

BUILDING FULLY INTEGRATED DIGITAL TWIN FOR REFINERY OPERATIONS

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MOL GROUP IN BRIEF

INTEGRATED DOWNSTREAM IN CEE

PRODUCTION UNITS

6



20.9 mtpa REFINING AND
2.2 mtpa PETROCHEMICALS
CAPACITY

EMPLOYEES

15.000

SERVICE STATIONS

~1.900

IN 10 COUNTRIES



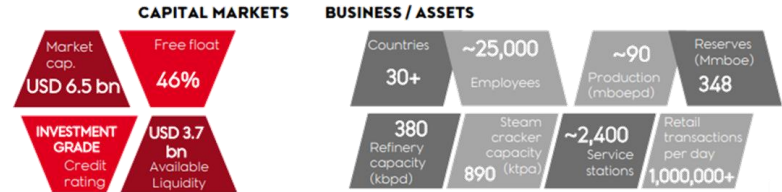
CORE ACTIVITIES



CLEAN CCS EBITDA BY SEGMENTS IN 2022 (USD MN)



KEY FIGURES

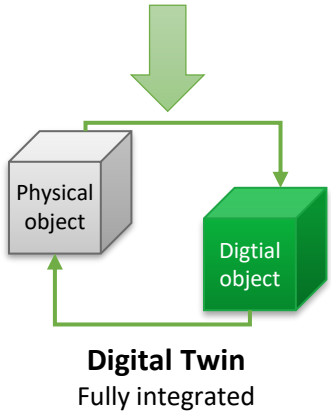
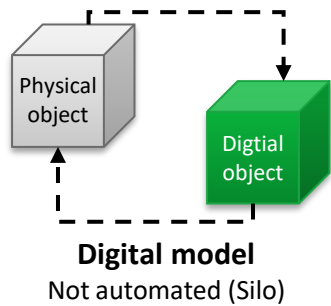


WHY - DIGITAL TWIN (DT)

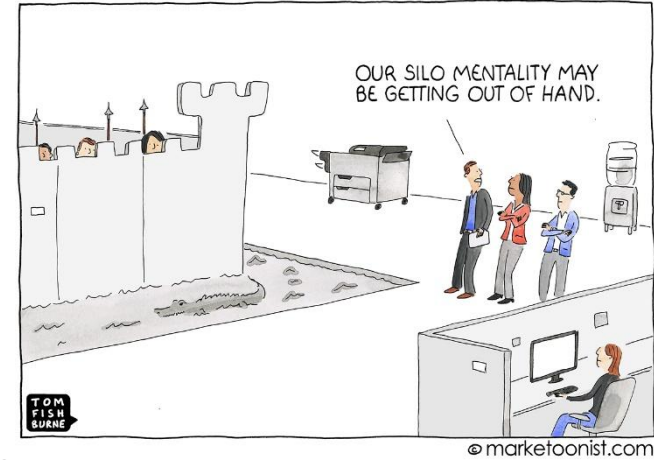
A Digital Twin:

- **cyber-physical integration** by which data can be collected, analyzed, and visualized
- **to make more informed decisions**

} **to optimize operations**



- Separate **models** with **different scope**
 - *Simulation models,*
 - *Energy prediction, monitoring,*
 - *Quality prediction,*
 - *Crude selection,*
 - *Anomaly detection, etc..*
- Model generation ad-hoc, **problem driven**
- Models **not integrated** into one eco-system
- Models' health are not monitored -> **missing** continues **maintenance**, version control
- Simulation models are available only for a **narrow group**



A faster and continuous response to business needs could increase profitability by transitioning from siloed digital models to an integrated Digital Twin

RTO OR DIGITAL TWIN? WHAT'S THE DIFFERENCE?

RTO

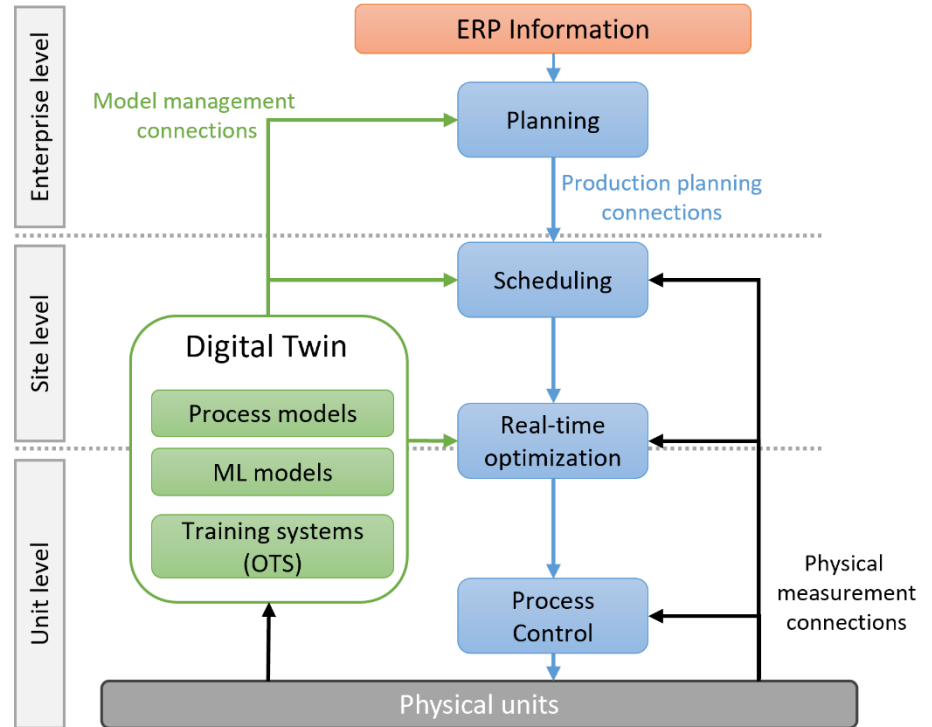
- **Dynamic process control** – Continuously adjusts operational parameters to optimize the performance
- **Aim:** move the **system towards optimum**, given current **boundary conditions**

Digital Twin

- **High-fidelity virtual model** of a physical process
- Integrates available process information („White Box“)
- **Can simulate various scenarios to analyze the impact of changes**, such as variations in catalyst activity or feedstock quality.

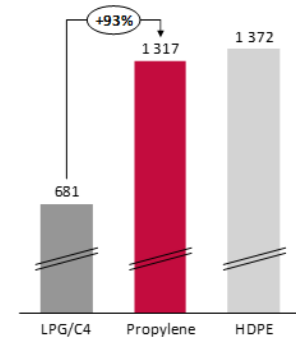
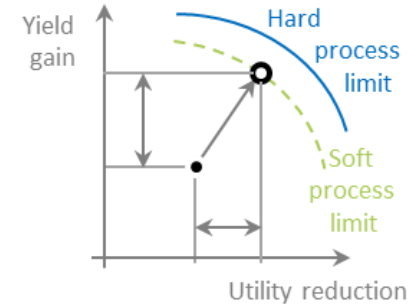
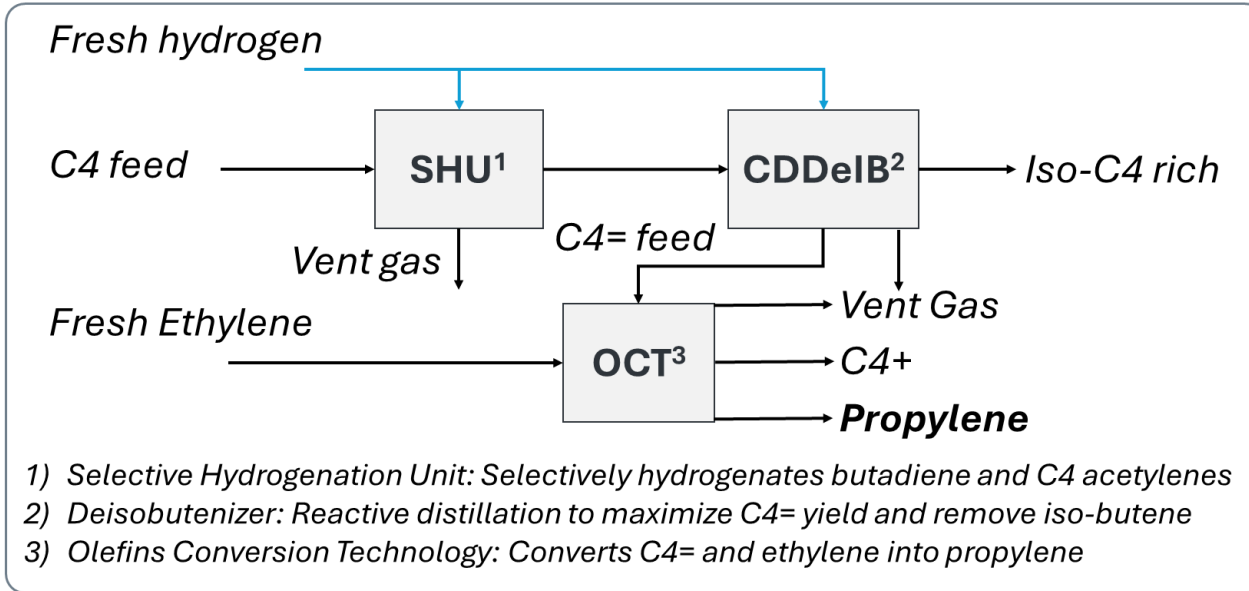
Objective:

- **RTO:** Focuses on **continuously optimizing the current process in real-time** to achieve the best performance under existing conditions.
- **Digital Twin:** Aims to **provide a virtual environment for testing and analysis**, allowing for the exploration of various scenarios and their impacts without disturbing the actual process.



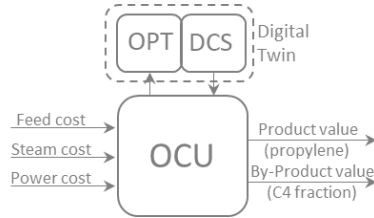
USE-CASE OLEFIN CONVERSION UNIT (OCU)

Metathesis of 2-Butene and Ethene:



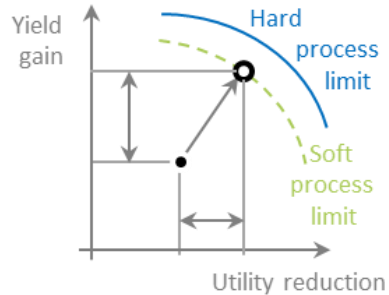
USE-CASE OLEFIN CONVERSION UNIT (OCU)

Aim: to optimize the operation of OCU to improve profitability



Objective: reduce specific production cost and increase the yield of propylene

Tool: Digital Twin pushes the system closer to the process limitations



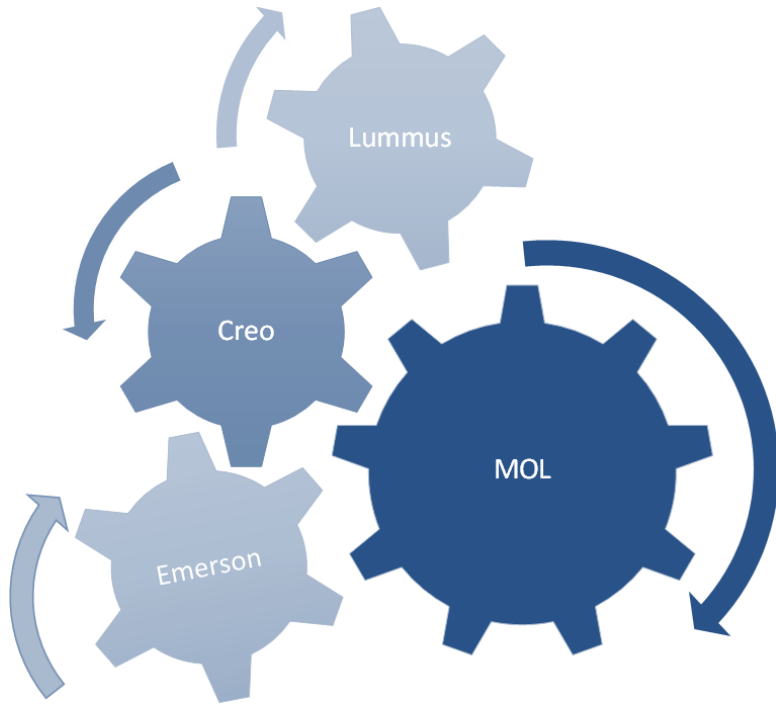
Parameters:

1. Yield : improving propylene conversion
2. Utility: steam and electricity of adsorber regeneration system

Estimated benefits due to using Digital Twin

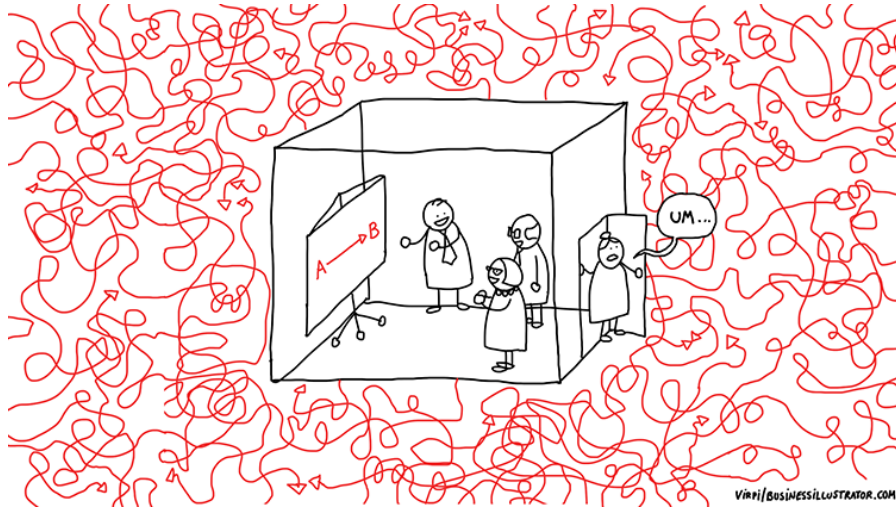
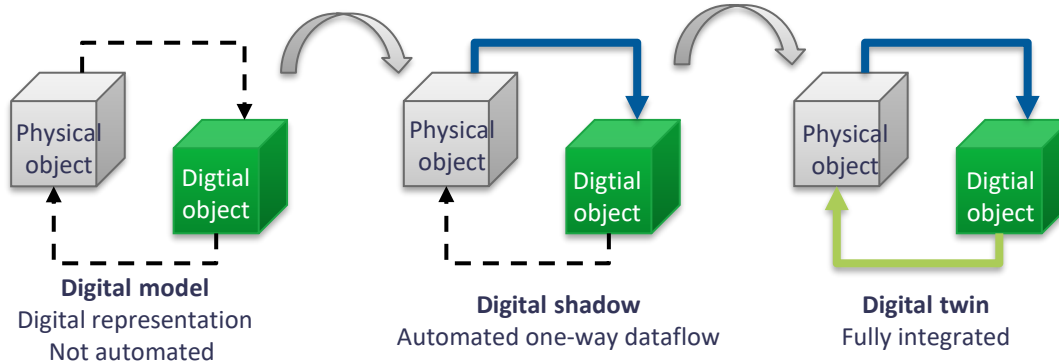
- MOL Group Global Material&Utility balance calculation yield and utility improvements followed by economic valuation
- **Yield improvement:** +1ktpa (1%) product – Licensor confirmation
- **Utility improvement:**
 - Overall utility decrease to start-up: 8% (steam, electricity) for the first 6 years of operation – Statistically analyzed in other processing units
 - Regeneration cycle time increase for adsorbers and OCT reactor
 - 2200GJ/y electric power saving (Powerplant loaded less: -4ktpa CO₂, -1ktpa Natural gas purchase)
 - 800 GJ/y natural gas saving
 - 150 thUSD saving on nitrogen, air and hydrogen saving
- Total calculated benefit can payback up to **10MUSD** total CAPEX

OCU DIGITAL TWIN PARTNERSHIP



- **MOL**: Domain knowledge holder. Digital Twin concept development and project coordination
- **Lummus**: OCU **technology licensor**, building **steady-state high-fidelity process simulation** models, and supporting Digital Twin development with technology-specific domain knowledge
- **Emerson**: Providing technology to **translate Digital Twin results into control strategies**
- **Creo**: Software and machine learning development company, **creating a Digital Twin framework** and interfaces for different system components

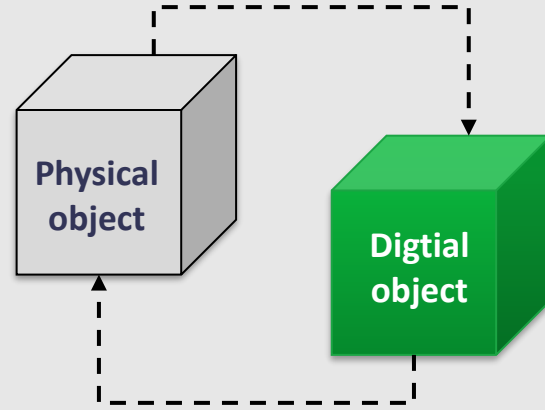
MOVING TOWARDS DIGITAL TWIN SEEMS TO BE SIMPLE...



Challenges

- Real-time automated connection adds **excessive system complexity**.
- **Multi-model integration** (first-principles + ML).
- **Model management** – monitoring, continuous calibration, and version control.
- Poor **data quality** → poor model output.
- Siloed models instead of **multi-purpose use**.
- Weak/missing **validation**.
- **Low trust** – caused by **complex** and **hard-to-interpret** solutions.

DIGITAL MODEL

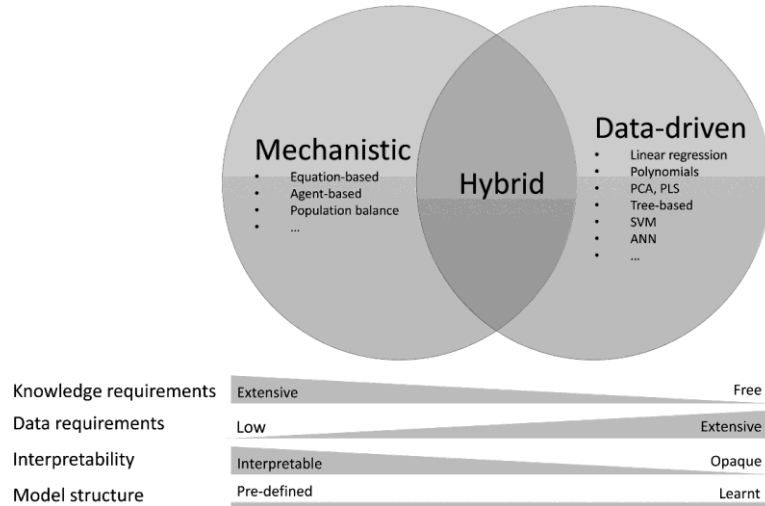


Digital model
Digital representation
Not automated

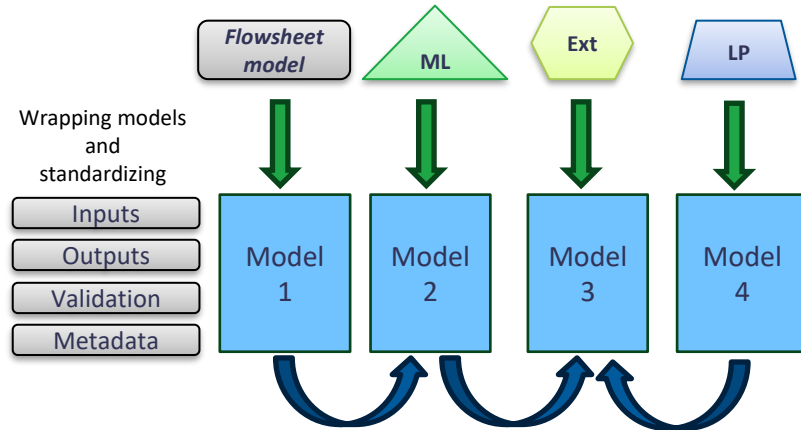
THE HEART OF A DIGITAL TWIN: MODELS

Within Digital Twin the model(s) can **vary in type, level of detail, and granularity**. These models:

- Simulate physical system behavior
- Coherent multi-layered view of the system (interconnectedness).



How can we seamlessly integrate diverse models in a digital twin?



META MODEL

The screenshot displays the 'Digital Twin Dashboard' interface. The top navigation bar includes the 'MOI' logo, 'Digital Twin Dashboard', a user profile icon, and the name 'BPalatal Admin'. The main content area is titled 'Model' and features a search bar and two buttons: '+ Add new model' and 'Lummus2 by Simulation'. Below this is a table listing various models.

Name ↑	Type	Driver
BFR_FEED_Convert	WORKFLOW	workflow
BFR-NEW-2025-V1	HYSYS	hysys
BFRANN_V3	ANN	ann
DBEK4	ANN	ann
DLNI_SimpleModel	SPREADSHEET	spreadsheet
LUMMUS_CODEIB_async_v4	LUMMUS2	lummus2
LUMMUS_CODEIB_async_v5	LUMMUS2	lummus2

At the bottom of the table, there is a pagination control showing 'Rows per page 25' and '1-23 of 23'.

Dashboard by **Creo Group** - © 2025

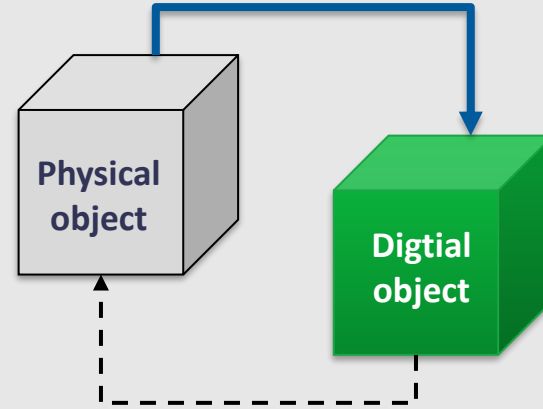
PLAYGROUND – WHAT-IF DASHBOARD

The screenshot displays the 'What if' dashboard interface. At the top left, the 'Digital Twin' logo is visible. The main header area includes a search bar and a 'What if' title. The central part of the dashboard is a table listing various configurations. The table has the following columns: Name, Group, Aspect, Transformer, Created, and Updated. The data rows are as follows:

Name ↑	Group	Aspect	Transformer	Created	Updated
BFR_DT_ANN	BFR-Group	BFR_ANN_Aspect		2023.11.21 13:37	2024.12.11 10:16
Naphtha Rodest (BFR)	NaphthaLineDT-Group	BFR-Aspect-2025-VI		2025.01.20 10:52	2025.02.04 10:56
NaphthaLine	NaphthaLineDT-Group	BFR-Aspect-2025-CONVFED		2025.01.20 11:09	2025.03.18 10:11
NaphthaLine-2025	NaphthaLineDT-Group	Naphtha-Line-DT		2025.04.02 15:26	2025.04.14 08:53
OCU_CDDDEB	OCU-Group	Lummus-CDDDEB-Aspect		2023.12.05 09:36	2024.10.22 09:56
OCU_OCT	OCU-Group	Lummus-OCT-Aspect		2023.12.05 10:35	2024.10.22 09:29
OCU_SHU	OCU-Group	Lummus-SHU-Aspect		2023.10.25 14:40	2025.04.29 14:31
OCU_SHU_FEED_MIX	OCU-Group	Lummus-SHU-FeedMIX2-Aspect		2024.05.24 12:06	2024.09.16 13:32

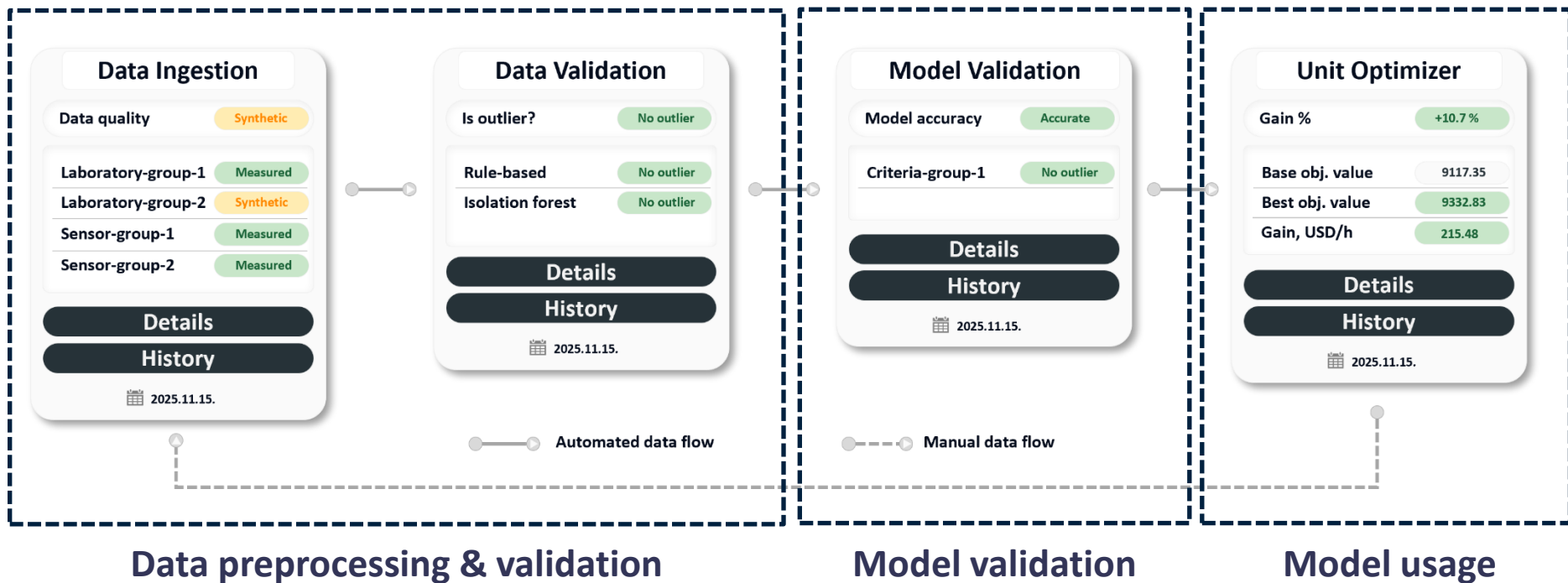
The sidebar on the left is divided into two sections: OPERATOR and EXPERT. The OPERATOR section includes 'What if' (selected), Task Manager, Optimization Pipeline, Unit Optimizer, Optimization Case, Optimiser, Optimiser Log, Outlier Detector, What if, What if group, Transformer, Aspect, Dataset, and Measurement. The EXPERT section is currently empty. The footer of the dashboard reads 'Dashboard by Crea Group - © 2025'. At the bottom right, there is a pagination control showing 'Rows per page 25', '1-10 of 10', and navigation arrows.

DIGITAL SHADOW



Digital shadow
Automated one-way dataflow

INTEGRATION OF PROCESS DATA INTO THE DIGITAL MODEL



IMPORTANCE OF DATA QUALITY

Reliable decisions require **trusted data**:

- **Filter by operating range** – apply models only where they are valid.
- **Validate data** – remove outliers, correct errors, ensure consistency.
- **Integrate sources** – merge sensor, system, and database inputs.
- **Harmonize** – align units, formats, and timestamps for clarity.
- **Explain with visuals** – clearly show what was changed, removed, or corrected, and why.

Poor quality or out-of-range data can lead to inaccurate results, limiting the model's effectiveness and compromising decision-making.



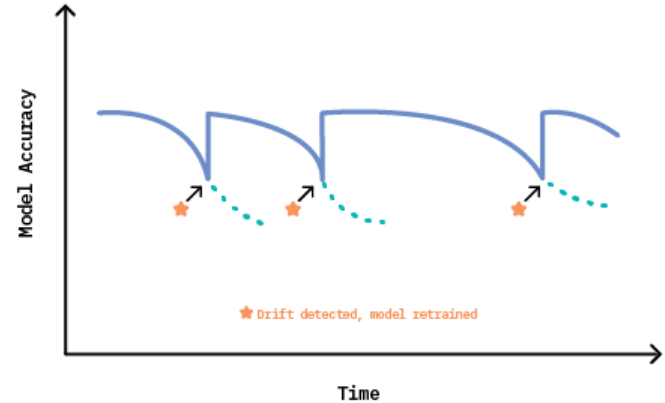
MODEL INTEGRATION & VALIDATION

Maintaining flowsheet model performance is critical as **real-world degradation occurs**. Online connectivity demands continuous monitoring and timely intervention when drift is detected.

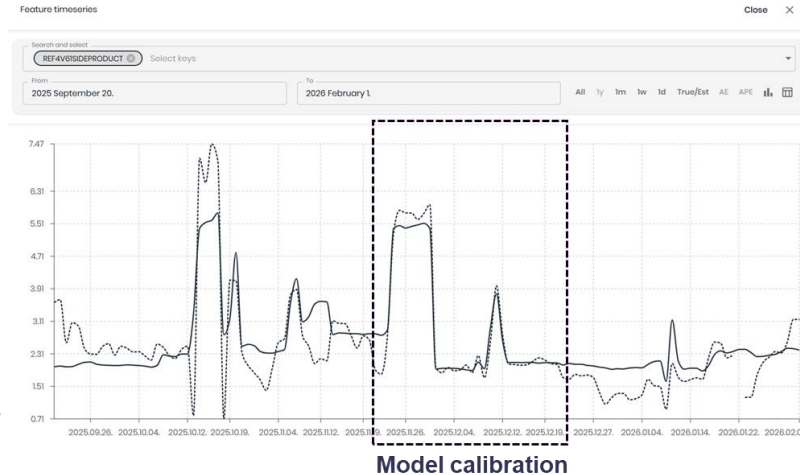
- **Clear ownership** – model changes are handled by subject-matter experts.
- **Performance monitoring** – detect concept drift and degradation
- **Online calibration** – use automated/semi-automated tuning to maintain accuracy.
- **Transparent validation** – track and explain model performance before and during application.

Model calibration:

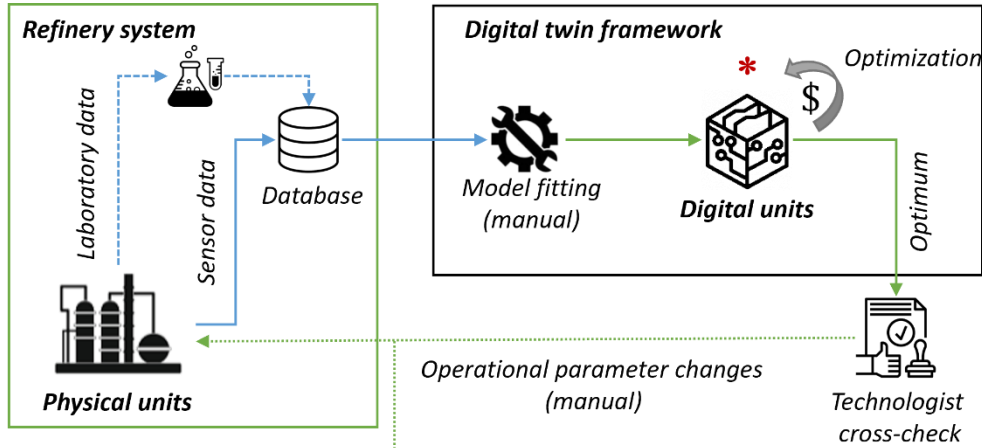
- Palotai, B., Kis, G., Abonyi, J., & Bárkányi, Á. (2025). Surrogate-based flowsheet model maintenance for Digital Twins. *Digital Chemical Engineering*, 15, 100228.
- Palotai, B., Kis, G., Chován, T., & Bárkányi, Á. (2025). Online learning supported surrogate-based flowsheet model maintenance. *Digital Chemical Engineering*, 100287.



Monitoring model prediction performance

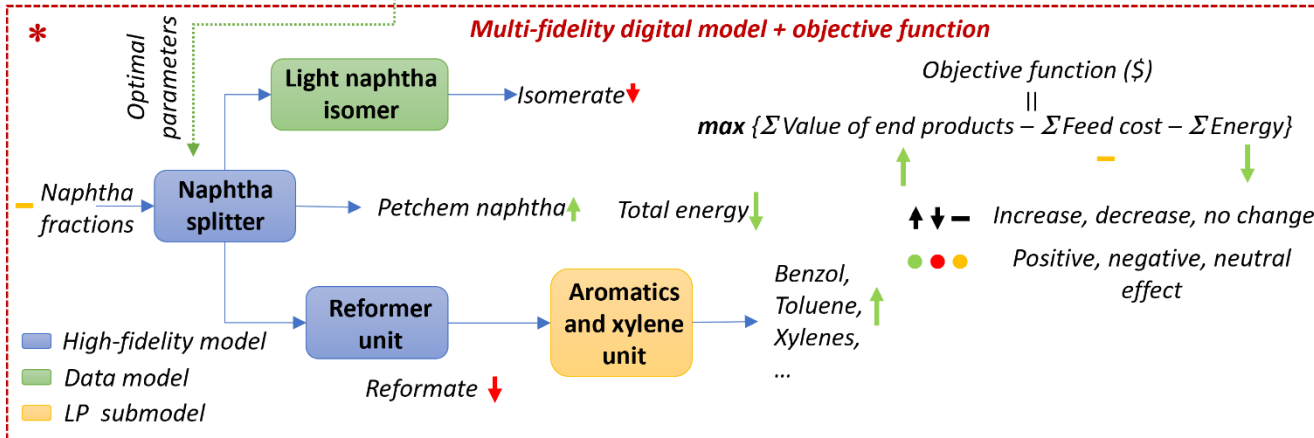


MODEL USAGE – DIGITAL SHADOW PROOF OF CONCEPT

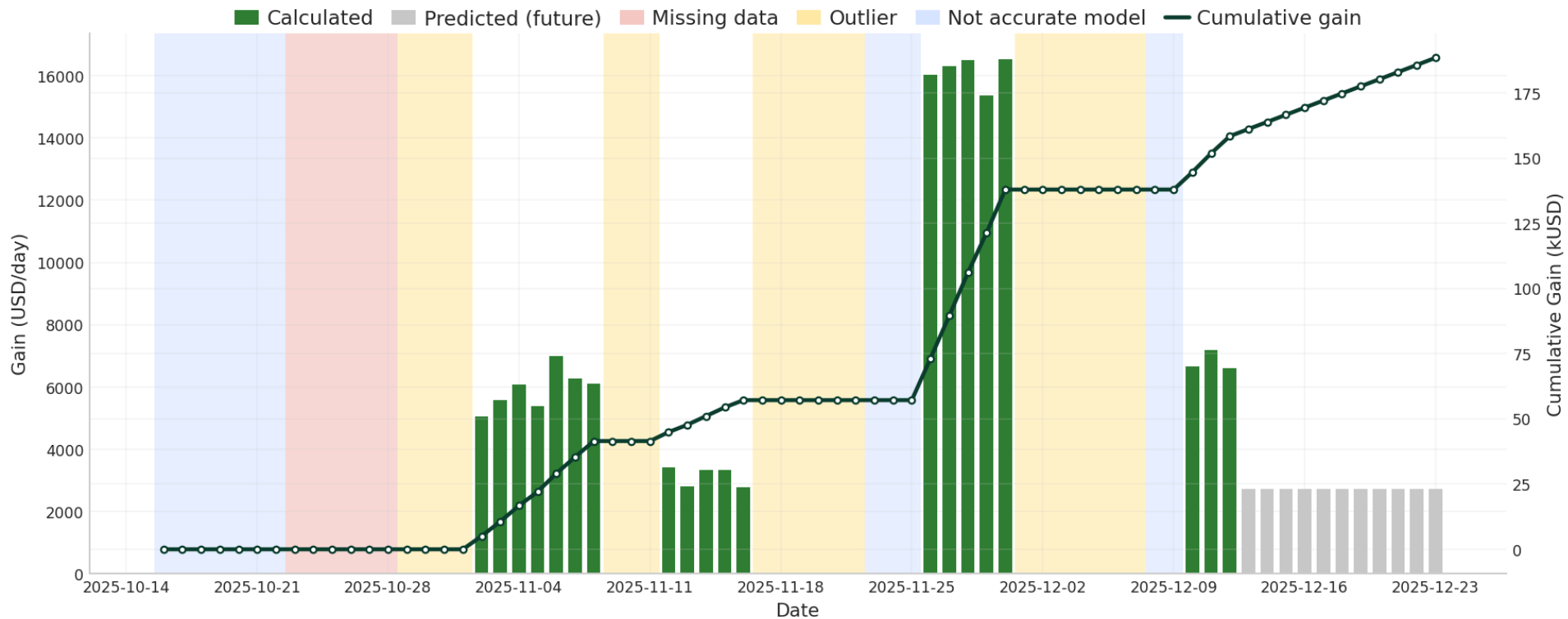


Targets

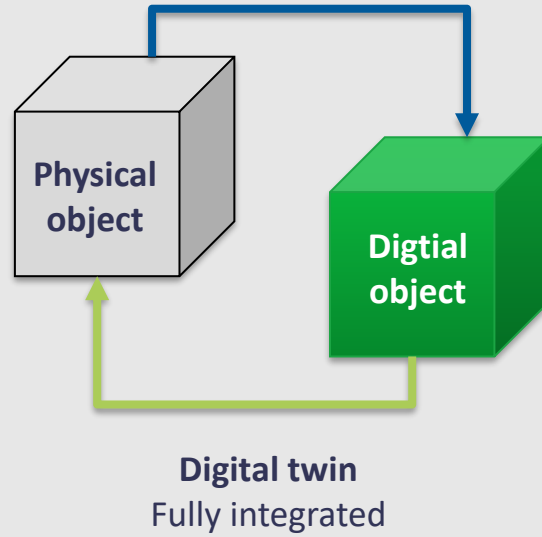
- Demonstrate **Digital Shadow** architecture
- Integrate **multi-fidelity** process models
- Automate **data collection and preprocessing**
- Enable **daily economic optimization**
- Support **human-in-the-loop** decision making
- **Validate** recommendations on real plant operation
- Establish **feedback loop** between plant and models



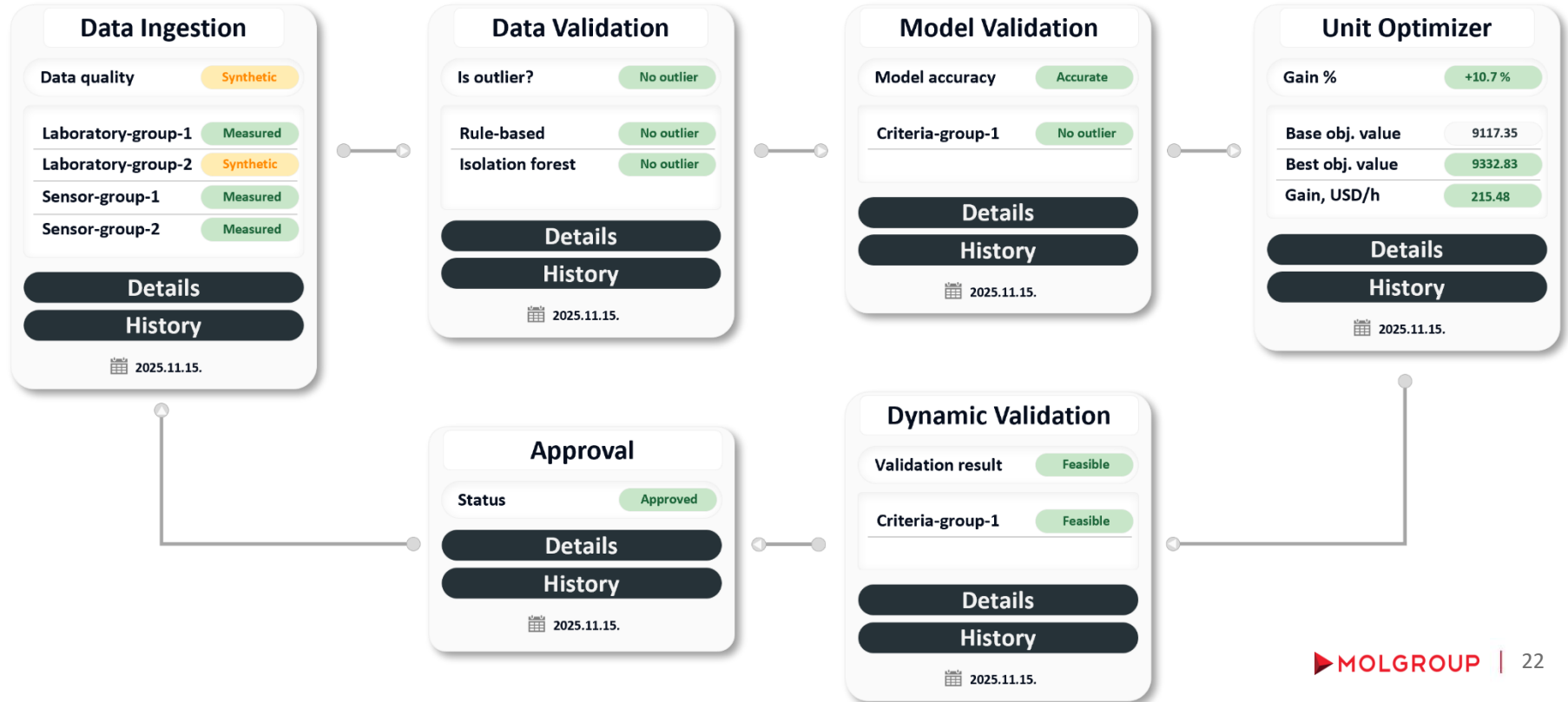
MODEL USAGE



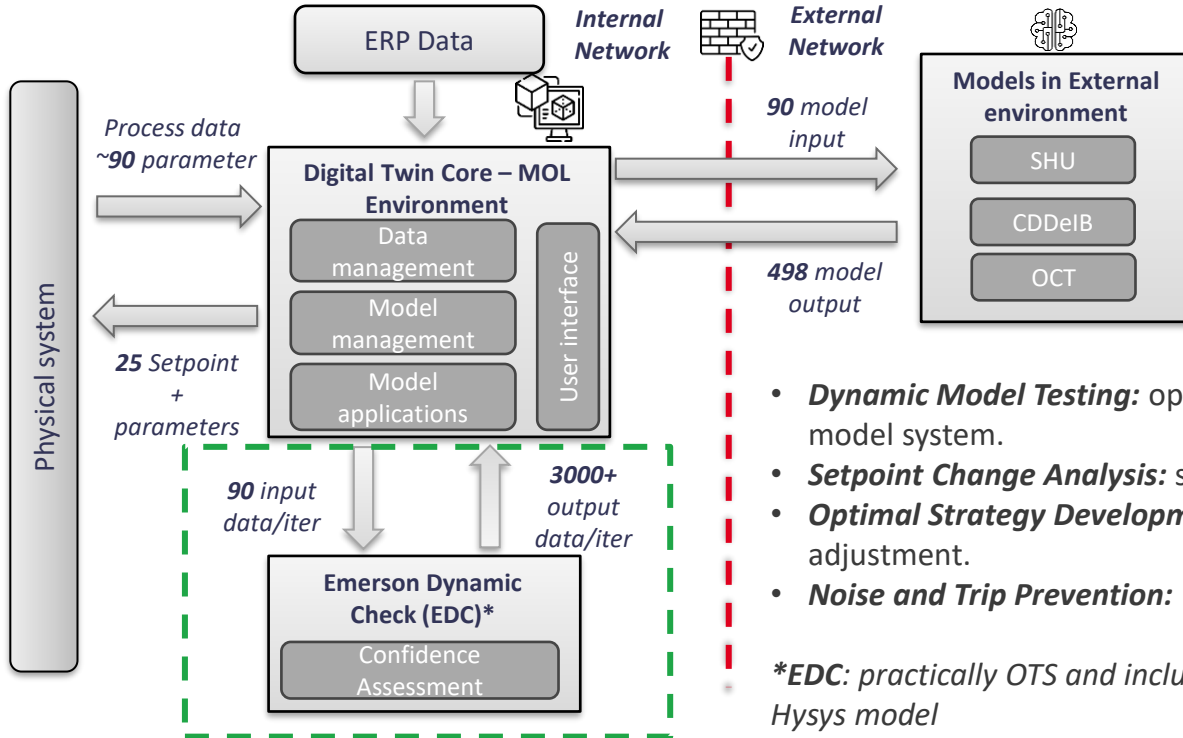
DIGITAL TWIN



INTEGRATION OF PROCESS DATA INTO THE DIGITAL MODEL



IMPORTANCE OF DYNAMIC VALIDATION IN DIGITAL TWIN



Paramount importance of Emerson Dynamic Check (EDC) is to avoid tripping the physical system and/or not losing money and credibility

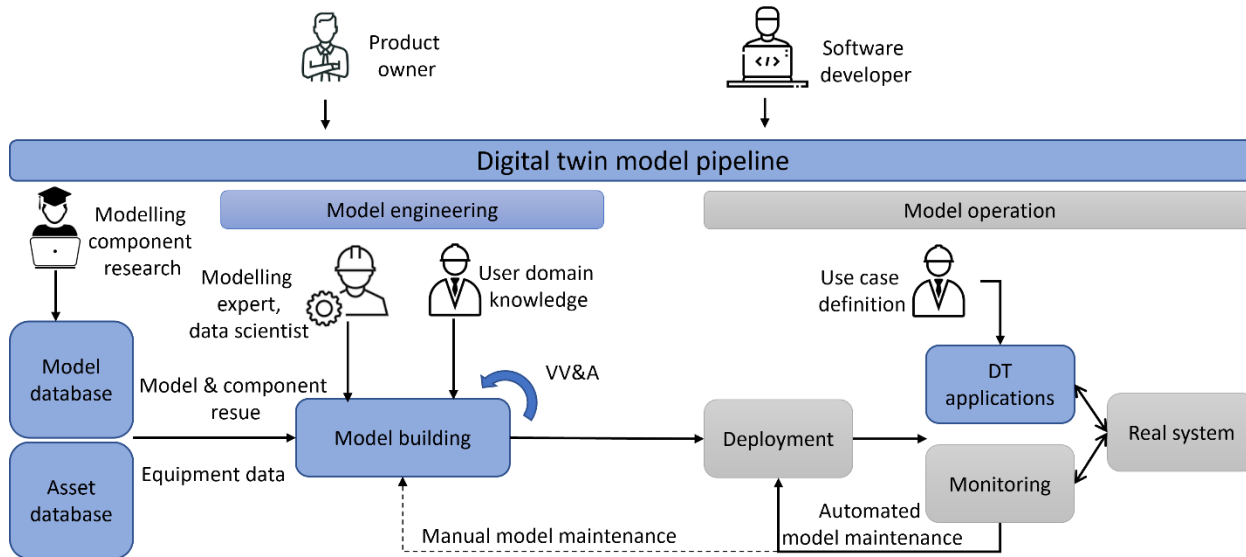
- **Dynamic Model Testing:** optimal operating state testing in a dynamic model system.
- **Setpoint Change Analysis:** setpoint change analytics and understanding.
- **Optimal Strategy Development:** strategy development for setpoint adjustment.
- **Noise and Trip Prevention:** noise and trip avoidance in the real system.

*EDC: practically OTS and include offline DeltaV and dynamic AspenTech Hysys model

SUMMARY

Clarity and explainability make **digital twins** trusted tools in refinery operations:

- **Clear blocks** – show how each part works and connects.
- **Explained decisions** – why data/models are valid, why optimizers choose a point.
- **Robust validation** – ensure safety and operational feasibility.
- **Flexible use** – optimization, ad-hoc analysis, advanced insights.
- **User trust** – built through clarity, visualization, and realistic testing.





THANK YOU