Automate engineering processes at scale

Hybrid Digital Twin for monitoring and tuning gas treatment unit

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Bruno Trebucq, CGI France
bruno.trebucq@cgi.com

Laurent CHEC, Datadvance SAS
laurent.chec@pseven.io

CGI Innovation Center Industry 4.0 in Toulouse

An immersive journey structured around 8 key issues

01 Real time monitoring — splunk> OSIsoft.

02 Data Continuity — SAP MarkLogic RFgen

03 Augmented Worker — CGI UBLEAM

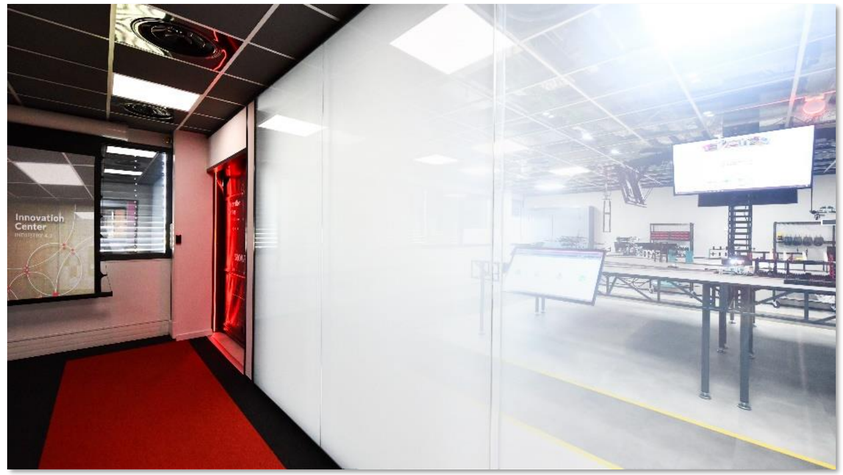
04 Robotic Process Automation — UiPath

05 Process Mining — celonis

06 Digital Twin — SAYpartners

07 Computer vision — ThinkDeep

08 Cybersecurity — CGI



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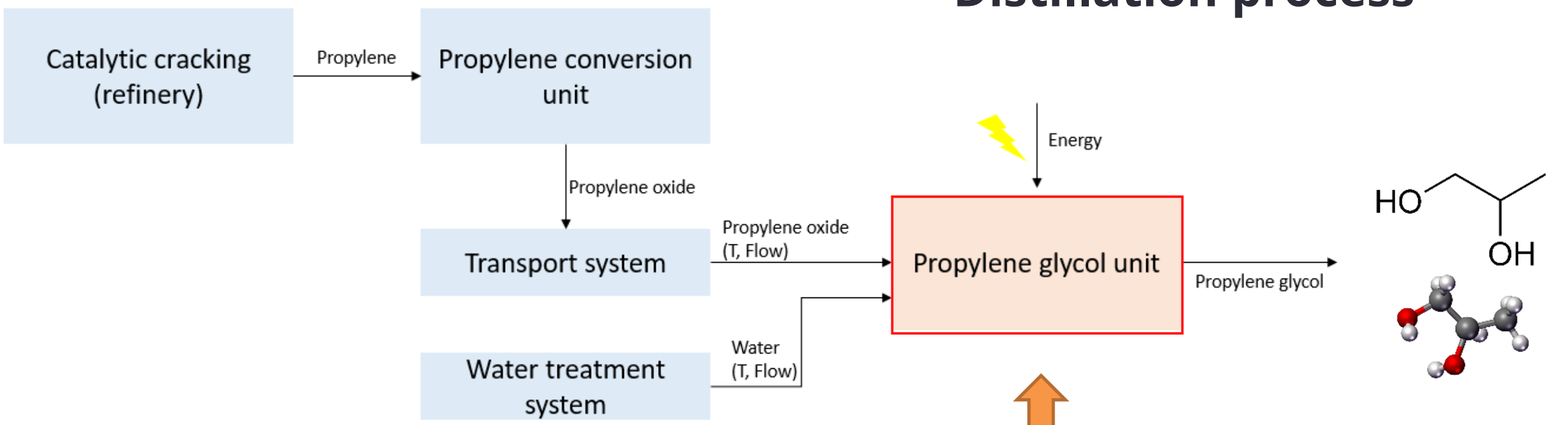
Ideation — Experiment — Industrialization

CGI Innovation Center demonstrator

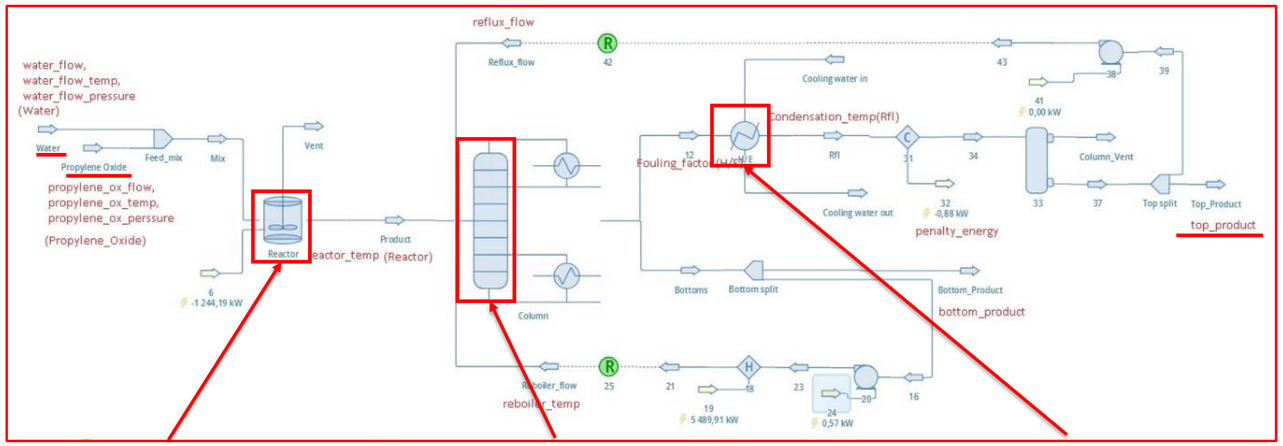
On-line monitoring of production unit

on-line monitoring of production unit

Distillation process



pSeven Enterprise **Digital Twin**



- Reactor – to mix and process the initial mixture.
- Column – to distillate water from key product (propylene glycol)
- Heat exchanger – to condensate the gas fraction from the column and partially return to column (reflux flow) for deeper separation.

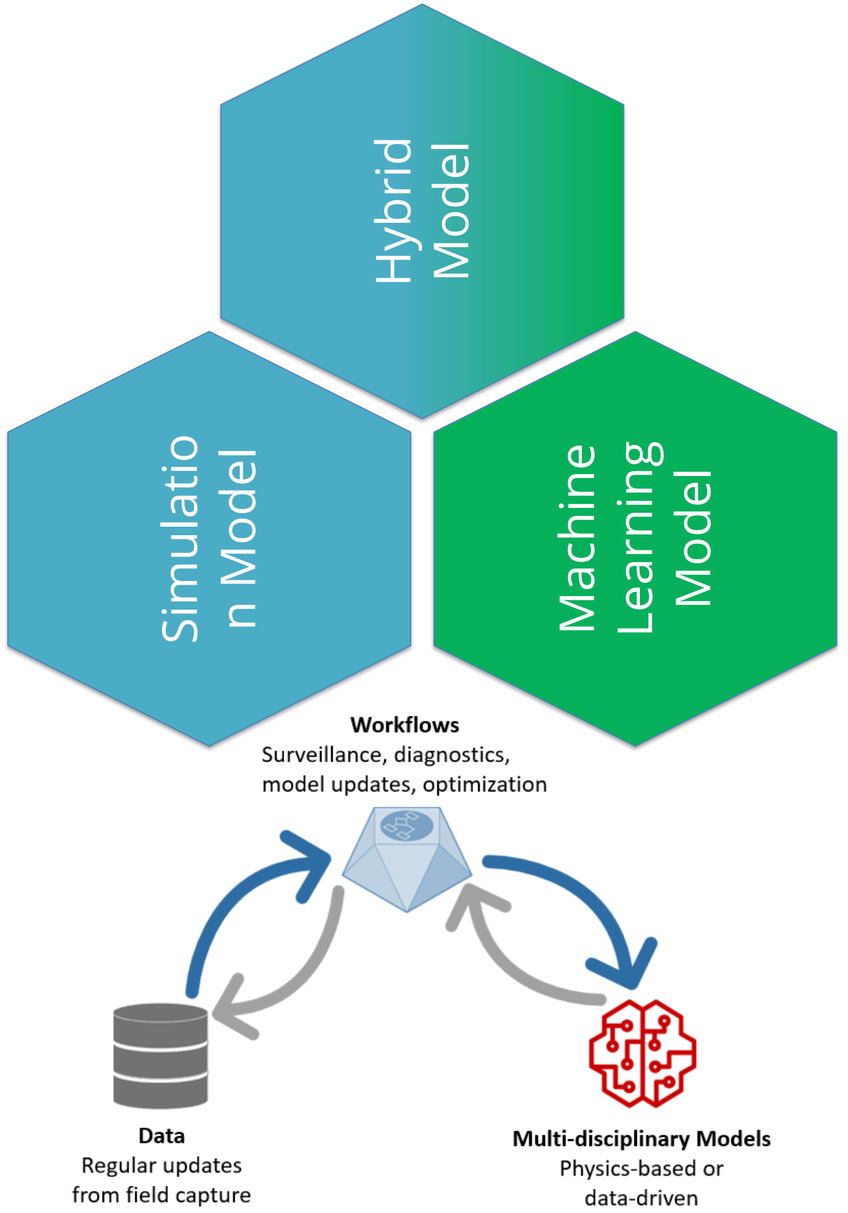
Monitor
- Detect anomalies (fooling)
- Use virtual sensor (fooling factor)

Maximize profit
- Optimize production asset settings
- Reduce energy consumption

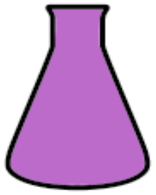
Control maintenance costs
- Decide when to trigger maintenance operation
- Reduce down time

Hybrid Digital Twins

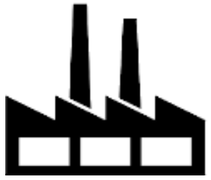
- Hybrid digital twin combines the benefits of simulation and machine learning.
- Simulation models can be used directly (or exported from specialized software, for example in FMU/FMI format).
- Adaptation of simulation models to real operational data without the involvement of engineers to manually fine-tune simulation models. ML models embedded into simulation models.
- Building models using machine learning methods based on operational data and/or synthetic data obtained from simulation models.
- Re-training of ML models is carried out constantly, allowing you to give relevant recommendations when changing operating modes.



Hybrid digital Twins



Lab Data



Process Data

Business data

Feed and Products qualities

Process data from the field

Feed and Product cost

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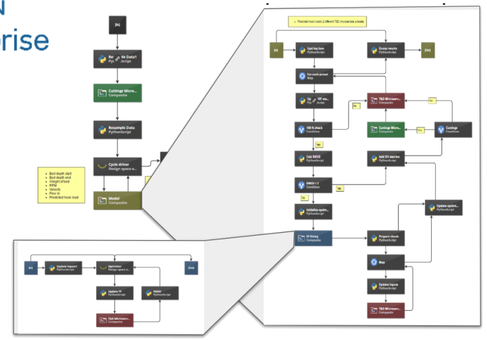
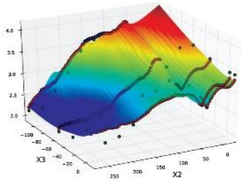


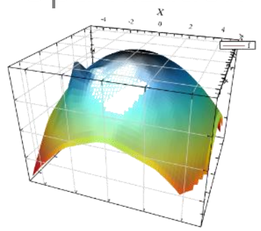
Low-code environment to create, deploy and manage Digital Twins at Scale

Predictive Modeling



Effect estimation

Optimization

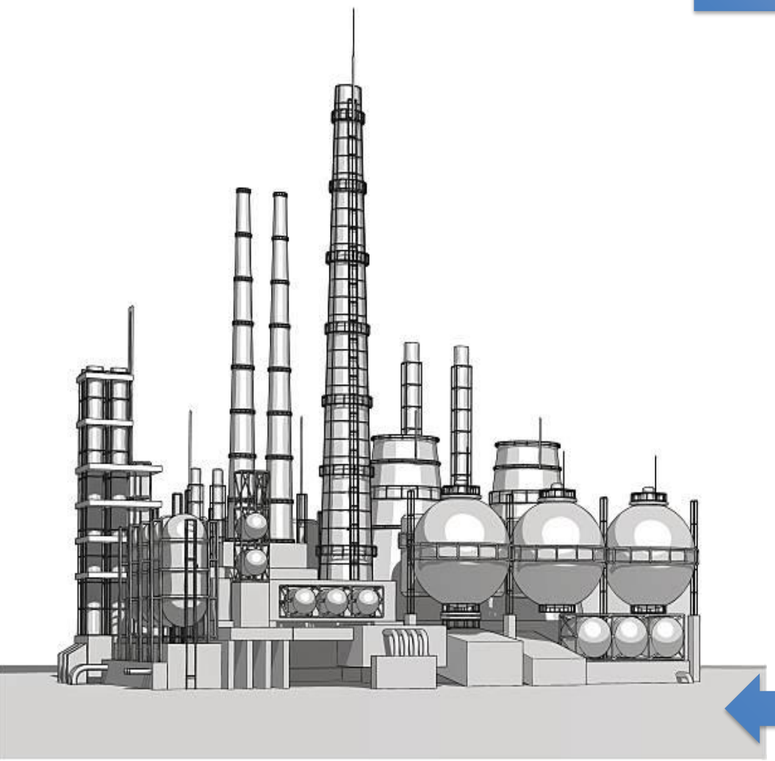


Decision Making

Petro-SIM

Process & Chemical Modeling SW

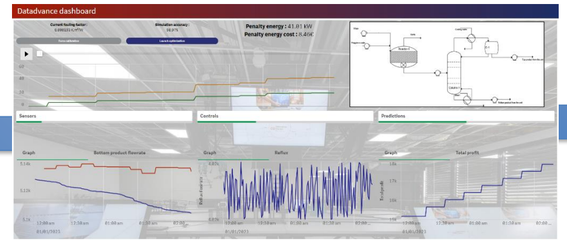
Building Hybrid Digital Twins



Telemetry data

TIME	Q1	Q2	Q3	Q4	X	Y	Z
10:58:51	-0.775506	0.451796	-0.431151	0.092625	-0.008350	0.031246	0.048060
10:59:51	-0.218972	0.800993	-0.551323	0.080649	0.000562	-0.000396	0.002956
11:00:51	-0.209406	0.802330	-0.549578	0.101878	0.000110	-0.000117	0.000048
11:01:54	-0.209518	0.804907	-0.545130	0.105169	0.000717	0.000156	-0.000647
11:02:54	-0.210605	0.801599	-0.550194	0.101838	0.000130	-0.000080	0.000033
11:03:56	-0.211824	0.801596	-0.549643	0.102305	0.000011	0.000216	-0.000190
11:04:56	-0.210696	0.800860	-0.551182	0.102125	0.000087	0.000042	-0.000018
11:05:56	-0.210882	0.800777	-0.551268	0.101926	0.000031	0.000016	-0.000050
11:06:56	-0.211182	0.800579	-0.551430	0.101980	0.000149	0.000080	0.000033
11:07:56	-0.211328	0.800571	-0.551364	0.102101	0.000147	-0.000235	0.000191
11:08:56	-0.211150	0.800743	-0.551232	0.101833	-0.000098	0.000155	0.000025
11:09:56	-0.211046	0.800647	-0.551360	0.102107	0.000025	-0.000089	0.000095
11:10:56	-0.211360	0.800523	-0.551463	0.101875	0.000015	0.000042	0.000050
11:11:56	-0.211435	0.800452	-0.551498	0.102084	-0.000019	-0.000171	0.000104
11:12:56	-0.211487	0.800628	-0.551240	0.101992	0.000015	0.000056	0.000081

Planning
&
Scheduling



Actions

Predictions &
Recommendations

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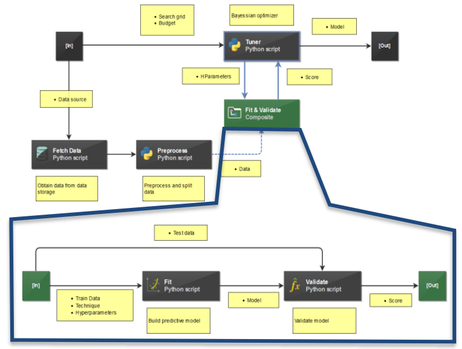
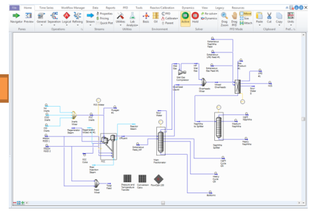
Hybrid Sim/ML models



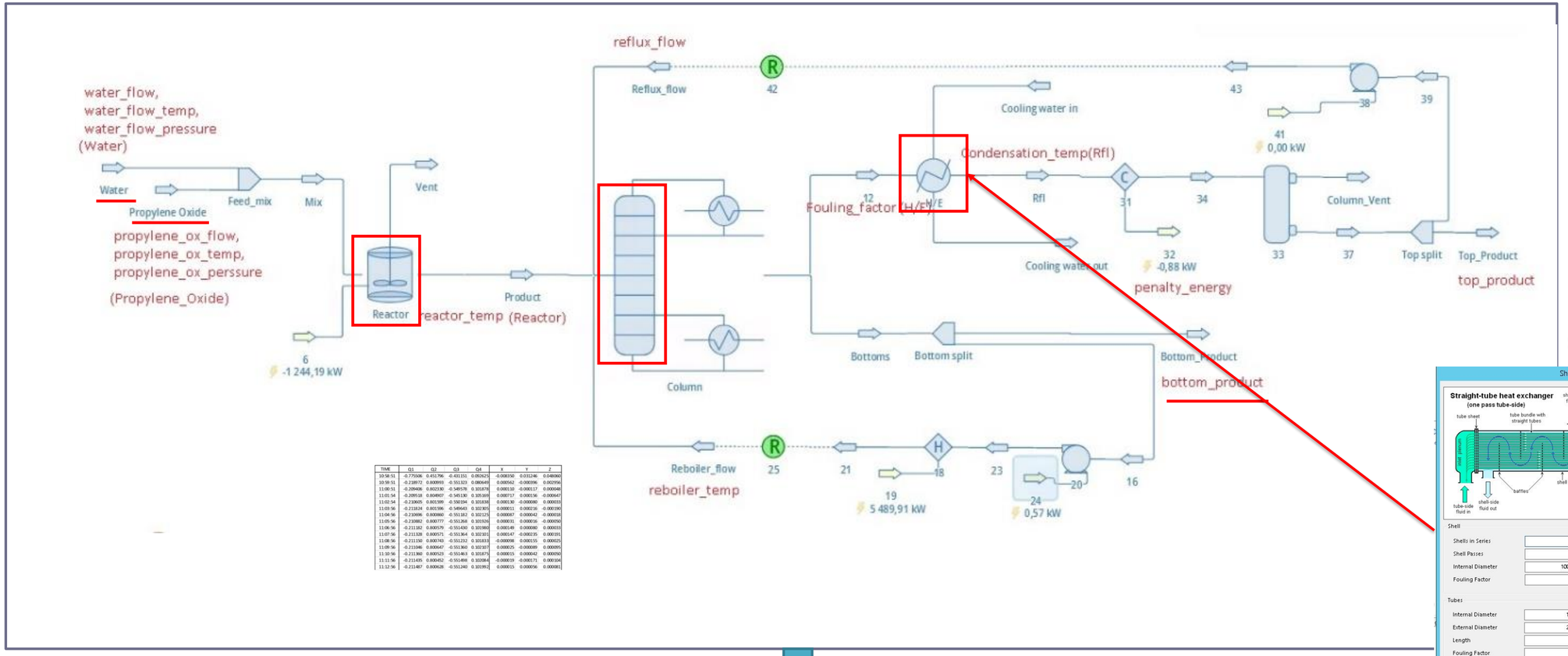
Workflows to:

- Connect/Integrate data between platforms and tools
- Perform Simulation models,
  Data-based ML models
- Do approximation and optimization tasks as a service

Sim model



CGI Innovation Center demonstrator: **on-line monitoring of** production unit



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11:03:56	-0.218324	0.801596	-0.549643	0.102305	0.000011	0.000216	-0.000190
11:04:56	-0.218086	0.800990	-0.551182	0.102125	0.000087	0.000042	-0.000018
11:05:56	-0.218862	0.800777	-0.551268	0.101926	0.000031	0.000016	-0.000090
11:06:56	-0.211182	0.800579	-0.551430	0.101960	0.000149	0.000080	0.000033
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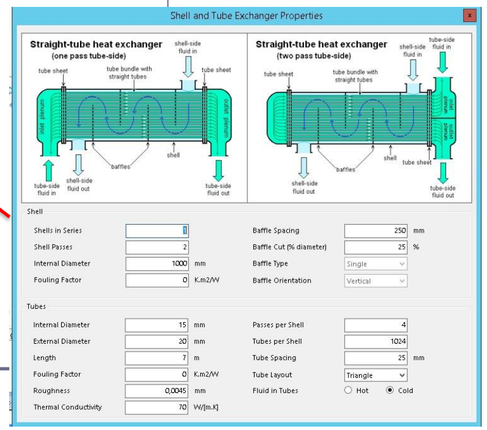
Heat exchanger unit subject to clogging!



Clogging = performance degradation.
More energy required to maintain quality

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Data streamed

Measured VS predicted

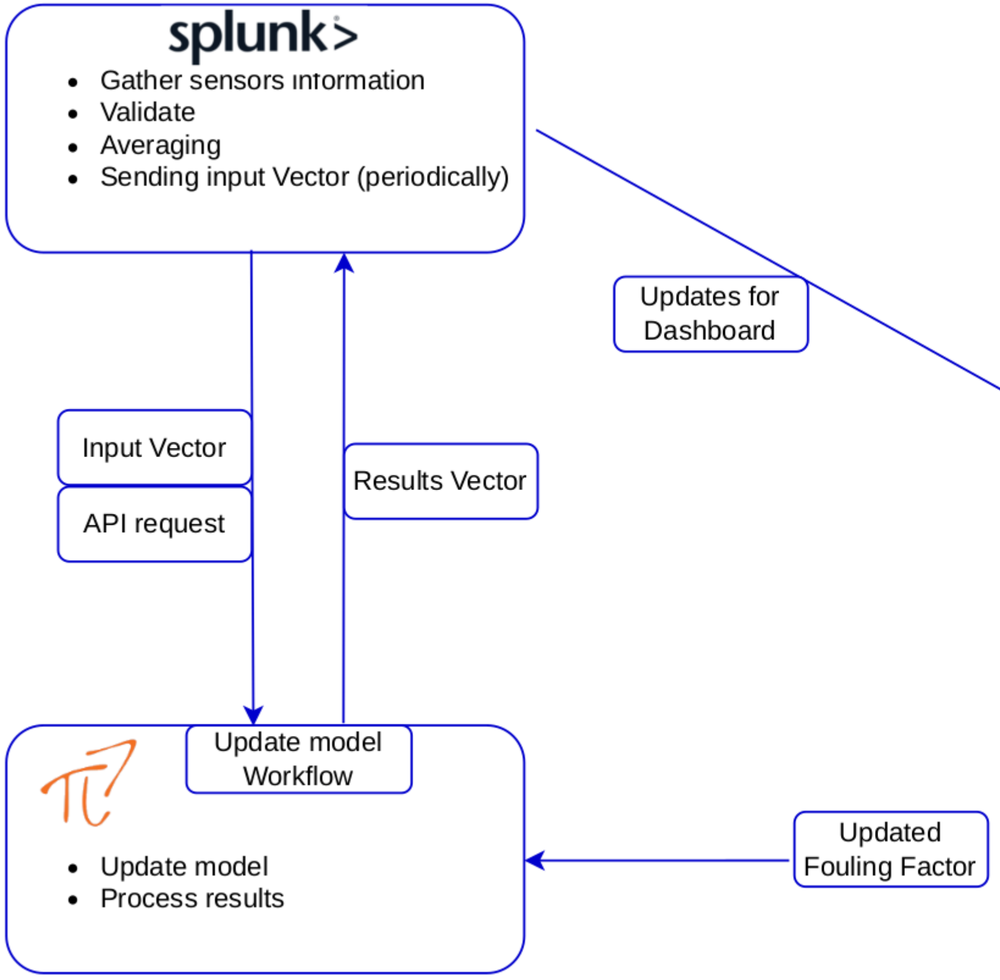
		Controls					Sensors							Prediction				
	Timestamp	propylene_ox_flow	reactor_temp	reboiler_temp	reflux_flow	water_flow	propylene_ox_temp	water_flow_temp	propylene_ox_pressure	water_flow_pressure	condensation_temp	top_product	bottom_product	condensation_temp_calculated	fouling_factor (VIRTUAL)	penalty_energy_calculated	top_product_calculated	bottom_product_calculated
0	01.01.2023 0(	4065.82748	60.3273395	191.709698	4018.30676	4999.43159	24.8006202	24.8001123	24.8021481	24.8015319	70.0018215	3900.03944	5100.28408		0			
1	01.01.2023 0(	4065.11382	59.7884469	191.693404	4017.88528	5000.12759	24.8051891	24.8009186	24.803858	24.8042654	70.0040125	3900.14808	5100.41844					
2	01.01.2023 0(	4065.87473	61.0815738	191.533863	4018.66443	5000.8539	24.8095167	24.801686	24.8063708	24.8044786	70.0073401	3900.36089	5100.8134					
3	01.01.2023 0(	4065.73315	61.2574295	191.530111	4018.65611	4999.3711	24.8099217	24.8043932	24.8070857	24.8051335	70.013858	3900.40622	5100.96339					
4	01.01.2023 0(	4065.58778	59.9789351	191.787955	4018.10247	4999.92282	24.8118404	24.8049332	24.808865	24.8052886	70.0207263	3900.46861	5101.19385					
5	01.01.2023 0(	4065.70318	60.567107	191.511476	4017.01573	4999.4605	24.8121922	24.8051662	24.810472	24.8074976	70.0284621	3900.48944	5101.22015					
6	01.01.2023 0(	4064.39106	60.1302874	191.534088	4018.57141	4999.11857	24.8122705	24.8057458	24.8124906	24.8075082	70.0313351	3900.76613	5101.49304					
7	01.01.2023 0(	4065.06024	59.6560418	191.707691	4017.46469	5000.35086	24.8148123	24.8059164	24.8131518	24.809156	70.0315557	3901.13078	5101.67764					
8	01.01.2023 0(	4064.14638	60.5251864	191.662131	4018.75014	5000.57042	24.8157176	24.8065802	24.814176	24.8092332	70.035277	3901.2281	5101.90969					
9	01.01.2023 0(	4064.5834	60.6435644	191.889466	4018.2123	5000.49637	24.8168743	24.8080599	24.8156019	24.8108339	70.039475	3901.30772	5102.25631					
10	01.01.2023 0(	4064.15903	61.4341108	191.855326	4017.24662	4999.75788	24.8181018	24.8083731	24.8157625	24.8109262	70.0447844	3901.31118	5102.41373					
11	01.01.2023 0(	4065.29695	60.9960648	191.614303	4018.40683	4999.70037	24.8181148	24.8087991	24.8165688	24.8117014	70.0478916	3901.54331	5102.4679					
12	01.01.2023 0(	4064.51118	59.7739611	191.875112	4018.36315	4999.51185	24.81823	24.8097922	24.8196482	24.8125457	70.0560668	3901.86374	5102.55346					
13	01.01.2023 0(	4064.13089	61.4674149	191.707401	4017.32033	5000.49044	24.8188117	24.8104311	24.8224918	24.8127371	70.05676	3902.04911	5103.12238					
14	01.01.2023 0(	4065.79031	61.0841832	191.612625	4017.77118	5000.09395	24.8203924	24.8111795	24.8234592	24.8133195	70.0574277	3902.17216	5103.13932					

Operating scenario

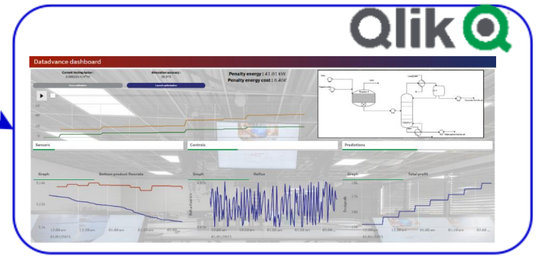
Stages

1. System monitoring and alerts
2. Digital Twin automatic recalibration
3. Optimization of unit parameters due to operating condition changes
4. Operator triggers maintenance operation at the right time

Stage 1 : monitoring and regular re-simulation for new conditions



Parameters observed and tuned by operator:
- Controlled parameters of unit
- Measured by sensors
- Predicted by Digital Twin (includes virtual sensor)



Alert

Check prediction quality and automatically trigger model recalibration when needed.

Operator can also enforce recalibration.

Goal: provide the simulated results to compare with data from sensors to control the current accuracy of simulation model
Accepts: data from asset (sensors and controls) + current value of fouling factor
Results: predictions for process output parameters, penalty energy due to current fouling factor value and difference for condensation temperature.

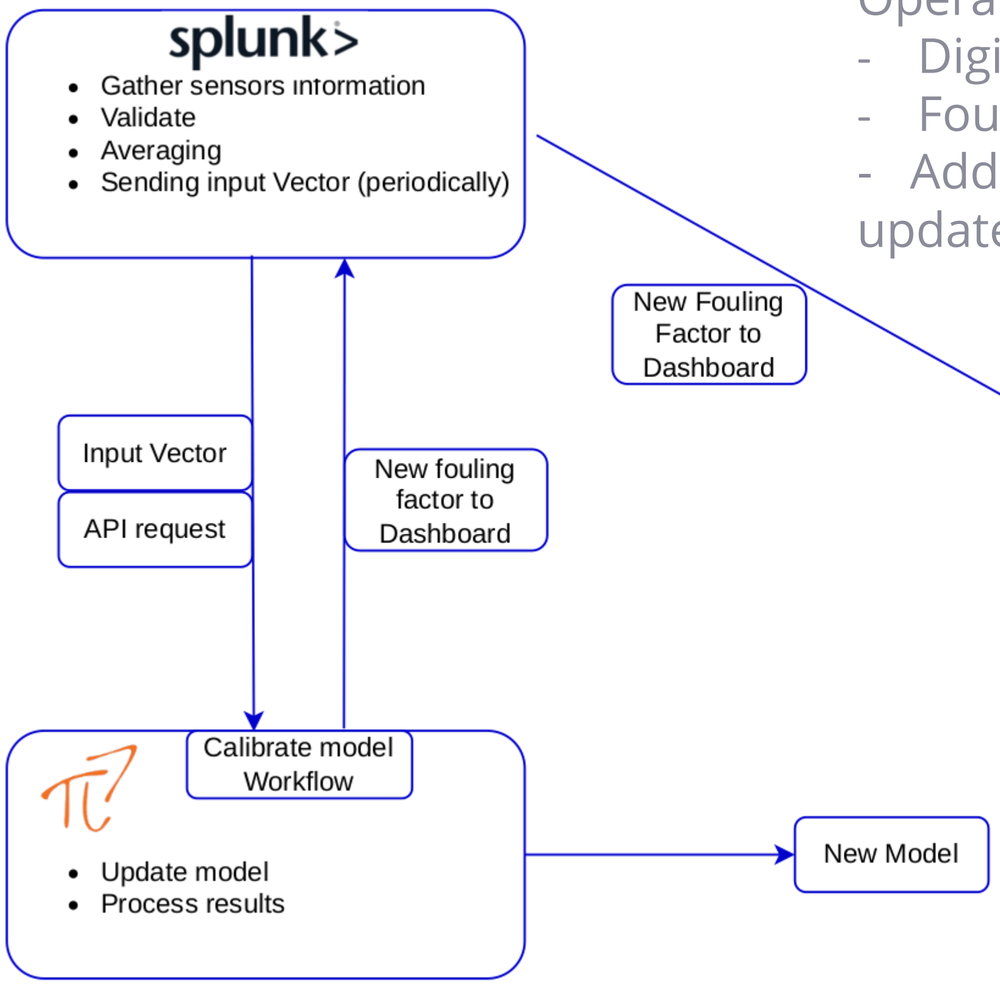
Monitoring and alert

- Values are available in the dashboard. They include control parameters (settings of the unit, affecting the performance), measurable parameters of the unit (i.e. sensor values such as temperatures and pressures) and calculated values (coming from Digital Twin). The pSeven Enterprise **workflow is automatically triggered** after new data from sensors arrives, to get the expected simulated parameters for the measurements.
- Inputs from the dashboard (Splunk) to be used by simulation are processed by the *Inputs* block.
- The re-simulation of DwSim is managed by the *Run DWSIM* block.
- The goal is to ensure there is no huge discrepancy and the **simulation model is accurate** so that parameters in the model (even unmeasurable ones), are close to real. The *Post* block is used to compute the discrepancy.
- Operator (engineer) sees an alert from dashboard when the discrepancy of condensation temperature is higher than one degree K(°C) due to the thermocouple sensors error.

Monitoring is handled by following workflow:

- If the discrepancy violates the limit, Splunk triggers the calibration with a second workflow.

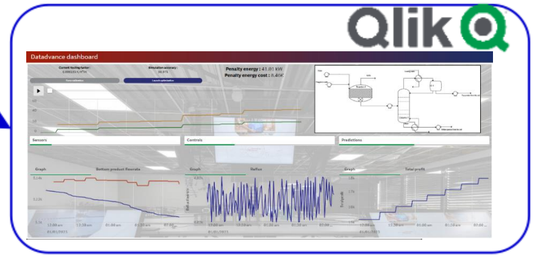
Stage 2: Calibration of the model triggered by threshold discrepancy with reality



Operator is informed about:

- Digital twin was calibrated (updated to reflect actual state)
- Fouling factor was updated (also used as a virtual sensor)
- Additional cost to maintain production under current condition

updated to support decision making



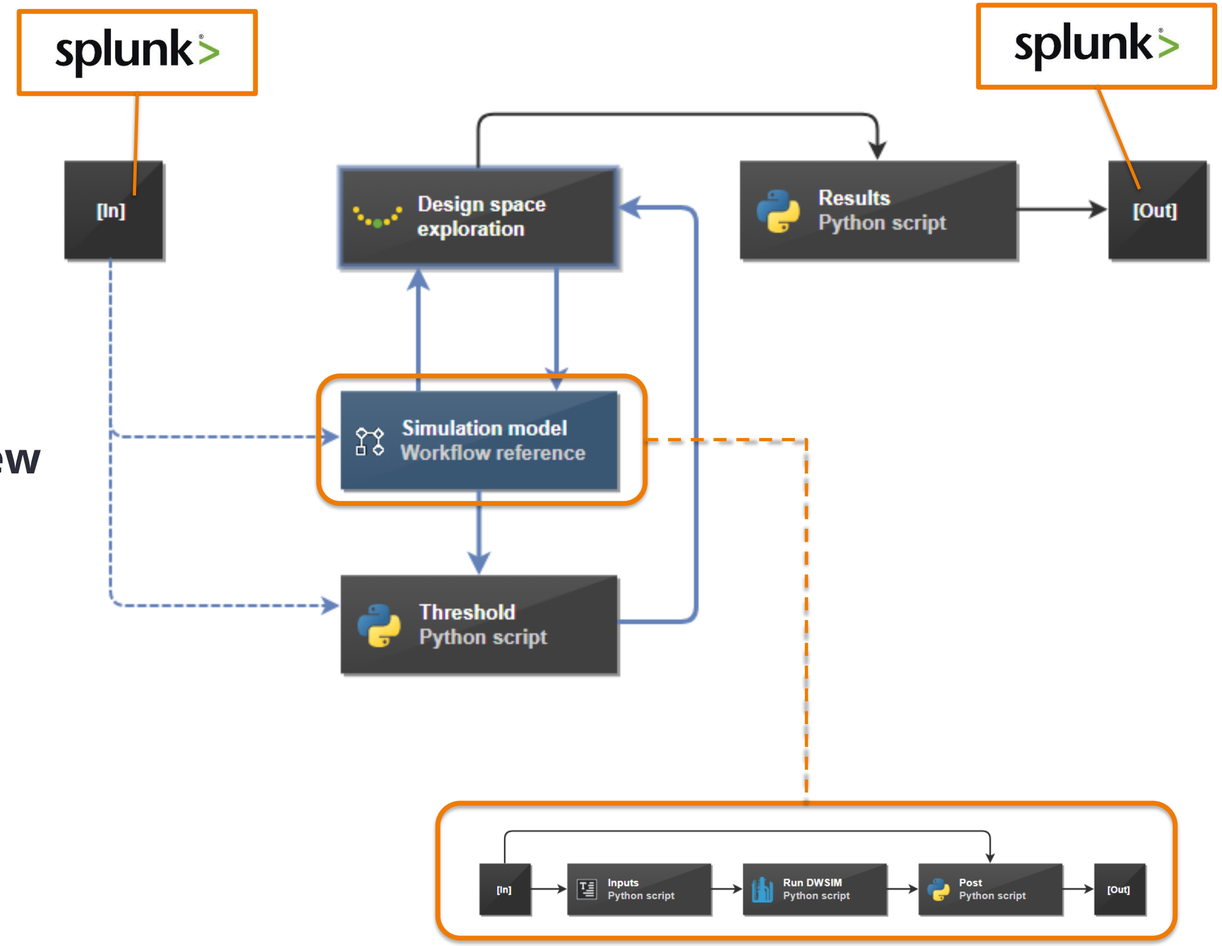
Alert

Fouling factor indicates the equipment clogging

Goal: provide new estimation for current value of fouling factor to match simulation and reality (“virtual sensor”).
Accepts: data from asset (sensors and controls)
Results: new estimation of fouling factor + penalty energy for new value of fouling factor

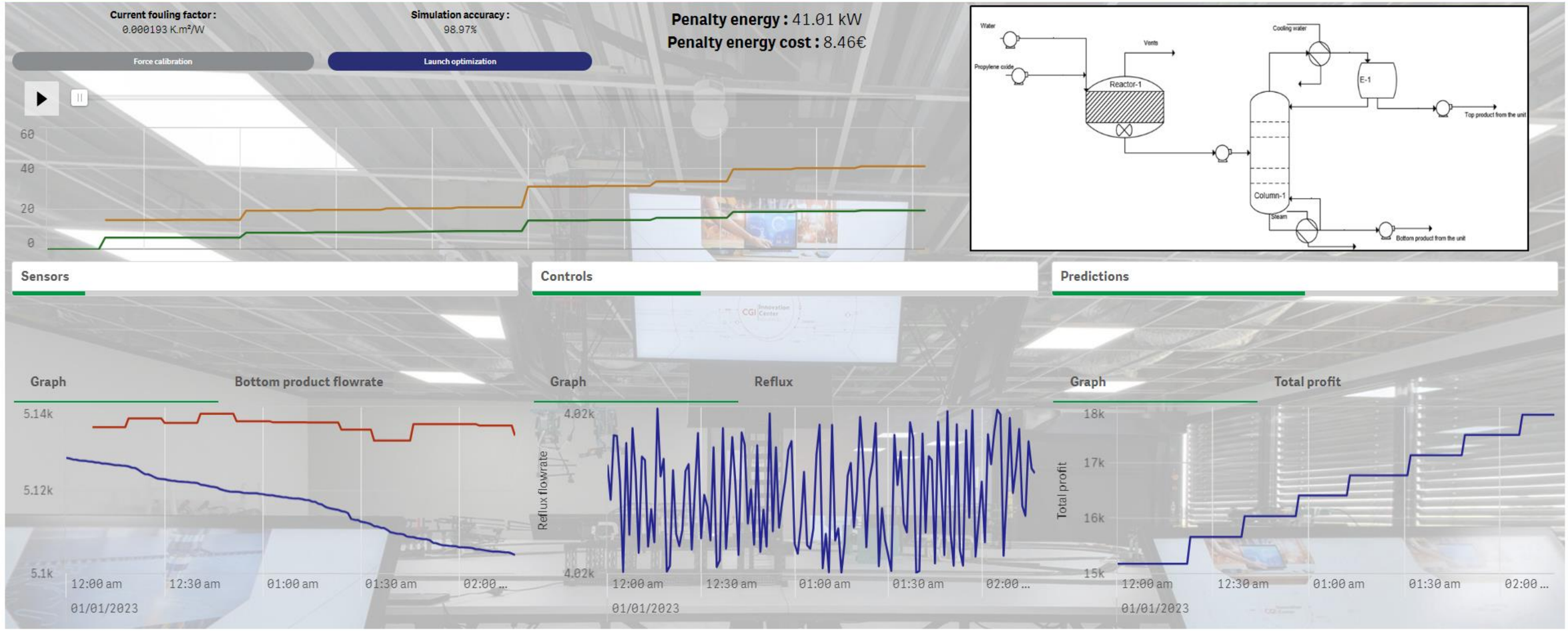
Model recalibration

- Recalibration workflow is **triggered automatically** while the condensation temperature discrepancy violates the threshold.
- The workflow runs an **internal optimization study to minimize the difference between real and simulated output** (condensation temperature value) for current conditions by changing the fouling factor in the model. Once the model provides the results, equal to real, the **new identified fouling factor is returned to Splunk.**
- In the end, dashboard shows that prediction is matching measurement again.
- The new value of fouling factor will be **used for new monitoring simulations** until next calibration will be triggered.
- Together with it the energy required to maintain production with this level of fouling is also displayed (the higher the fouling, the more energy we need to spend to overcome its effect) – this additional energy consumption may be an implicit indicator to decide to clean the system.

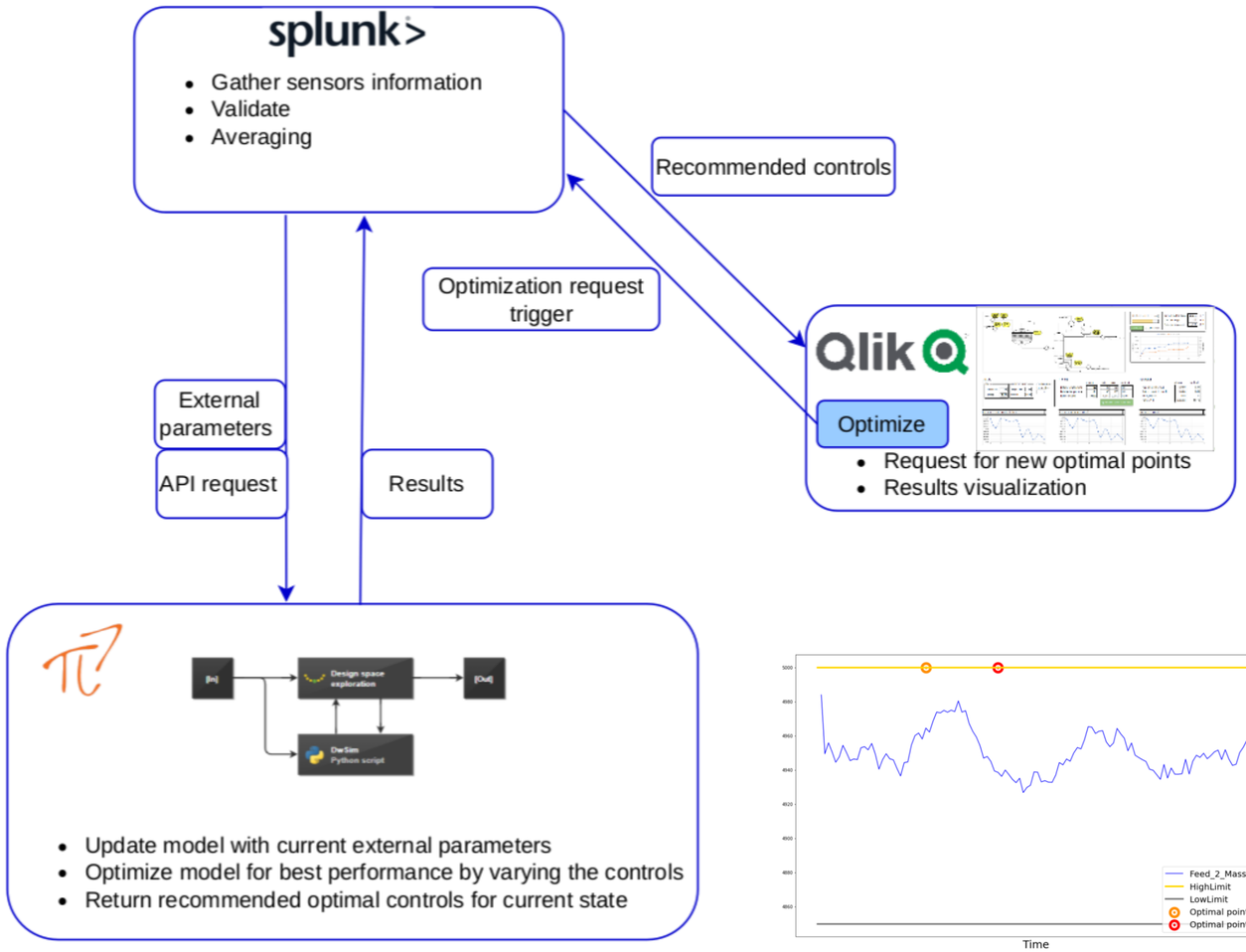


Operator dashboard

Datadvance dashboard



Stage 3 & 4: On-event/on-demand process optimization and predictive maintenance



*Based on evolving operating conditions (environment like T° in ex. or energy cost), operator can request **unit parameters optimization** based on target function like price margins.*

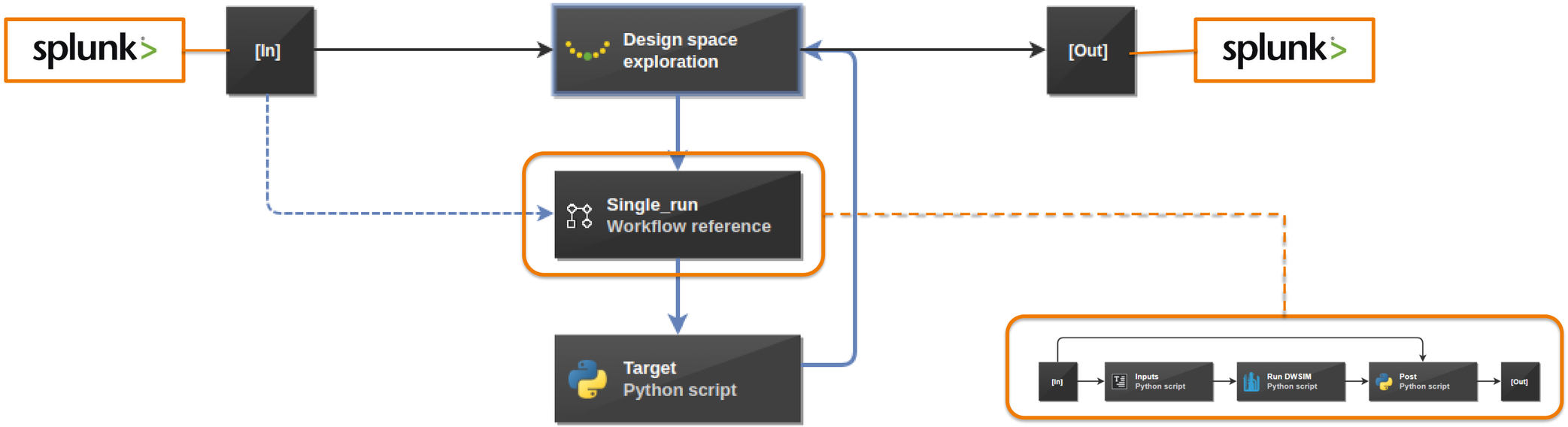
*When margin, or predicted margin, doesn't satisfy economical requirements anymore, **maintenance operation can be triggered**.*

→ Maximize profit margins and reduce downtime

Goal: provide estimation for control values to achieve maximum economical performance in current conditions.
Accepts: data from asset (sensors only) with current state of external and operating conditions
Returns: recommended values for control parameters, expected output values and expected revenue.

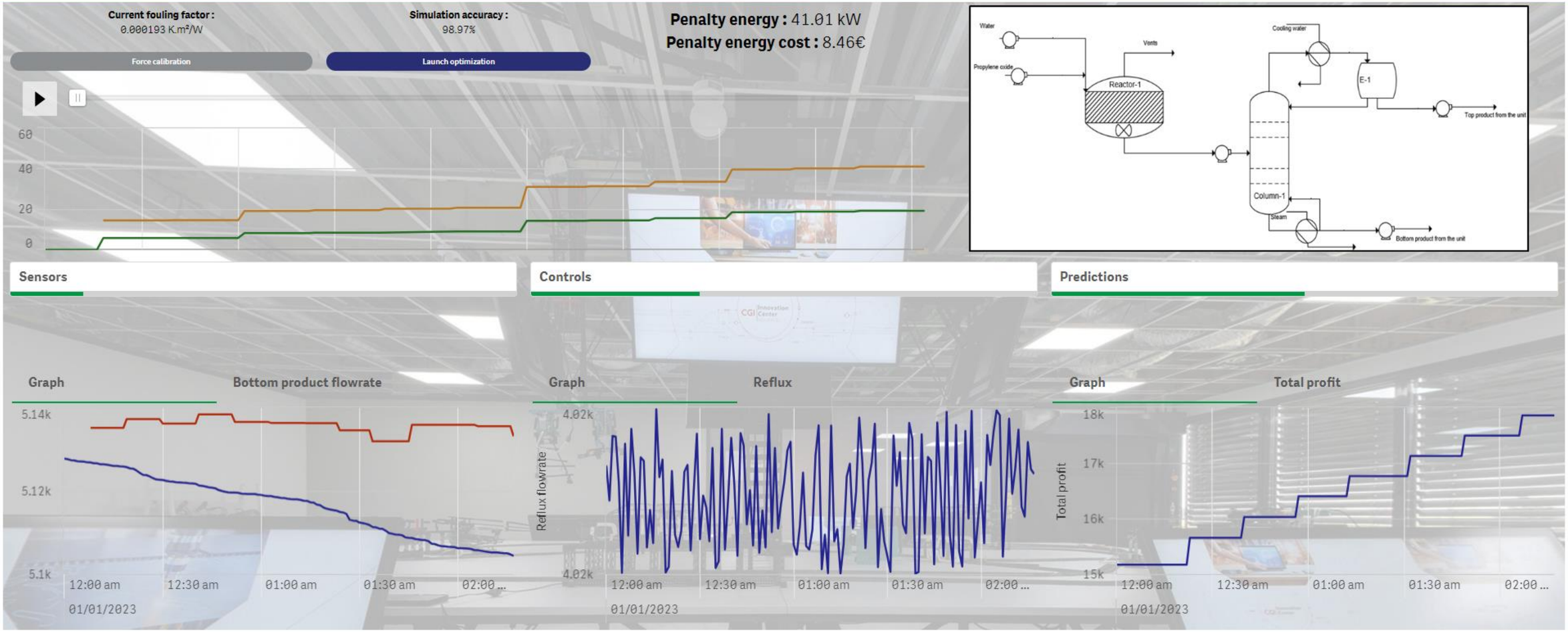
Asset control parameter optimization

- In any given conditions, operator engineer may like to **optimize performance of the unit** with respect to **control parameters**.
- After trigger from the operator engineer, the **model updates** with actual data from the **latest calibration** and optimization workflow runs.
- After optimization workflow is executed, **dashboard shows the recommended values** and expected target values if such controls will be applied.
- Target function is economical : **energy price *energy consumption**.

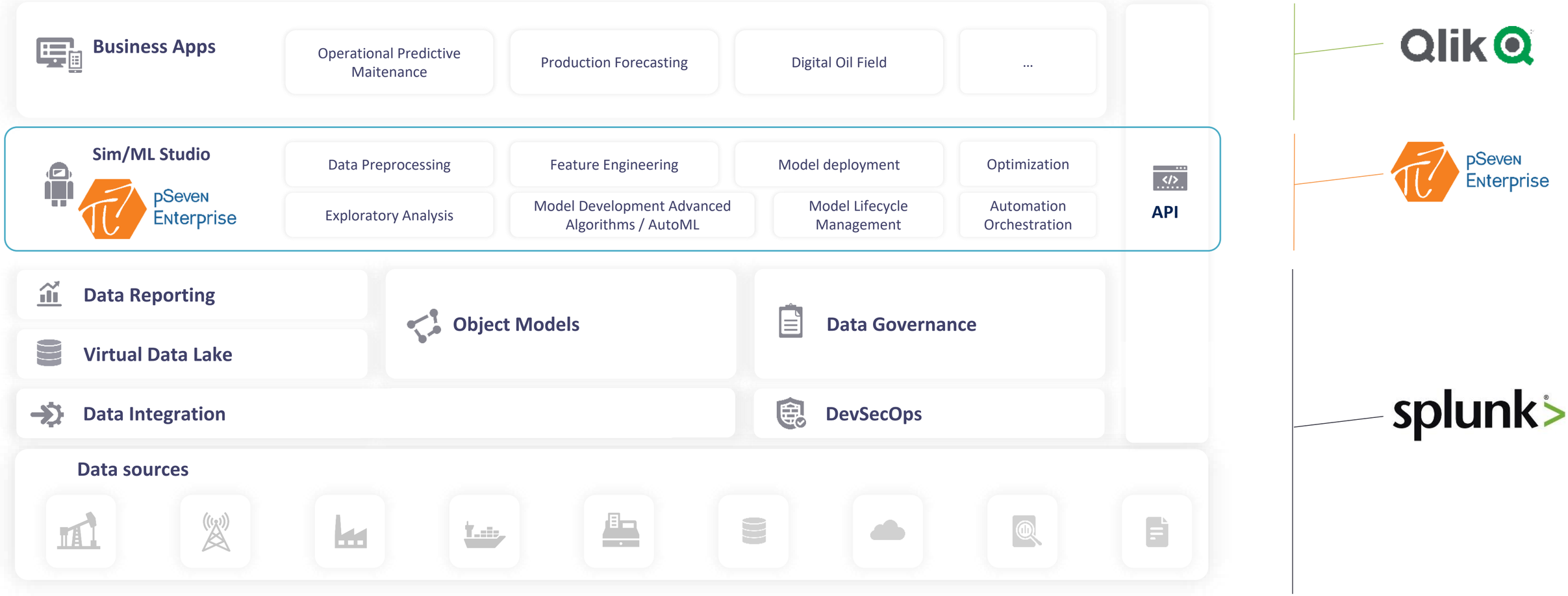


Operator dashboard

Datadvance dashboard



Infrastructure for Operational Digital Twins



Conclusion

- Production unit monitored 24/7
- Reliable prediction of unit health thanks to constantly updated Digital Twin
- Hybrid Digital Twin leverages models built by engineering teams
- Down time reduced
- Profit maximized

THANK YOU

pseven.io
info@pseven.io

Laurent CHEC, Datadvance SAS
laurent.chec@pseven.io

CGI

https://www.cgi.com/en/innovation/centers

Bruno Trebucq, CGI France
bruno.trebucq@cgi.com