence

Pseudo-steady-state models

- But now, APM capabilities are accelerating

Improved DAE solvers

Better initialisations

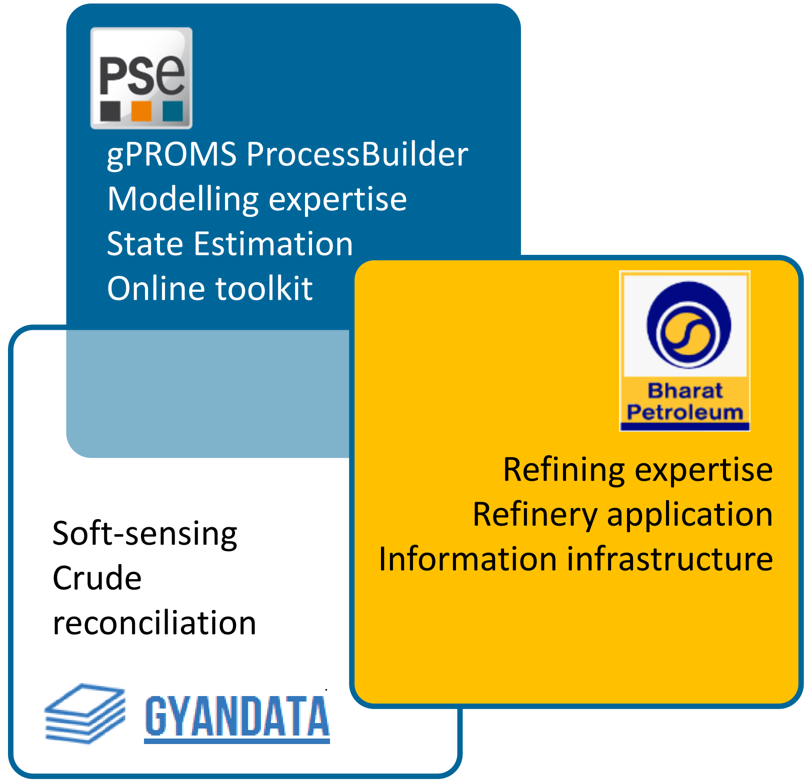
Parallel-isation

Convergence time reducing

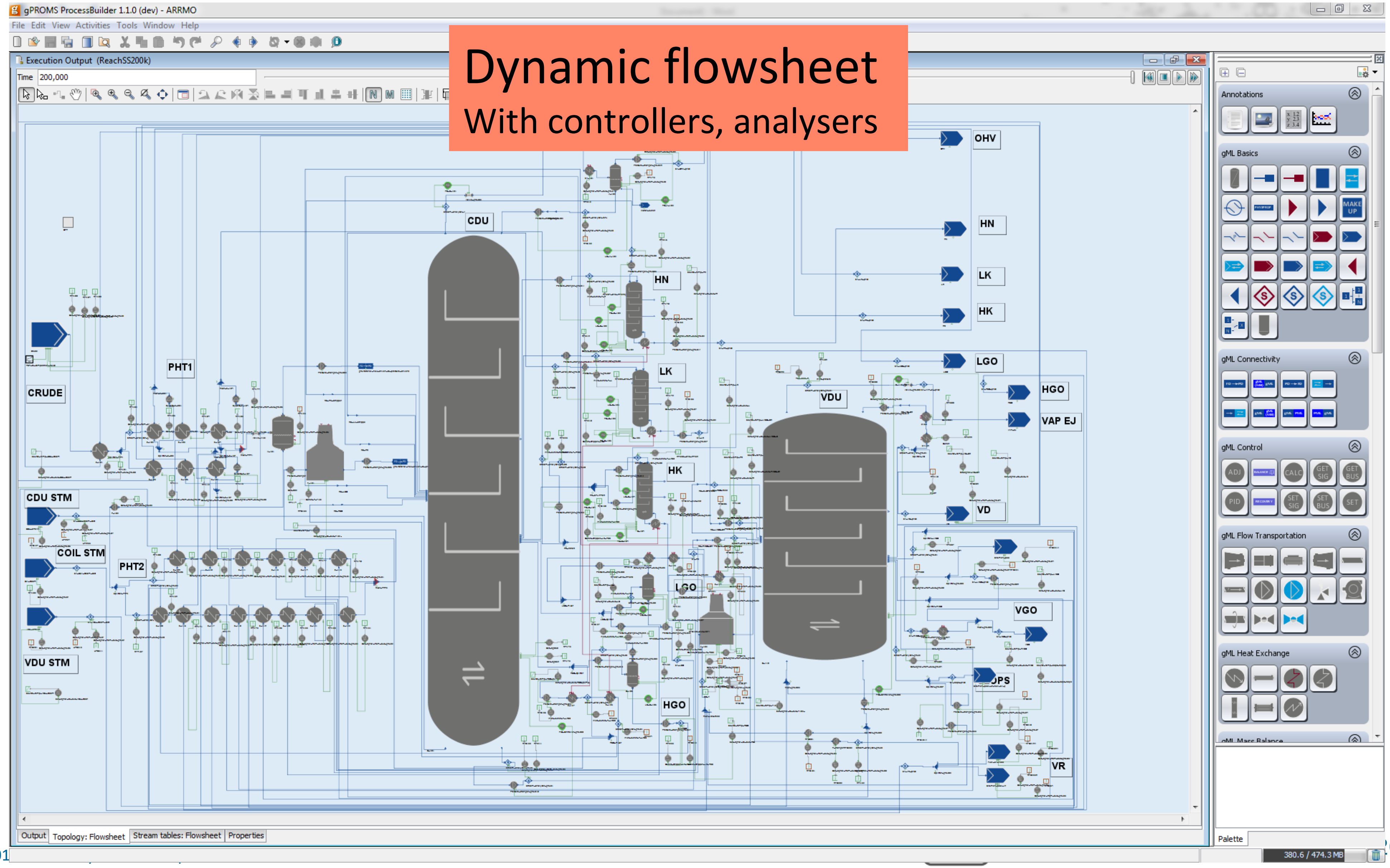
Improved robustness

ARRMO project recap

- Objective: develop an on-line application which will maximise profit during the switch from one crude to another – real-time dynamic optimisation



ARRMO project recap

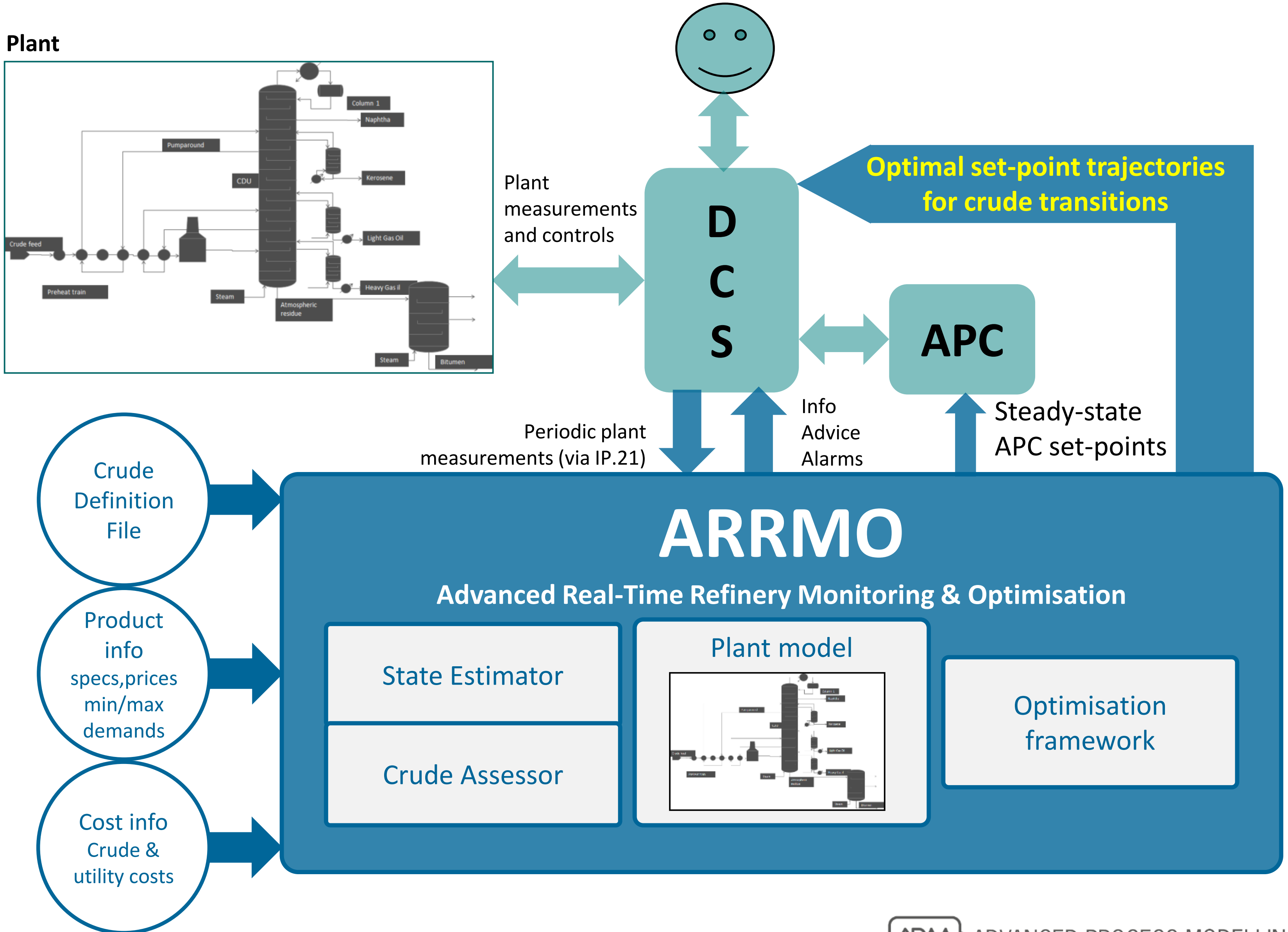


Dynamic flowsheet

With controllers, analysers

Advanced Real-time Refinery Monitoring & Optimisation

Integration within refinery infrastructure



ARRMO project recap

- Product revenues
  - Economics very much favour HN and HK v LK and HGO
- Costs
  - Steam increased, fuel gas decreased
- **Overall increase in profit of $79.5K / day identified**

ARRMO's PSE Team:
Charles Brand
Maria Viseu

Overall

		% change
Product revenue	▲	1.29
Utility costs	▲	0.07
Crude costs		0.00

Product revenue – CDU

Revenue		% change	% total
OHV	▲	3.47	17.22
HN	▲	20.00	3.90
LK	▼	-20.00	3.18
HK	▲	19.72	11.72
LGO	▼	-6.00	17.07
HGO	▼	-40.00	1.80

Product revenue – VDU

Revenue		% change	% total
VAP-EJ	▼	-30.04	0.23
VD	▲	18.05	5.04
VGO	▲	12.71	24.64
Slops	▼	-71.43	0.05
VR	▼	-12.32	15.15

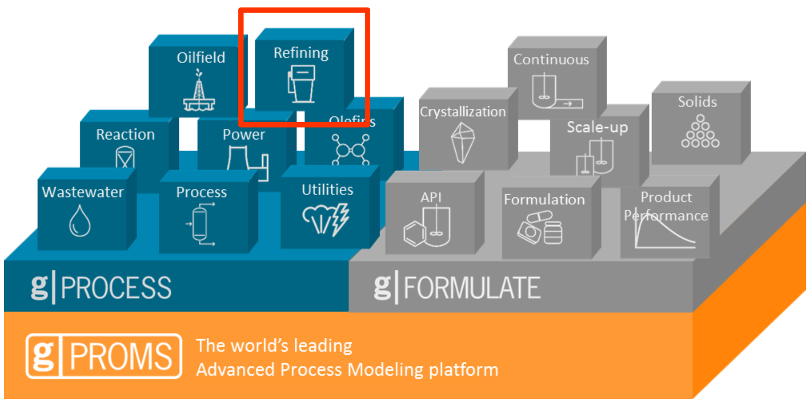
Costs

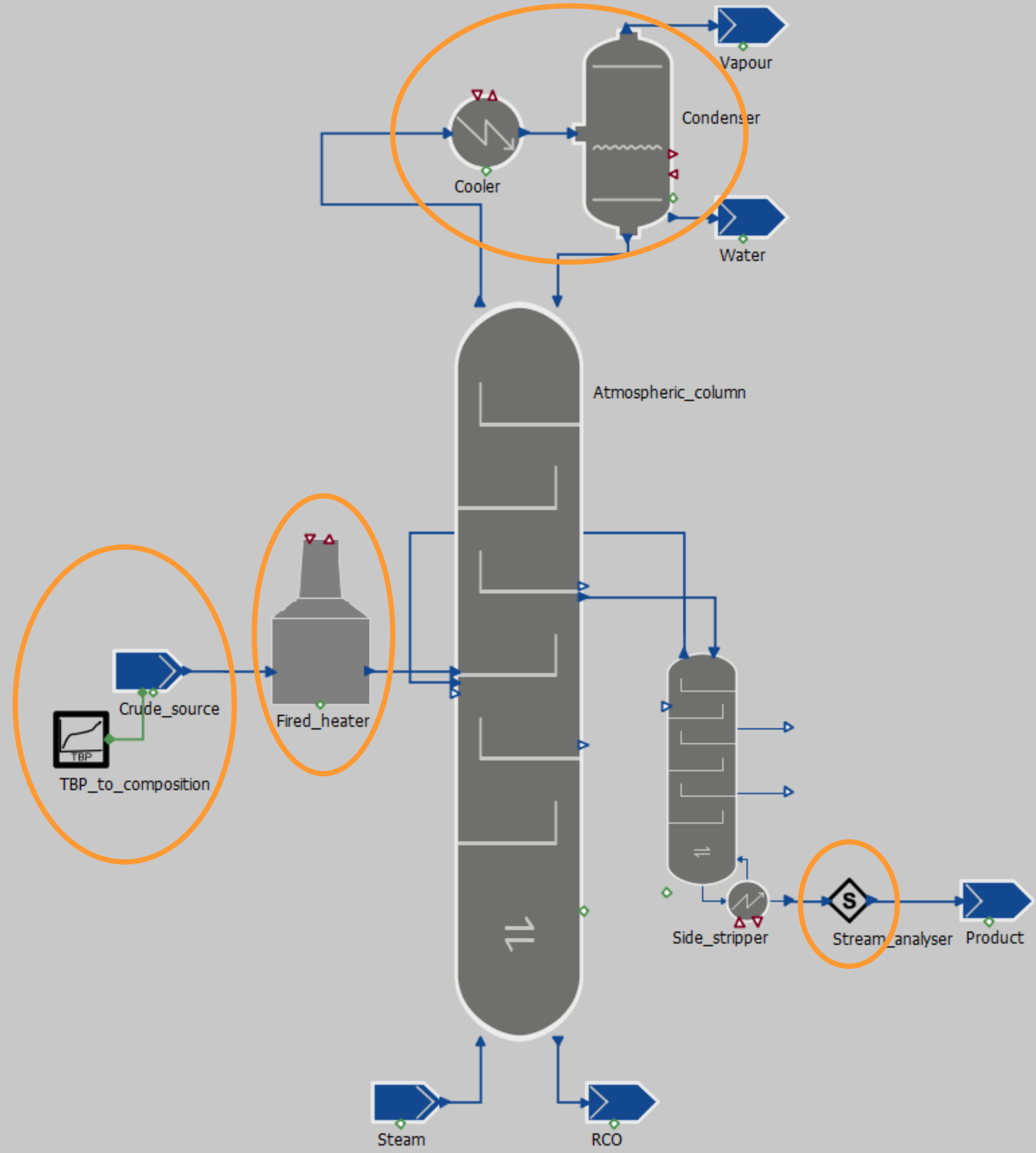
Cost		% change
Steam	▲	17.05
Fuel gas	▼	-2.48

New gPROMS model library: Refining

NB. Most units required for CDU/VDU modelling already covered by existing ProcessBuilder libraries

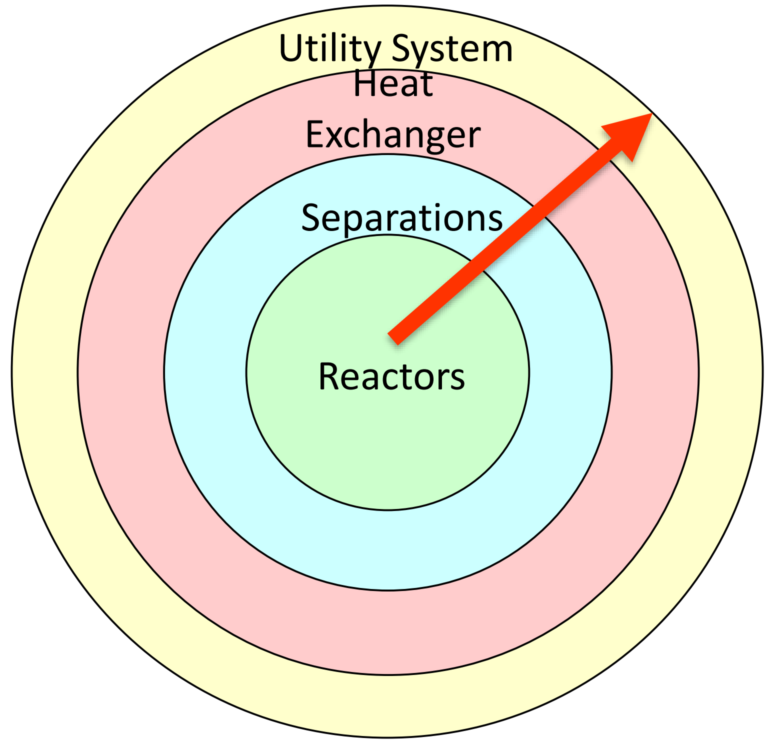
- Crude feed source
- Fired heater
- Product analyser
  - Distillation curves
    - TBP, ASTM D86-D1160
  - Properties
    - Watson characterisation factor
    - Flash point, Freeze point
    - Pour point, Aniline point
    - Smoke point, Cloud point
    - Cetane index, RVP





Modelling systems – reactors

- Start with reactors:
  - Fluid catalytic cracking (FCC)
  - Hydrotreating
  - Hydrocracking
  - Catalytic reforming
  - Alkylation

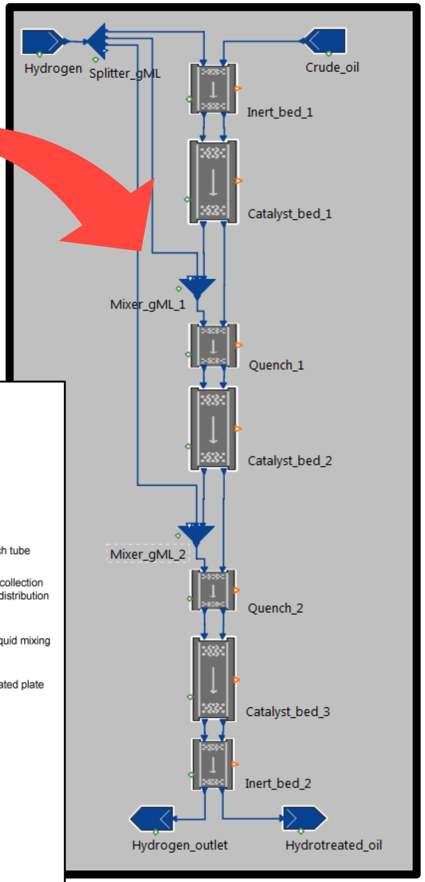


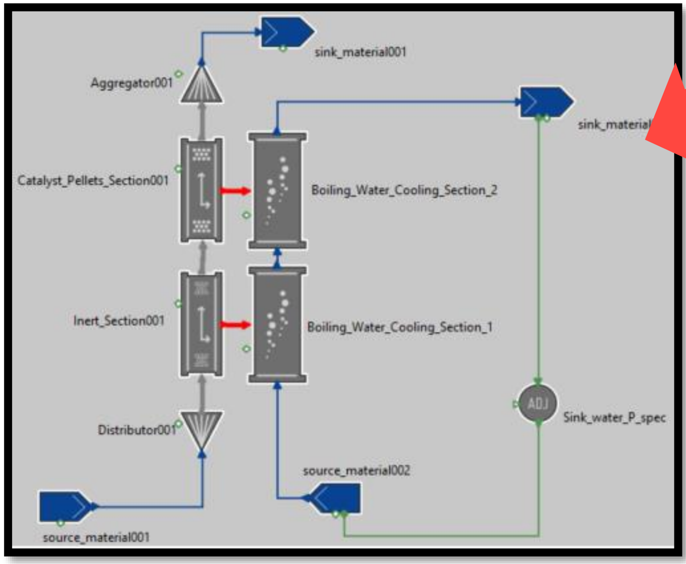
Design priority

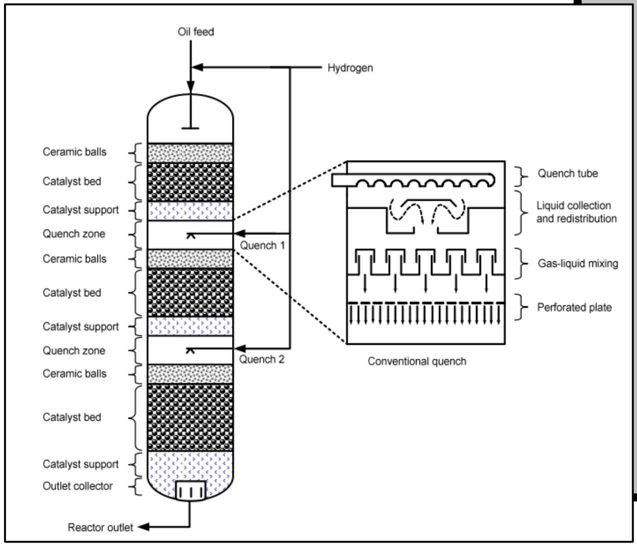
Modelling systems - reactors

New/improved models in gPROMS ProcessBuilder 1.2.0

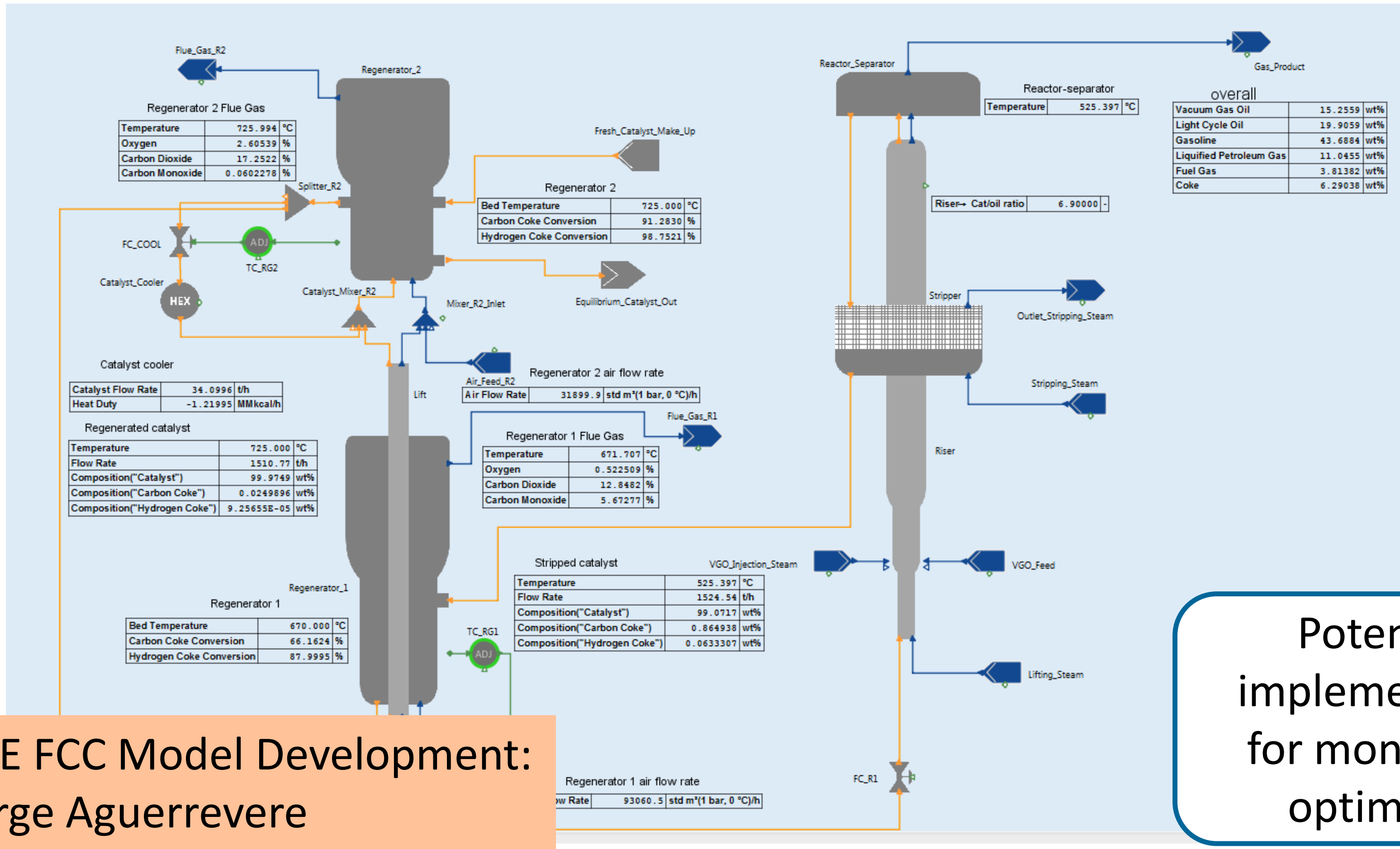
- New trickle bed reactor AML:TBR - hydrotreating
- Fixed-bed catalytic reactor AML:FBCR – reforming







- Other models in development: Fluidised bed reactor

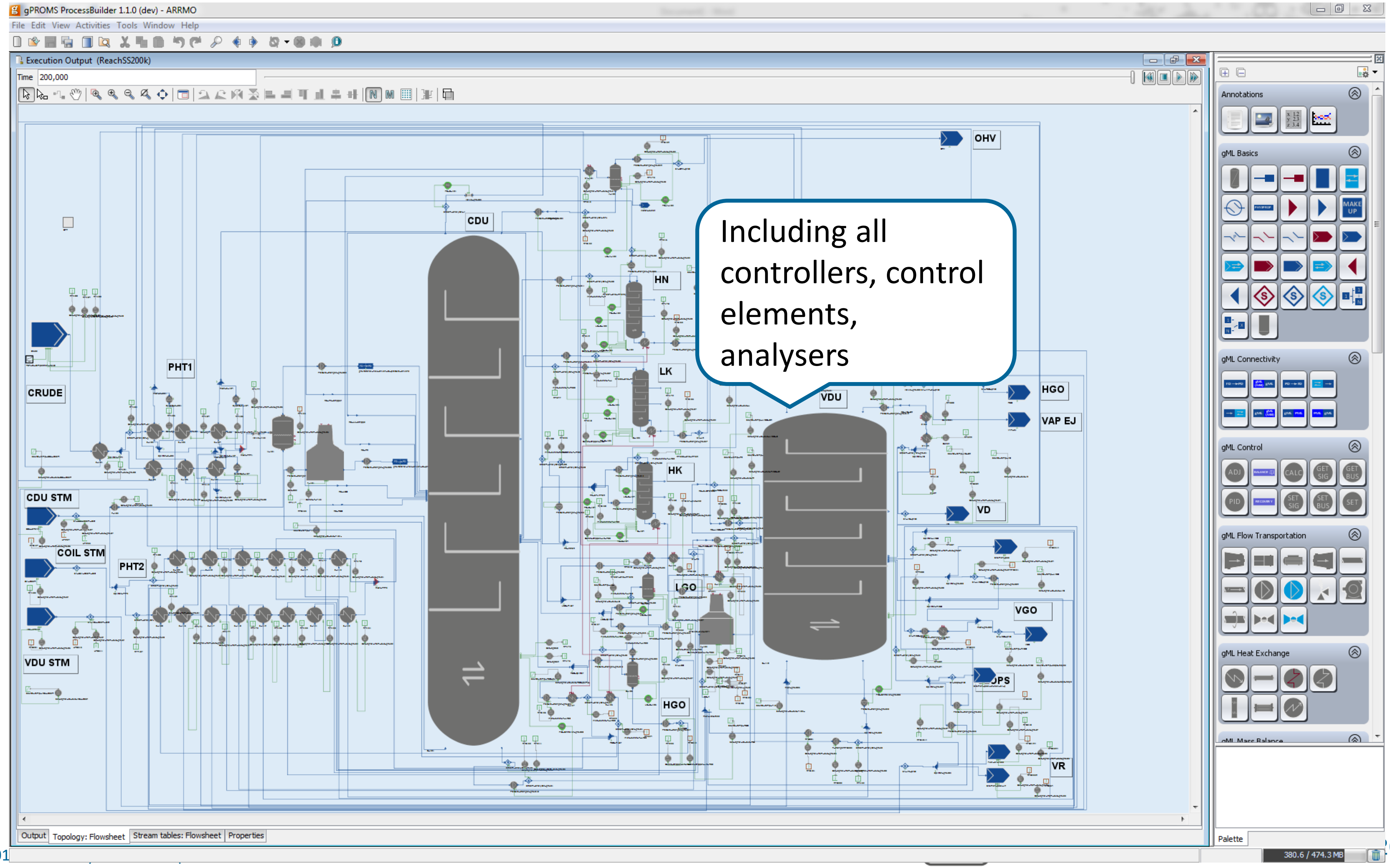


PSE FCC Model Development:
Jorge Aguerrevere

Potential to implement online for monitoring & optimisation

Flowsheet configuration from *Nonlinear Modelling of Industrial Fluid Catalytic Cracking Processes for Model-Based Control and Optimization Studies*

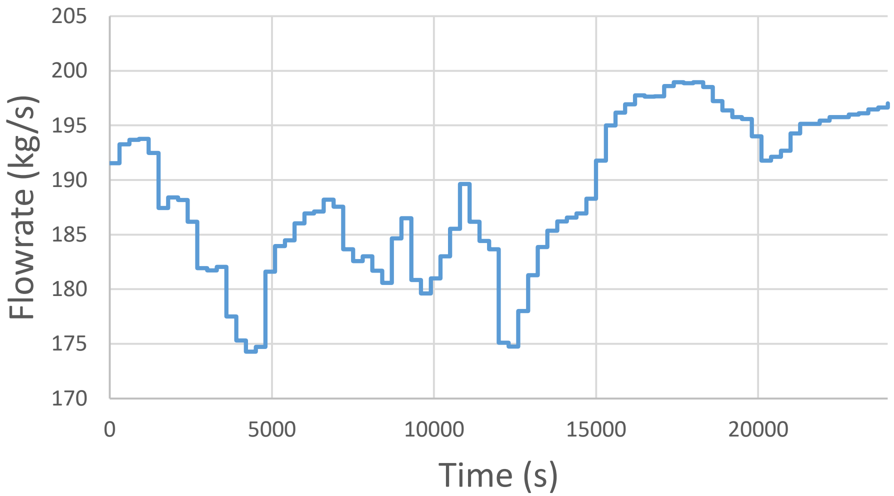
Modelling systems – distillation – back to ARRMO



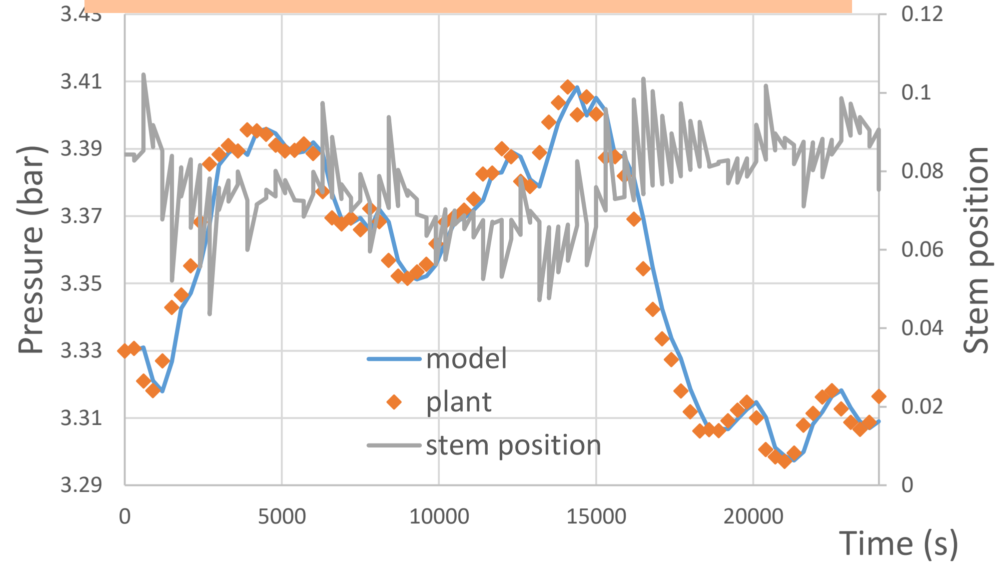
Modelling systems – distillation, dynamic simulation & Validation against plant data

PSE

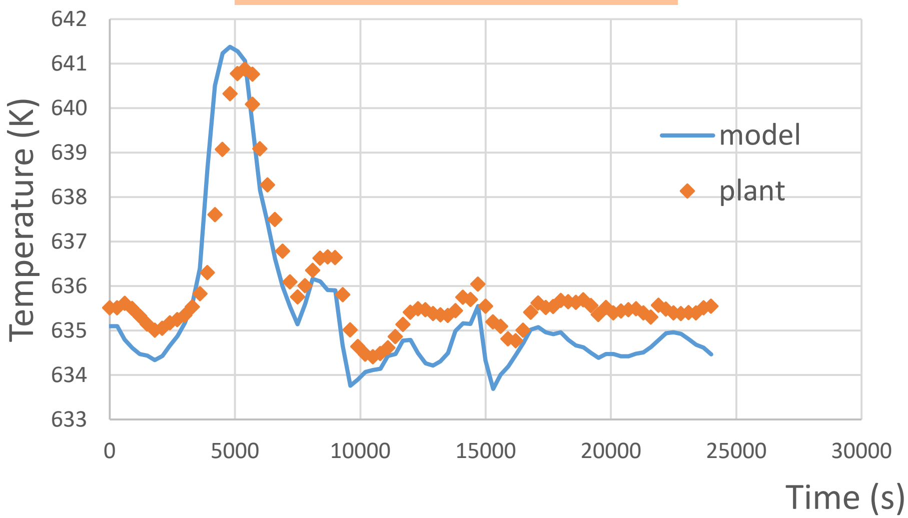
Main Crude Feed Flowrate



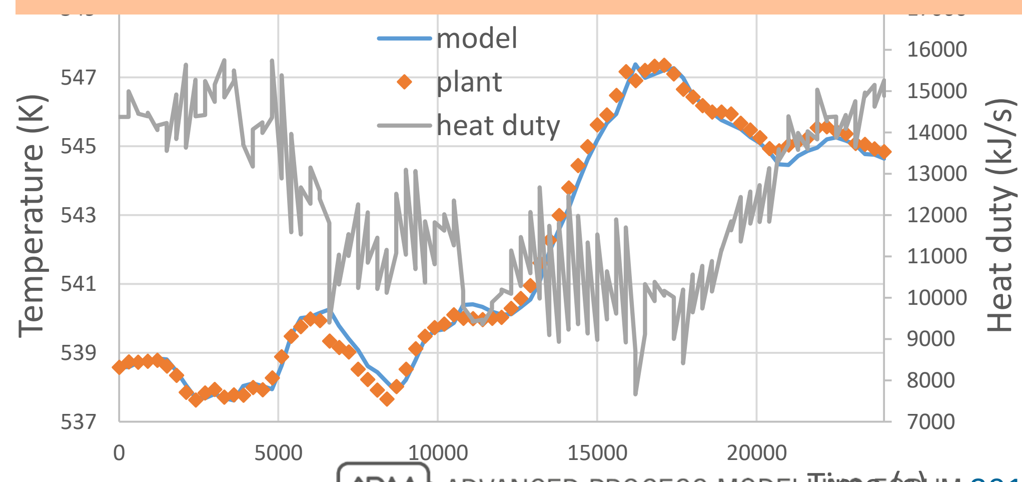
ATM Column Condenser Pressure



ATM Column Btms



Kerosene Side Column Reboiler Temperature



Application: Heat exchanger fouling

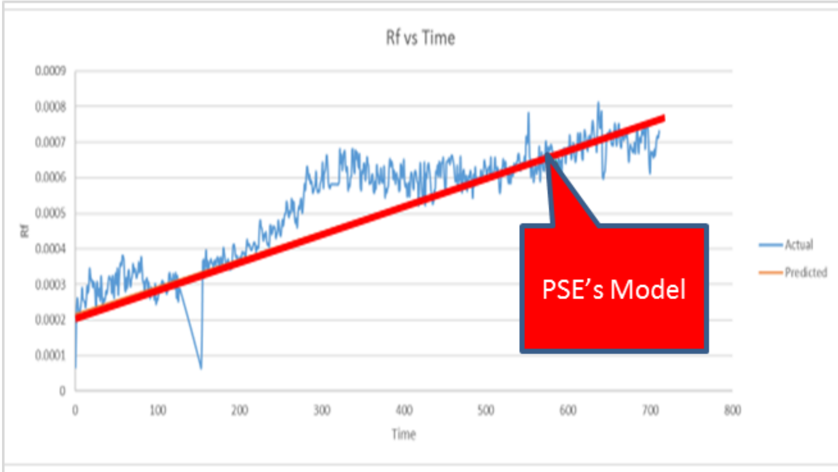
Basic Chemical Reaction Fouling Model – Ebert and Panchal:

$$\frac{dR_f}{dt} = \alpha Re^{\beta} Pr^{-0.33} \exp\left(\frac{-E}{RT_f}\right) - \gamma\tau_w$$

Fouling rate

Chemical Reaction (Deposition) Promotes fouling

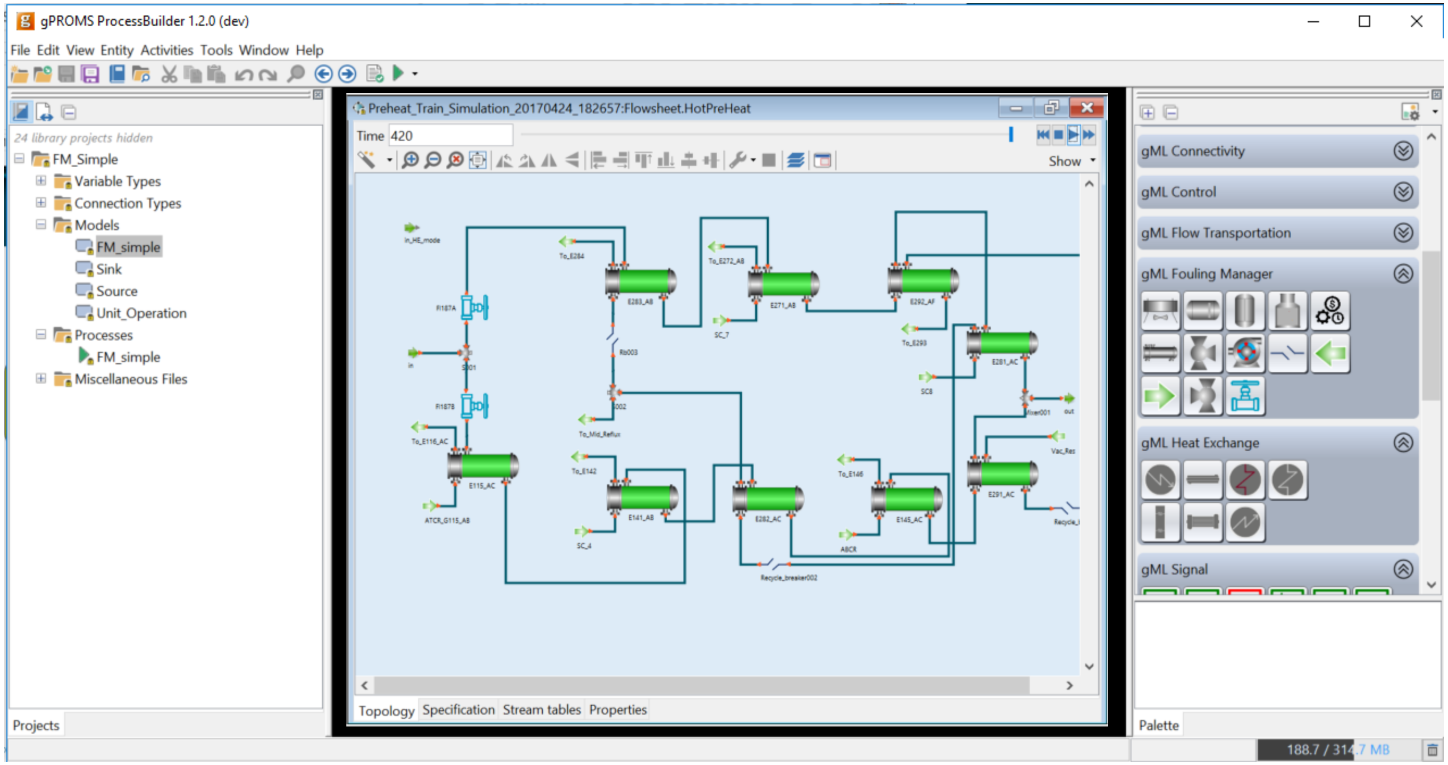
Wall Shear (Anti-deposition) Mitigates fouling



- Use parameter estimation for α, β, E, γ (modified E&P equation)
- Use several years plant data
- Recent project: CDU HEN temperatures – average deviation 0.15%, Standard deviation 1%

Modelling systems – heat exchanger networks

Heat exchanger fouling management

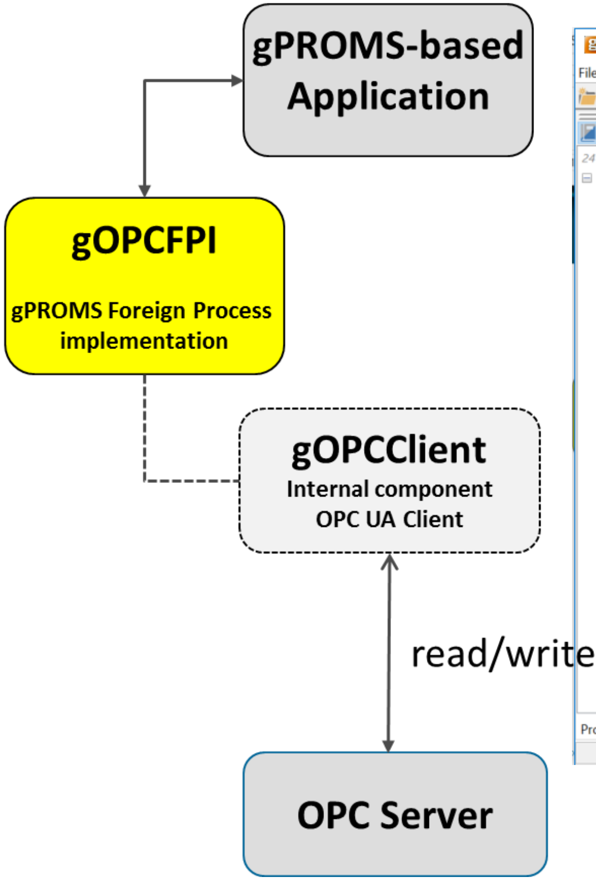


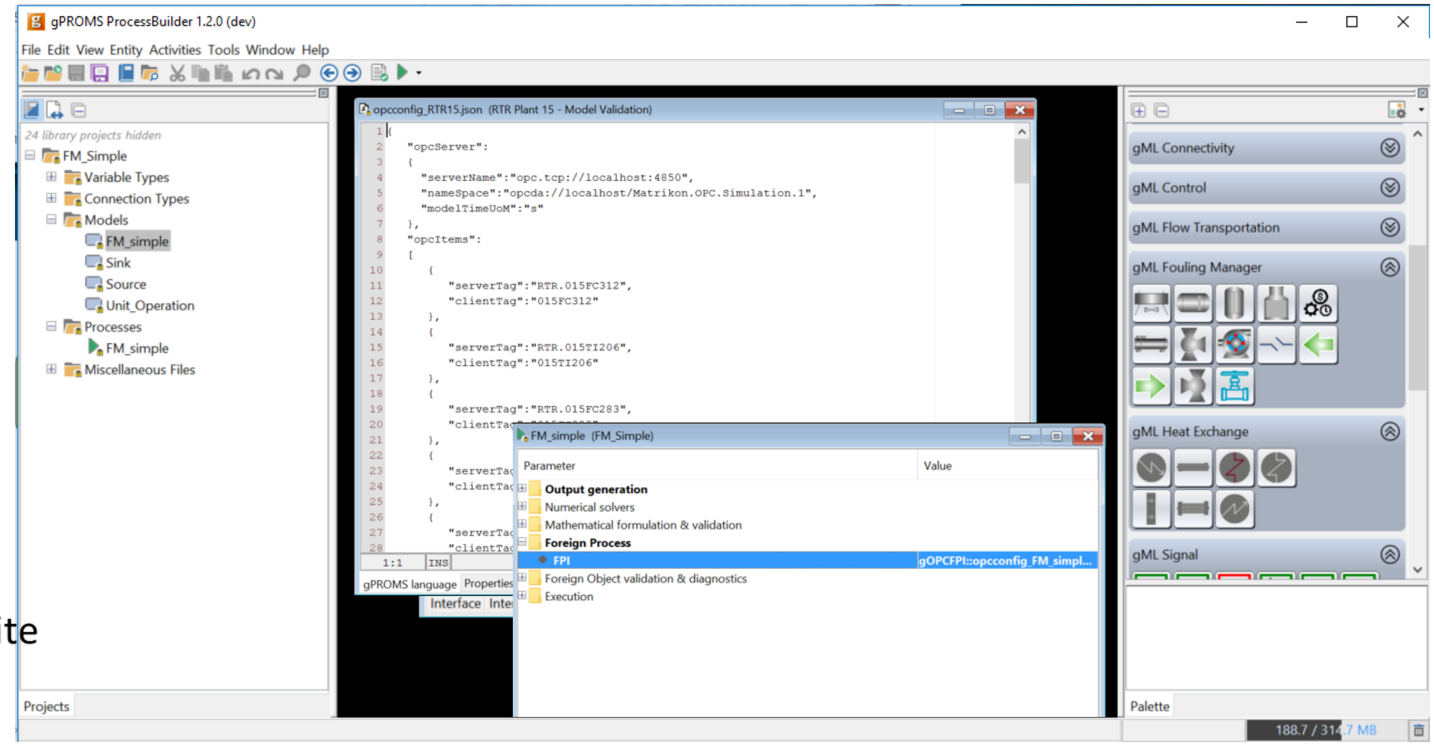
Determine: HEN state at any point in future

What HXs to clean and when

Modelling objectives – online applications

- OPC client – gOPC within gPROMS ProcessBuilder



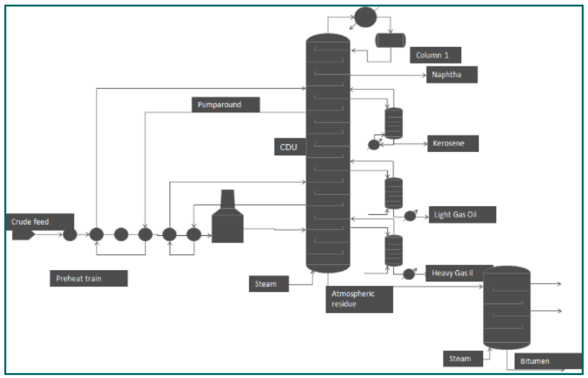


PSE OPC developer:
Trung Huynh-Quoc

Modelling objectives – closed loop/advisory

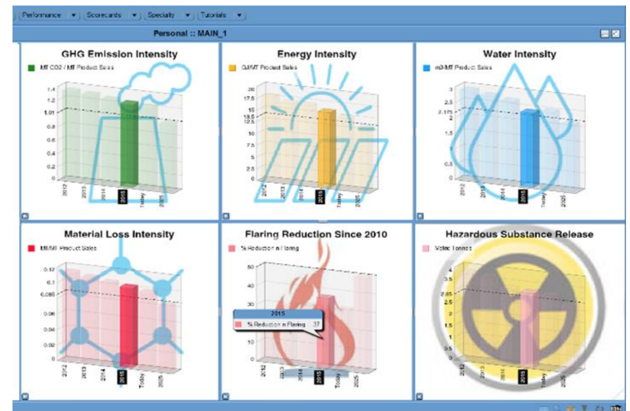
- Closed loop (nothing to see) to advisory (visualisation needed))

Plant



Plant measurements and controls

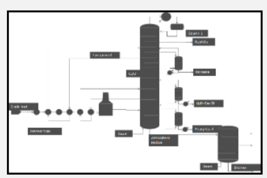
Dashboard



DCS & Historian

Real-Time Monitoring & Optimisation

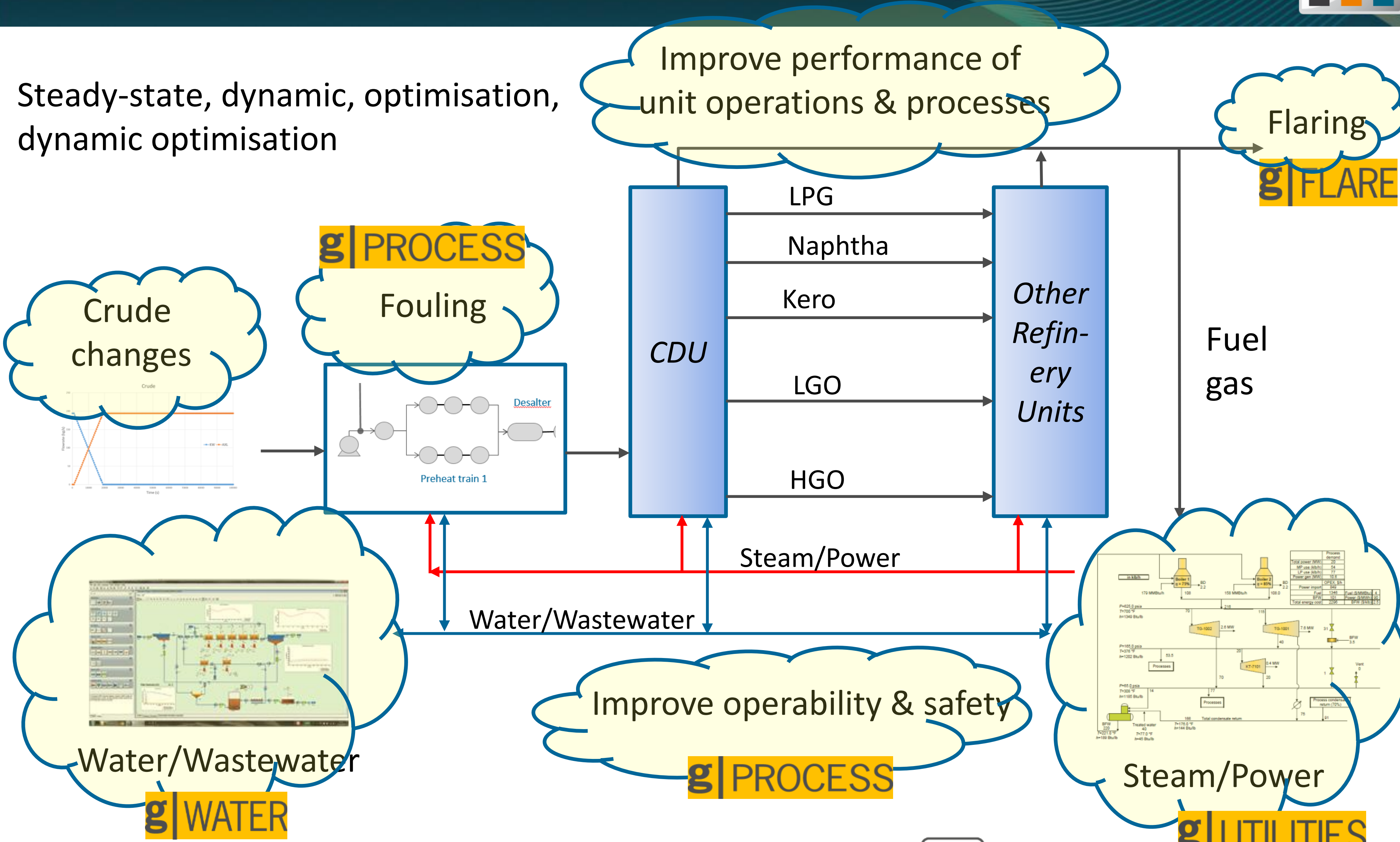
Plant model



Optimisation framework

Modelling objectives : focus

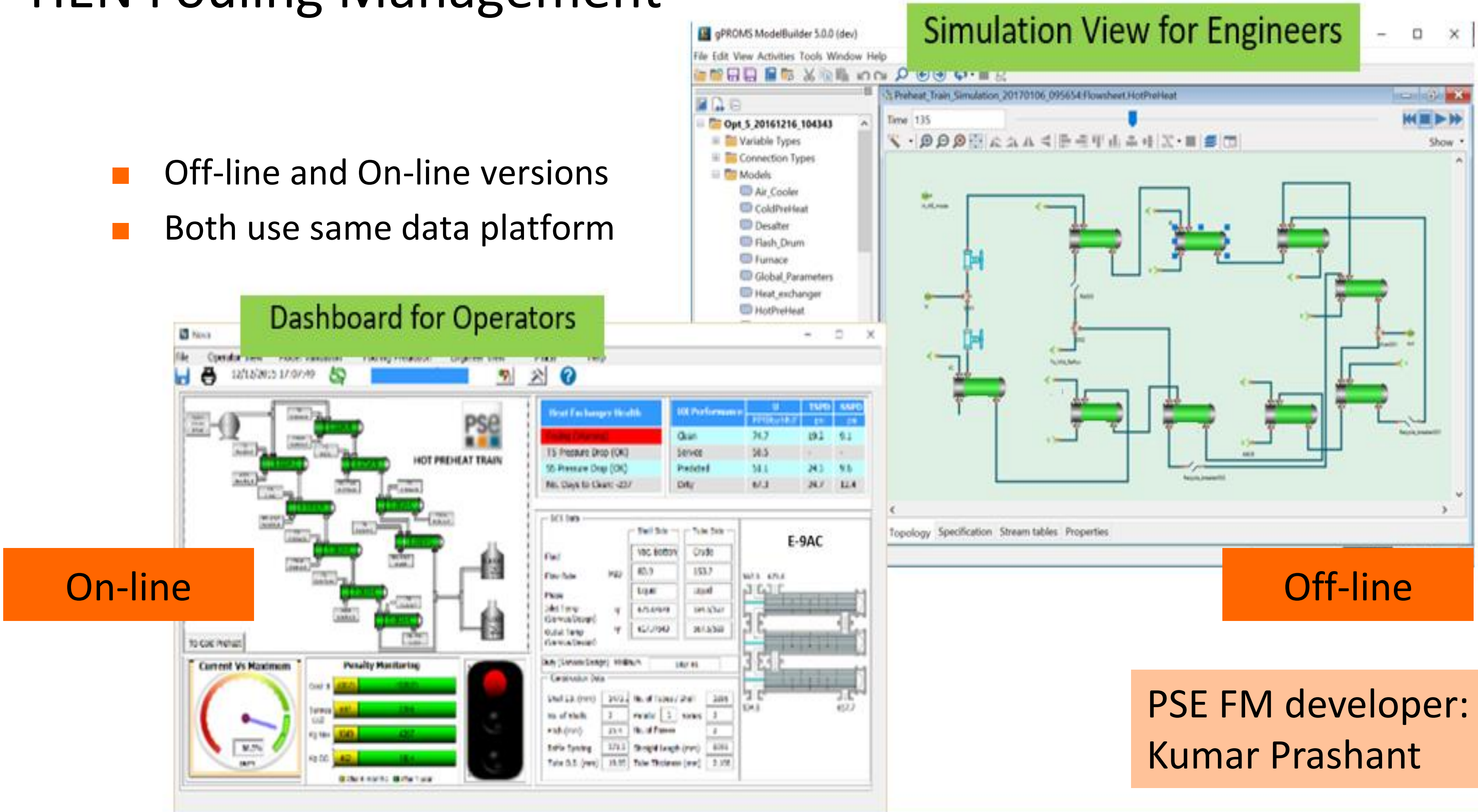
Steady-state, dynamic, optimisation, dynamic optimisation



Application example - fouling management

HEN Fouling Management

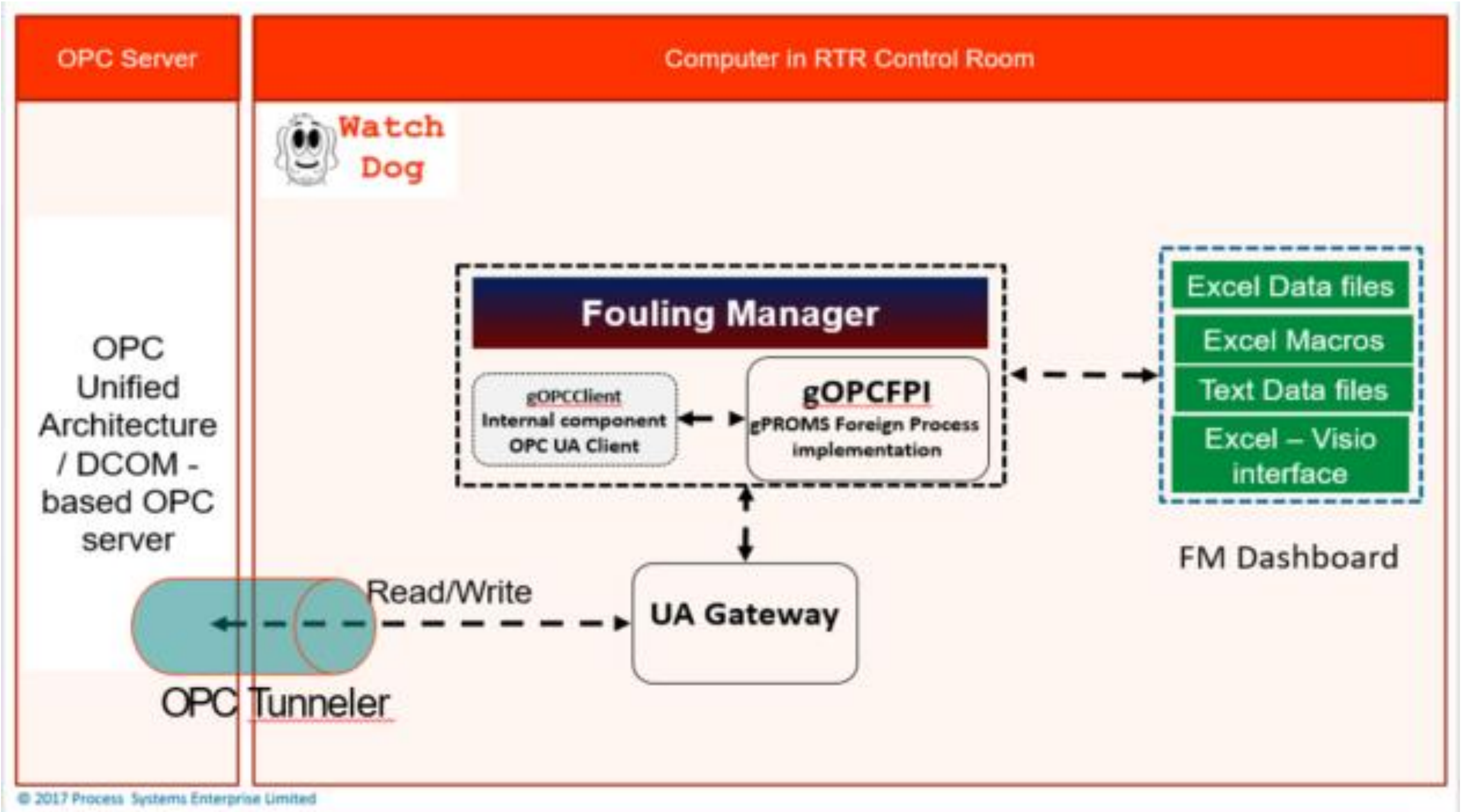
- Off-line and On-line versions
- Both use same data platform



PSE FM developer:
Kumar Prashant

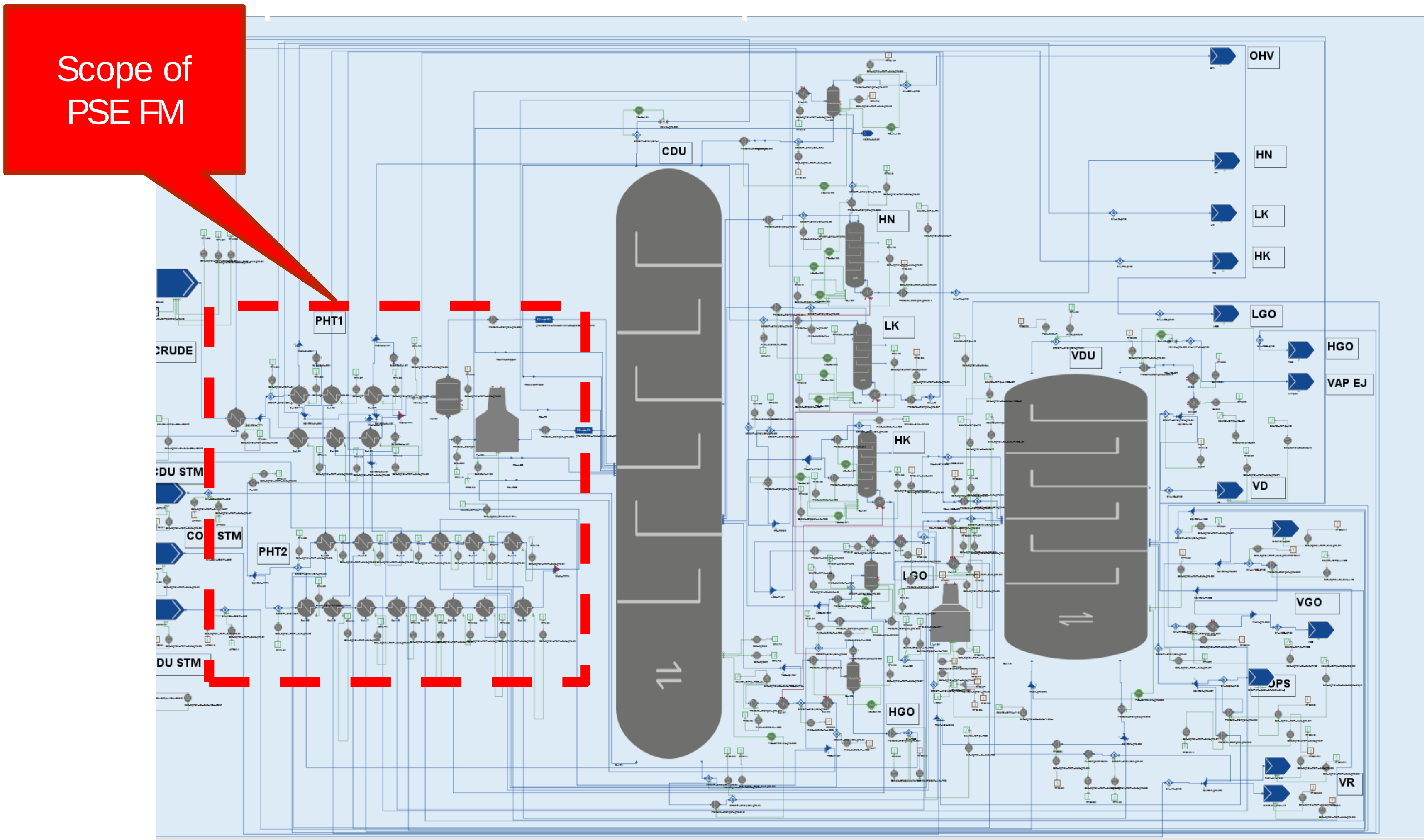
Application example – fouling manager

- FM communicates with a Data Access (DA) Client via OPC



- FM on or off-line always has the latest plant data

Application example – fouling manager - scope



Video of Fouling Manager application

Let’s recap on the refining challenges

- Increasing crude and feedstock variability
  - Evolving production techniques, new supply areas, enhanced oil recovery, transportation logistics
- Tightening environmental and product quality regulations
  - Air quality, [illegible]2 emissions, VOCs
  - US EPA addressing refinery flaring directly from 2018
- Maintaining high equipment reliability
  - Minimising fouling, corrosion, integrity, risk

Conclusions

- APM is addressing refining challenges with next-generation technologies
- Moving towards on-line models
- gPROMS ProcessBuilder environment provides a very flexible and powerful solution framework
- With new capabilities in problem formulation, solvers and hardware are making it easier
- Operational Excellence requires a closer link between APM and Dashboard technologies