Ensuring a successful FPSO start-up by phased lifecycle approach of process Digital Twins

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FPSO BRASIL CONGRESS 2020 LIVE!

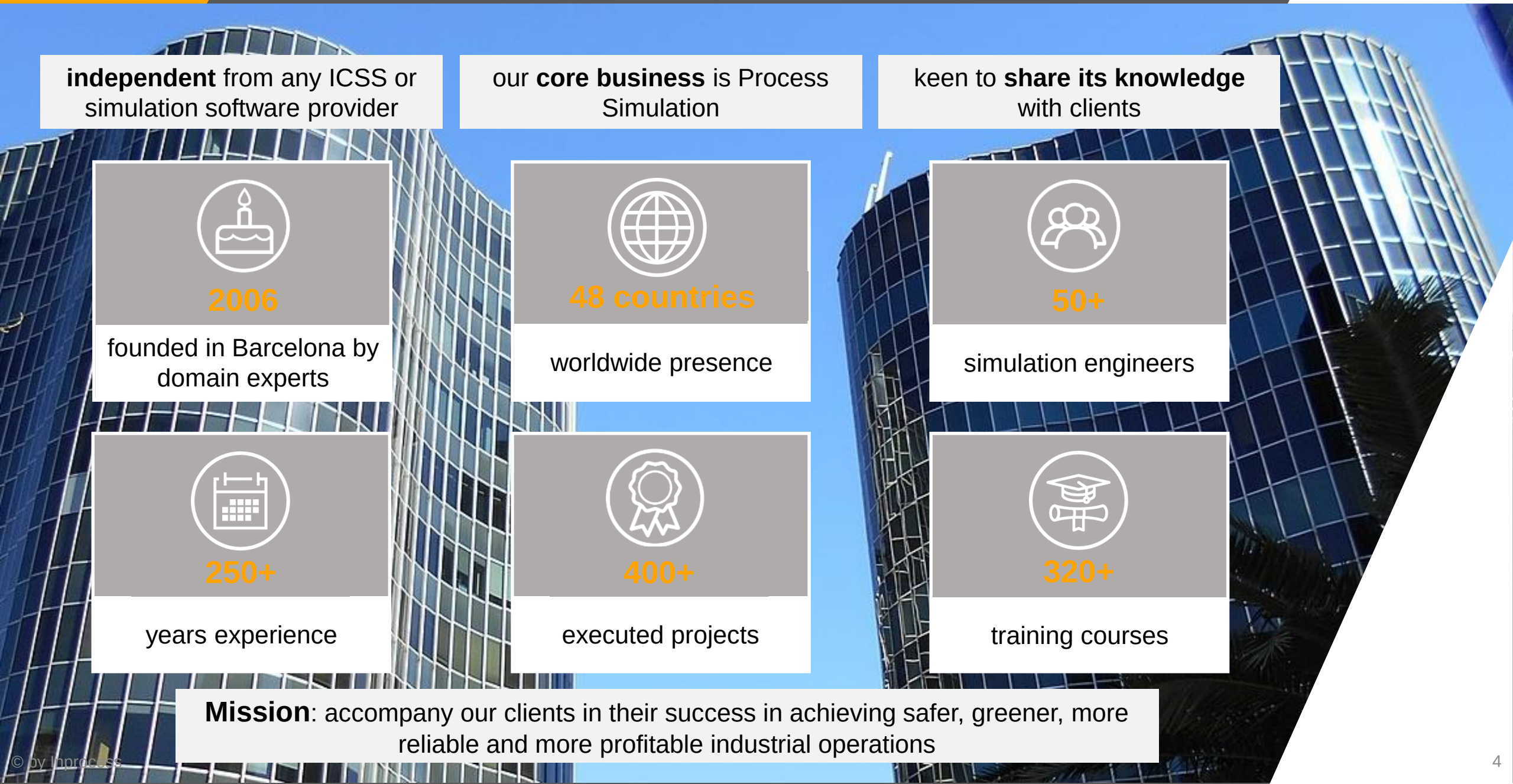
inprocess

Agenda

- **Who we are**
- **What could go wrong in an FPSO?**
- **Our Lifecyle Digital Twin vision to achieve Operational Excellence**
- **Inprocess Lifecyle Digital Twin Method**
- **Bad Actors Detector with online Digital Twins**
- **Benefits, references and Inprocess added value**
- **Your takeaways, Q&A**

Who we are

Inprocess in brief



independent from any ICSS or simulation software provider

our **core business** is Process Simulation

keen to **share its knowledge** with clients

2006

founded in Barcelona by domain experts

48 countries

worldwide presence

50+

simulation engineers

250+

years experience

400+

executed projects

320+

training courses

Mission: accompany our clients in their success in achieving safer, greener, more reliable and more profitable industrial operations

Lifecycle Modelling and OTS projects

Simulation Lifecycle	Feasibility Studies	Dynamic Simulation Studies (DSS) Validation of Control	Operational Procedures Early OTS	DCS check-out	OTS Operator Training System	Plant start-up support	Operations & Maintenance support with the Digital Twin
Plant Lifecycle	Conceptual Design, Basic Engineering (FEED) and Detailed Engineering (EPC)					Commissioning & start-up	Operations & Maintenance

Lifecycle Modelling

- Feasibility studies. Selection of alternatives
- Dynamic simulation studies before plant construction
- Validation of control philosophy
- Operational procedures development/enhancement
- Process trainer - Emulated OTS - Early OTS
- DCS check-out
- OTS for operators' initial and continuous training
- Support during commissioning and start-up
- Operations & Maintenance support (Digital Twin)

Process Simulation projects

Process Simulation Studies

- Steady State Analysis
- Dynamic Simulation Studies
- Integrated Flare Systems Analysis
- Flow Assurance Studies with OLGA
- Utilities Network Models
- On-line models
- Operations Staff Training
- O&M Support

Training & Knowledge Transfer

Training / Knowledge Transfer

- Process simulation courses
- Technology courses
- Knowledge Improvement Program – KIP
- Training for plant operators / technicians

Simulation Knowledge Profit

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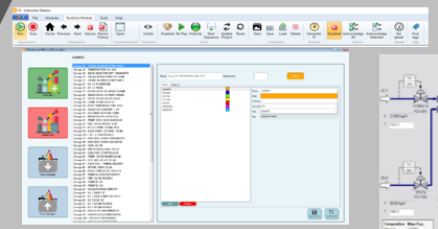
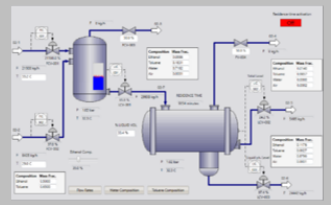
Applications & Software Development

Applications / Software Development

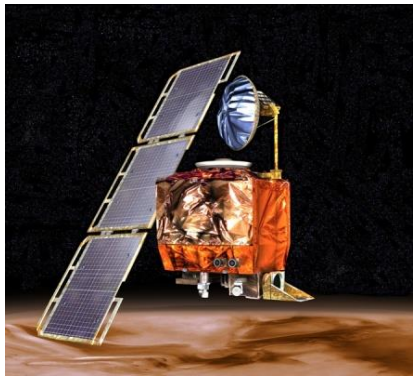
- **IIS**: Inprocess Infrastructure Suite
- **IPSV**: PSVs database
- **ITOP**: Inprocess Training for OPerators
- **ICOM**: Inprocess Competence Management System
- **IFLOW**: to link process simulators with OLGA®
- **IPSA**: Pressure Swing Adsorption simulator
- **OTS Web Access:** e-learning options
- Extensions for process simulators



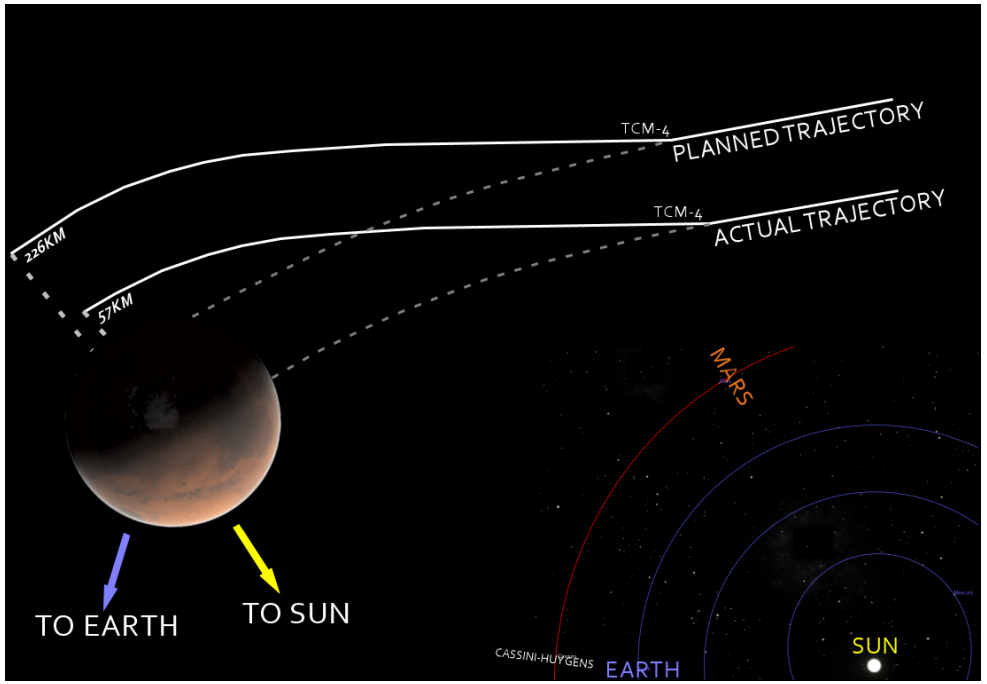


What could go wrong in an FPSO?

What could go wrong in a NASA mission?



1999: Mars Climate Orbiter vanished



A NASA review board found that the problem was in the software controlling the orbiter's thrusters, which calculates the force the thrusters needed to exert in **Pounds.** A separate piece of software took in the data assuming it was in **Newtons**.

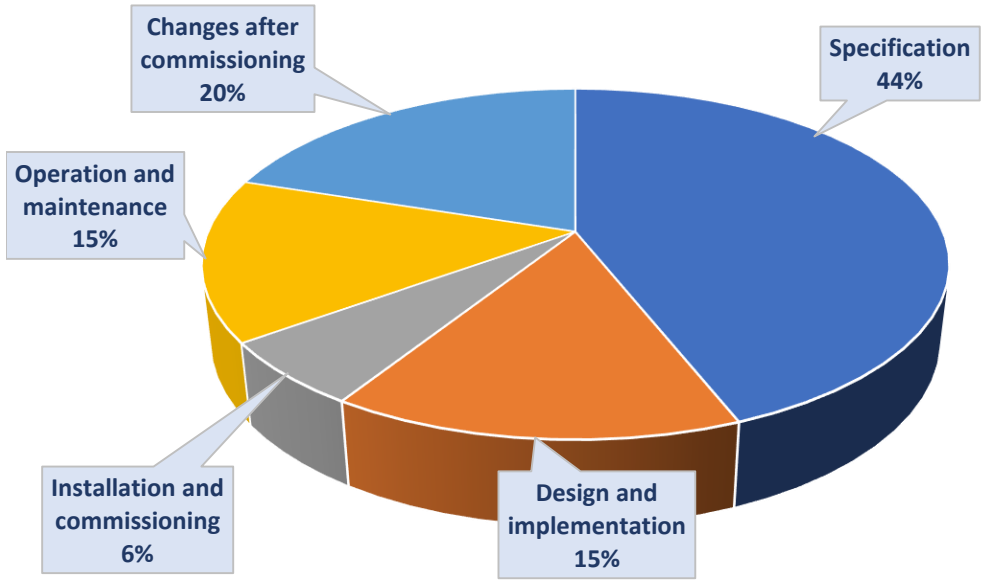
"People sometimes make errors"
"The problem here was not the error, it was the failure of NASA's systems engineering, and the checks and balances in our processes to detect the error"
said Dr. Edward Weiler, NASA's Associate Administrator for Space Science.

"Our inability to recognize and correct this simple error has had major implications"
said Dr. Edward Stone, director of the Jet Propulsion Laboratory.

Source: ftp://ftp.hq.nasa.gov/pub/pao/pressrel/1999/99-113.txt

Incident and Causes in the Process Industry

Analysis of 34 incidents and 56 causes identified.
The graphic shows the primary causes attributable to each lifecycle phase.



Source: Out of control, HSE

44% of cases the root causes is in the specification phase of a project

What could go wrong in an FPSO?

Basic Engineering (FEED)

Detailed Engineering (EPC)

Commissioning & Start-up

Operations & Maintenance

Simulation Lifecycle and Digitalization

Inherently Safer Design

Operational Excellence

What could go wrong in an FPSO?

PROCESS DESIGN

- Recycles valve sizing
- Hot Gas Bypass req.
- Compressor driver constraint
- GT constraint
- Set points consistency among process areas
- Trip value settings

OPERATING PROCEDURES

- Transition conditions
- Not feasible in real
- Excessive flaring
- Not safe Emergency procedures

CONTROL NARRATIVES

- Modules interaction
- Wrong parameters for loops, alarms, timing
- SIS definition

ICSS CODE

- Wrong Tags, Units, Ranges, modules…
- Errors in sequences
- Wrong loops tuning
- Alarms overload
- SIS implementation

HUMAN ERROR

- Insufficient quality training
- Unseen abnormalities
- Lack of monitoring, diagnose and operation support tools

LONG TERM IMPACT
Compromise the production along the whole FPSO life

SHORT TERM IMPACT
Causes spurious trips, equipment damages and delays in start-up in the order of 10-20 days

LONG TERM IMPACT
Decrease the %uptime along the whole FPSO life

Picture © bp p.l.c.

What could go wrong in an FPSO?

Basic Engineering (FEED) → Detailed Engineering (EPC) → Commissioning & Start-up → Operations & Maintenance

Simulation Lifecycle and Digitalization

Inherently Safer Design

Operational Excellence

PROC

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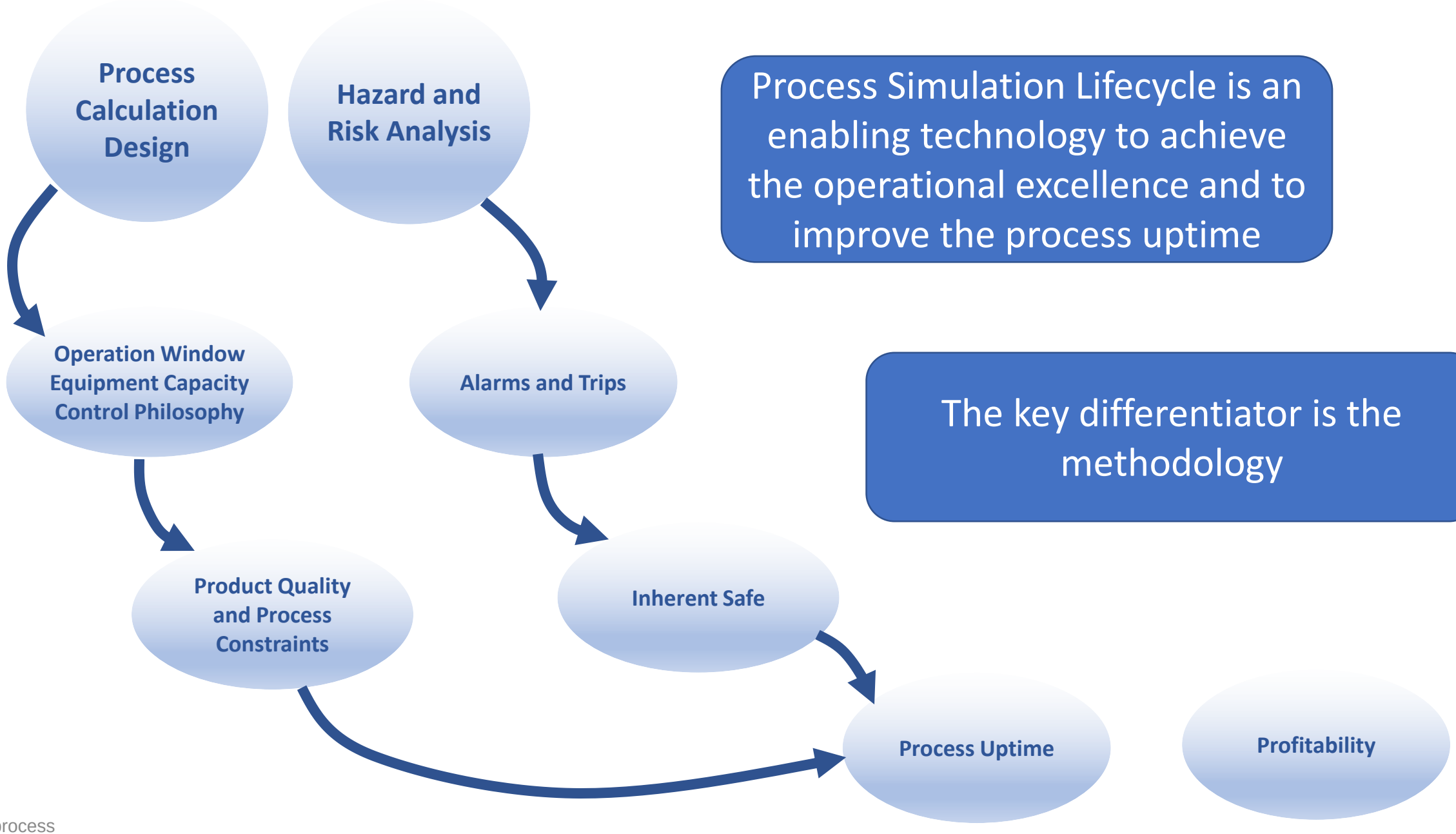
Picture © bp p.l.c.

Simulation Lifecycle



Process Simulation Lifecycle is an enabling technology to achieve the operational excellence and to improve the process uptime

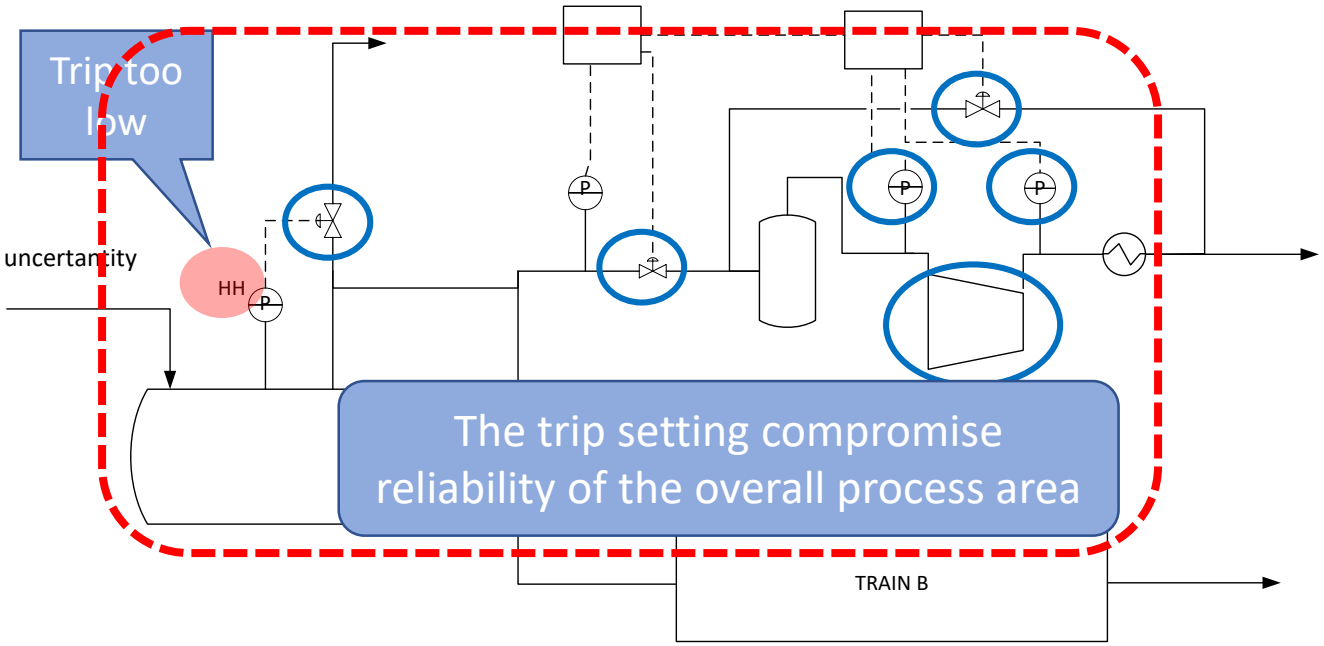
The key differentiator is the methodology

Sample Case of Spurious Operation

- **Why is important ?**
- **Where we can see the effect?**

Hazard and Risk Analysis → **Alarms and Trips**

Higher level of safety does not necessarily mean higher production regularity.
Improving safety without taking the production availability into consideration leads to safety design subject to spurious operations / activations.



How do we know the effect of the interactions?

Which is the margin to trip?

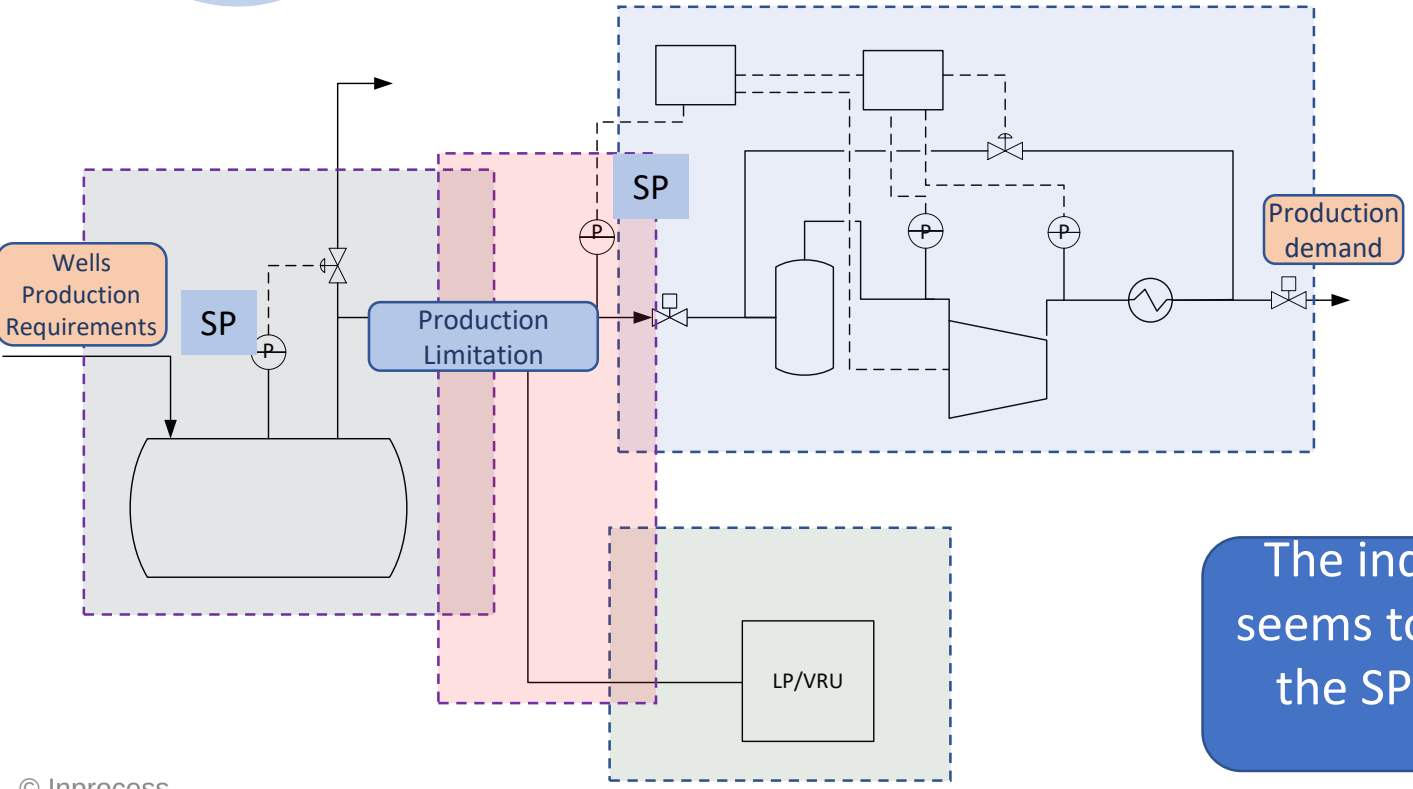
Dynamic analysis

- increase the knowledge
- allow calculating the margin to trip
- and assess how significant are the interactions

Vendor Packages Setpoints Consistency

- **Why is important ?**
- **Where we can see the effect?**

Hazard and Risk Analysis → **Alarms and Trips**



How do we know the effect of the interactions?

Which is the margin to trip?

Dynamic analysis

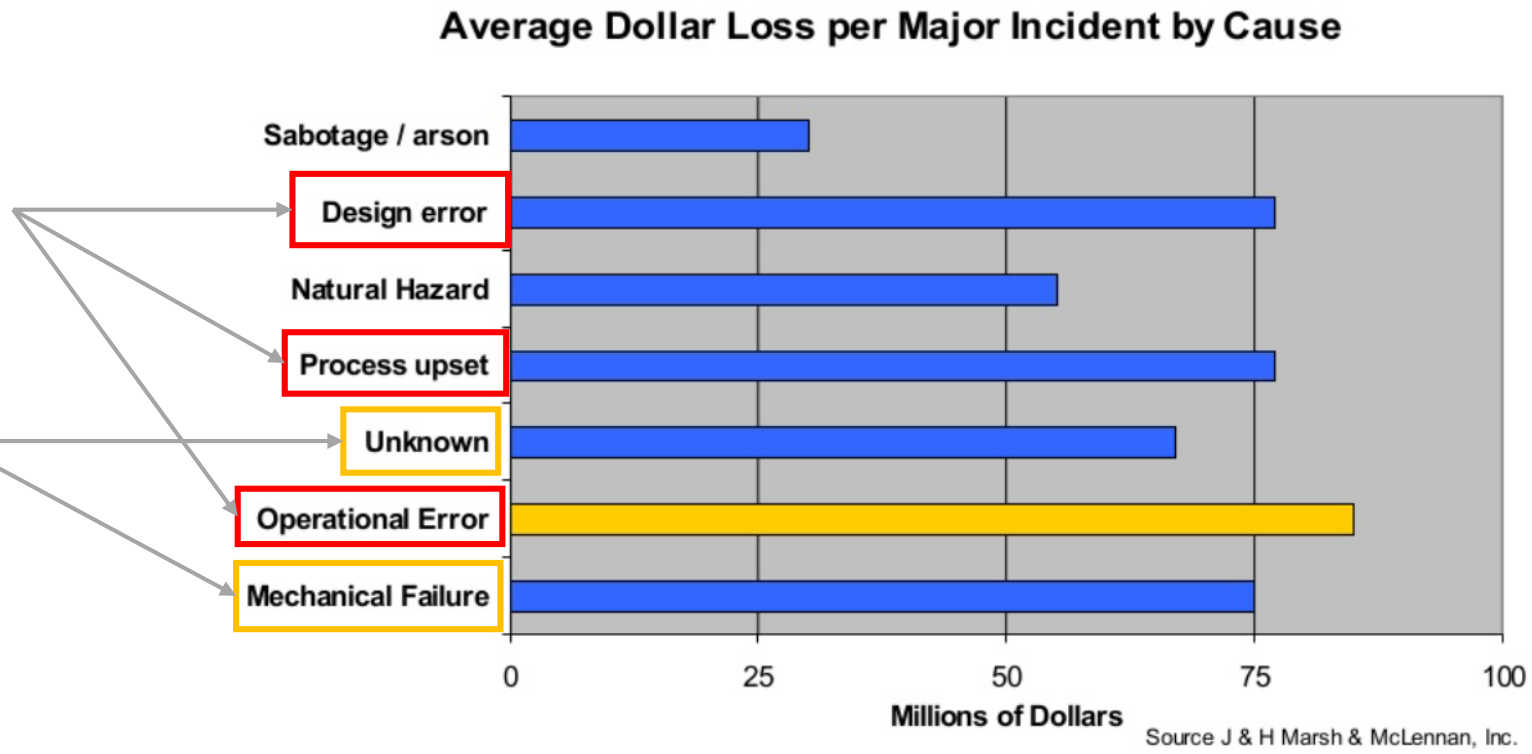
- increase the knowledge
- allow calculating the margin to trip
- and assess how significant are the interactions

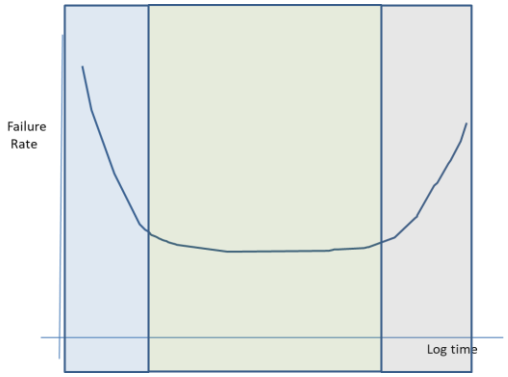
The individual setpoints of each package seems to be correct but when put together the SP are not consistent, this results in production limitation

Losses in the Hydrocarbons industry

We address these
with **Life-Cycle Digital Twin**

And also these
with **Online Digital Twin**





In the first 10 years of a plant's operation, most losses are caused by operations-related failures. As plant operations experience develops, the number of losses reduces, until age takes its toll and there is a steep rise in both loss frequency and magnitude in plants more than 30-years-old. In plants older than 30 years, mechanical-integrity-related failures account for 65% of losses.
Source J&H Marsh &McLennan

Our Lifecyle Digital Twin vision

Also called:

Lifecycle Operator Training Simulator (LC OTS)

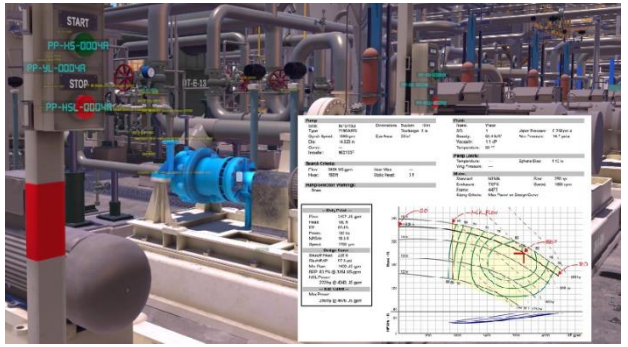
Or

Multi-Purpose Dynamic Simulator (MPDS)

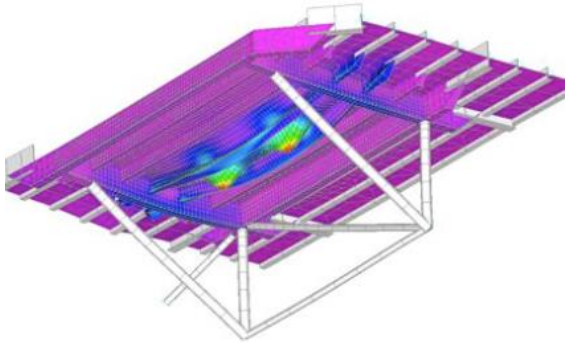
Inprocess' Approach to Digital Twins

- **Digital Twins are virtual copies of physical assets and their operating behaviours**
- **This definition has several points of view which are complementary to each:**

Contextualized 3D models

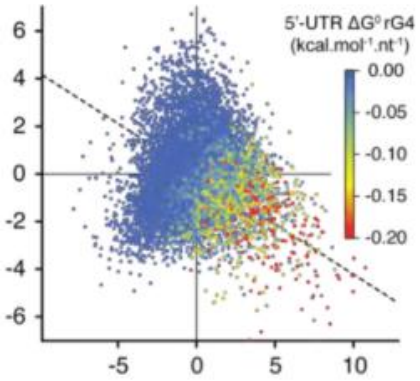


Mechanical and structure models

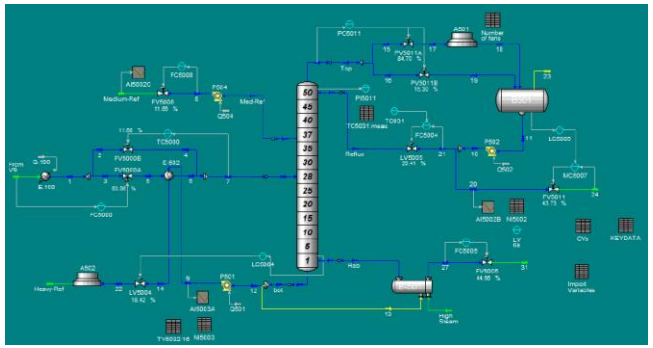


Digital Twins

Empirical Models (data fitting)

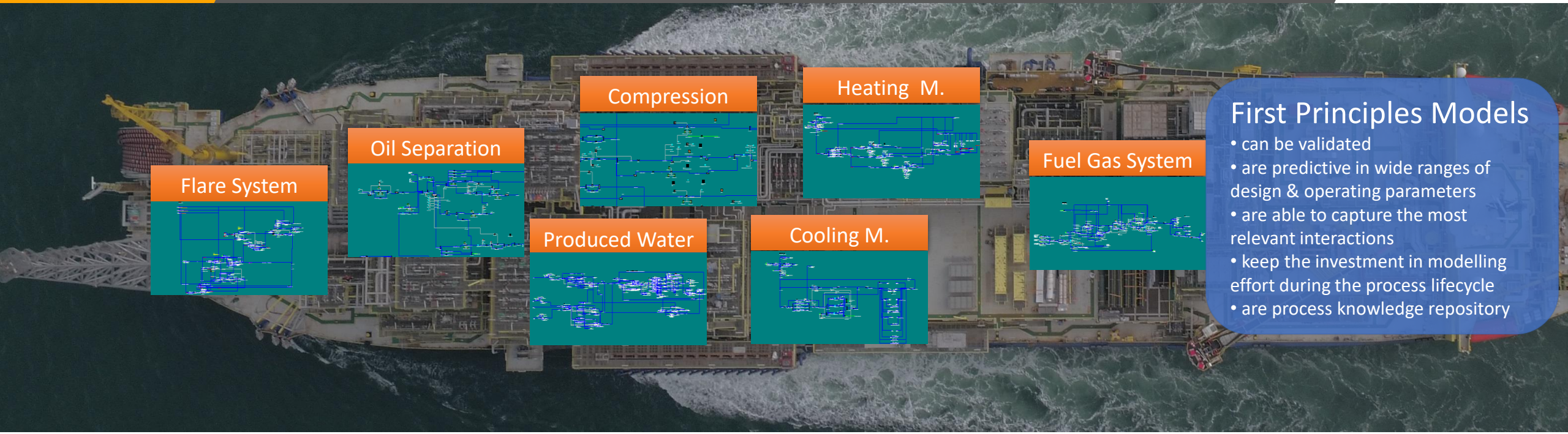


First-Principles Models



Centuries of Physics, Chemistry and Thermodynamics knowledge are consolidated here!

The Process Digital Twin concept



First Principles Models

- can be validated
- are predictive in wide ranges of design & operating parameters
- are able to capture the most relevant interactions
- keep the investment in modelling effort during the process lifecycle
- are process knowledge repository

The Process Digital Twin is a ***first-principles*** dynamic model with:

Use of thermodynamic models for properties calculation

All the process streams (P, T, Flow, Composition, properties)

All the equipment geometric data (dimension, elevation, sensor location)

All equipment manufacturer performance data (pump curves, compressor curves, heat exchanger rating data, etc)

All valves (size, pressure drop, characteristic, timings, PSVs, ESDVs)

All controllers and instrumentation (ranges, PID algorithms, logics, tuning)

Technicians can **safely** explore **what-if scenarios without** putting people or the asset at **risk**

It is a valuable **model of asset health**, forecasting and recommending action to avoid degradation and asset failure events.

All data is contained in a Process Model, built in the first principles commercial simulation tool used during design stage of the process

Software Component
Inprocess Infrastructure Suite

Methodology
Lifecyle Digital Twin Method

Basic Engineering (FEED) → Detailed Engineering (EPC) → Commissioning & Start-up → Operations & Maintenance

Simulation Lifecycle and Digitalization

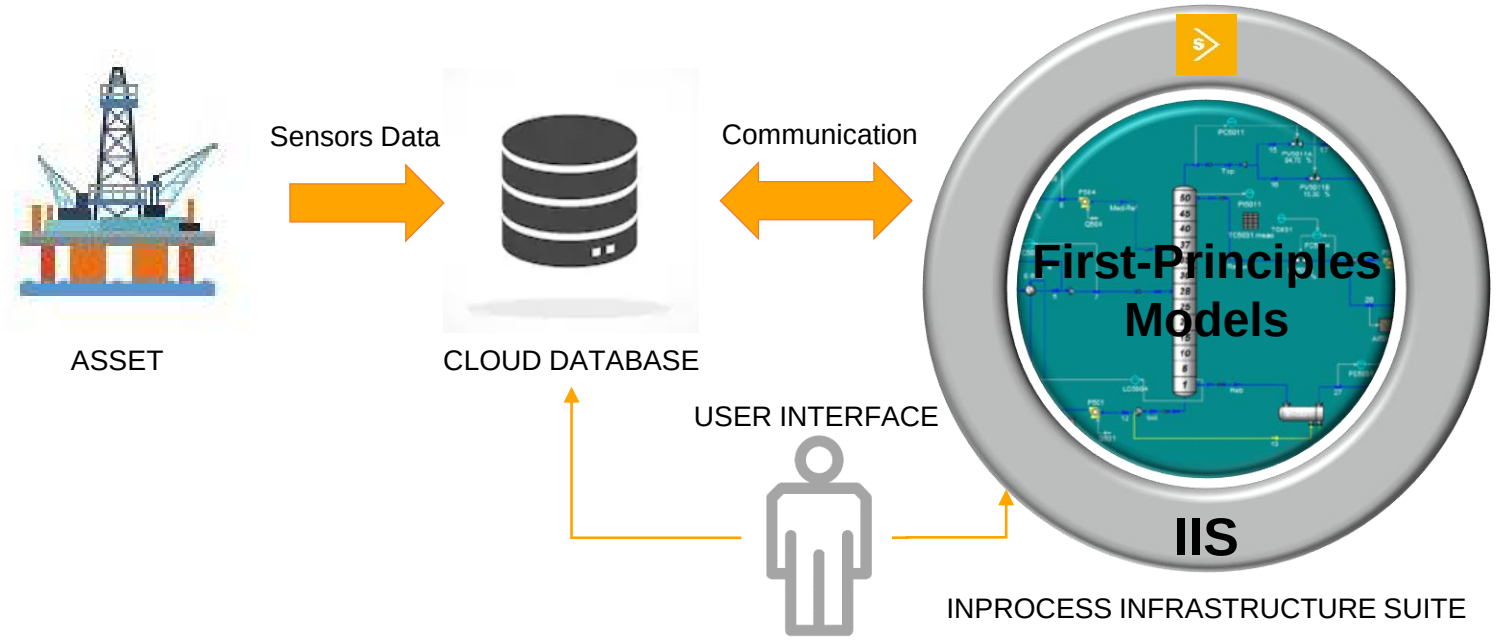
Inherently Safer Design

Operational Excellence

Inprocess Infrastructure Suite

Process Simulation Model + Inprocess Infrastructure Suite = Inprocess' Digital Twin

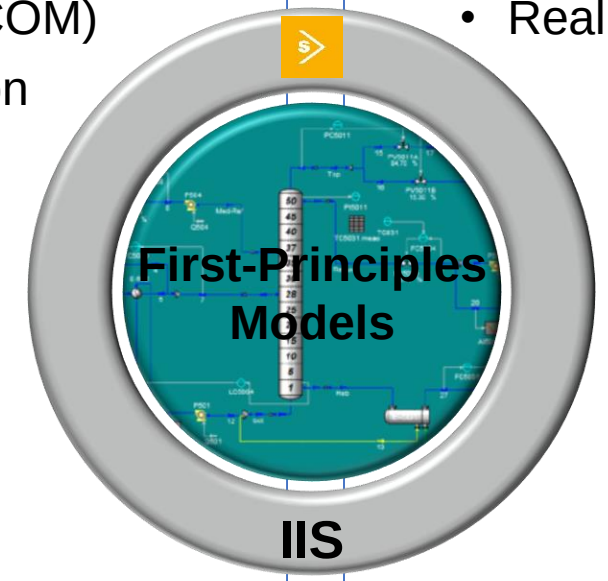
- **Inprocess Infrastructure Suite (IIS) expands the rigorous, first-principles model into a Digital Twin, by adding a software layer that allows to incorporate:**
  - **Connectivity** to any external data source,
  - **HMI builder**, to develop user-friendly interfaces
  - **Ad-hoc functionalities:** OTS instructor functions, online digital twin functionalities, etc.
  - **Cloud-based** installation, allowing for remote access



Applications for the Process Digital Twin

Off-line

- Engineering Design Support
- ICSS Validation
- Operator Training Simulators
- Competence Management (ICOM)
- Process & Control Optimization



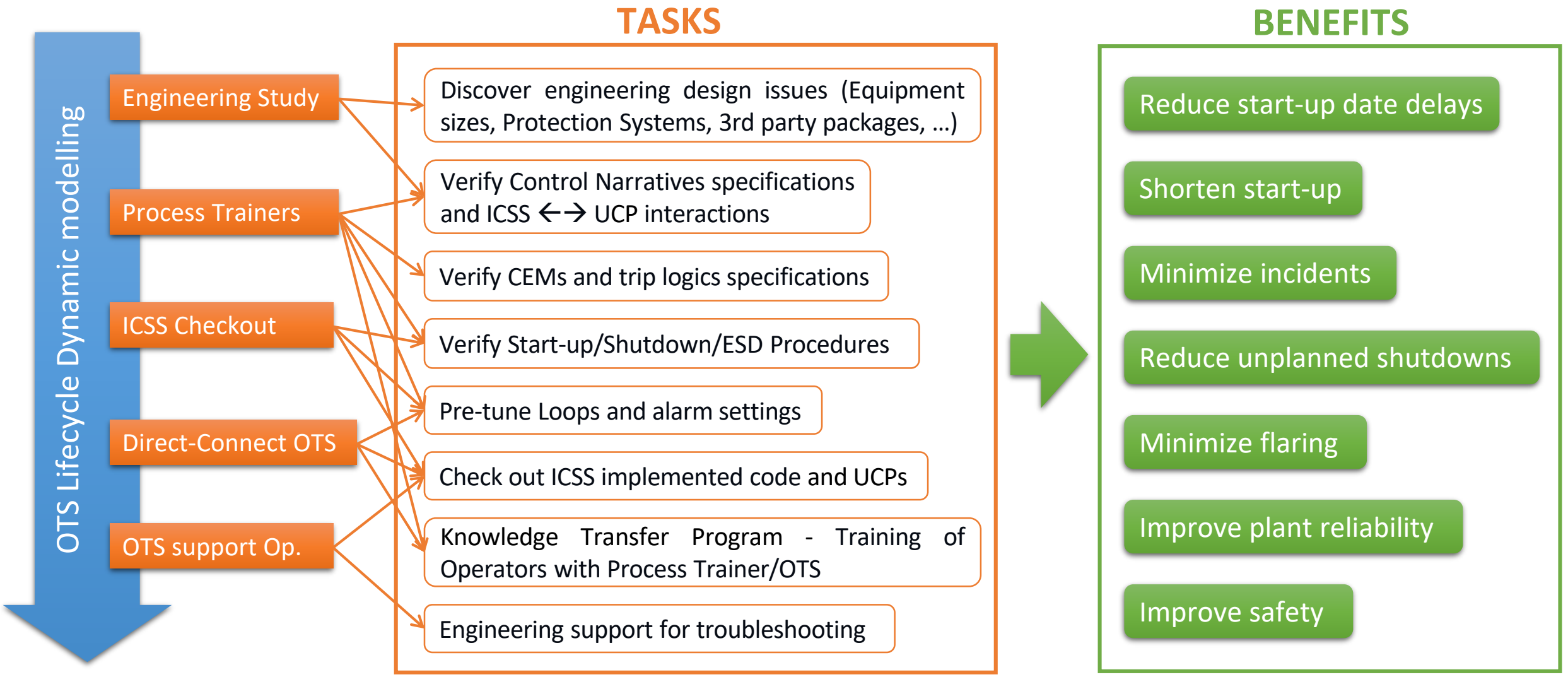
On-Line

- Equipment Load & Efficiency Monitoring
- Bad Actors Detection
- Look-ahead & What-if
- Real Time Optimization

Inprocess Lifecyle Digital Twin Method

Simulation Lifecycle Methodology Benefits

The phases are aligned with the specific needs of the project, to provide the necessary information to the engineering team and solve any issue encountered, which assists the project's success.



Steps in a Lifecycle OTS Project

Analysis of critical units

Control Narrative and Procedure Verification

Engineering Study

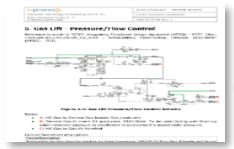
Additional equipment, ICSS/UCP Control Narrative, CEMs, interlocks

Model Adjust

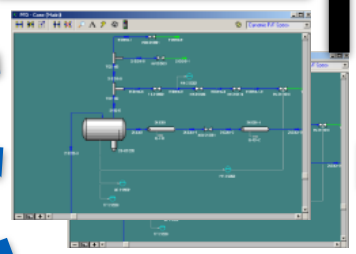
Process Trainers

ICSS HMI Emulated with Inprocess Instructor Station

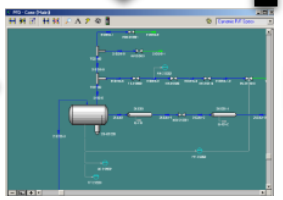
Early CRO Training -Knowledge Transfer



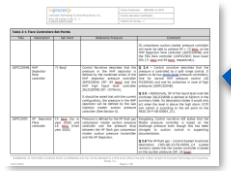
Engineering Data



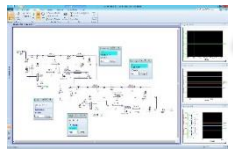
Dynamic Model built



Model Connectivity

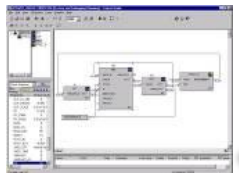


Plant Data

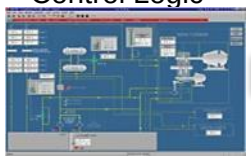


Model from engineering Studies

Direct-Connect OTS



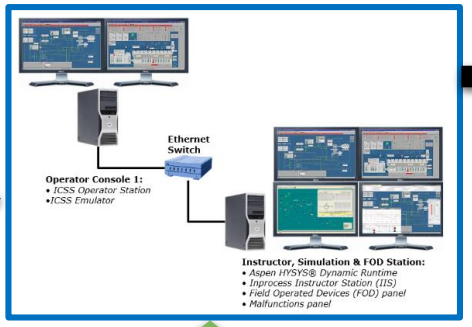
ICSS Database Control Logic



ICSS HMI displays

ICSS Checkout

ICSS Virtual Commissioning



Instructor Station, Training Scenarios, Additional ICSS Consoles

OTS ready

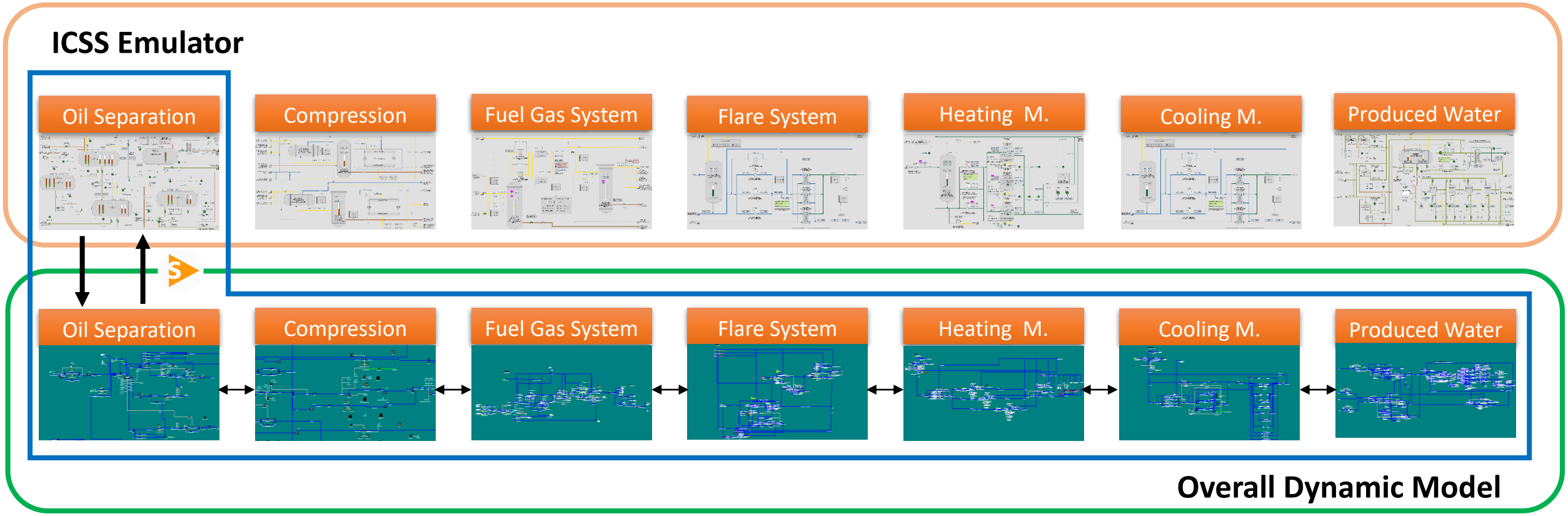
Training

Support Operations with Digital Twin

OTS Maintenance

ICSS database checkout – standalone unit validation

- **Initially the overall dynamic model is running and the process simulator controllers are controlling the plant.**
- **Afterwards, during the validation of the individual units we start connecting the Input and Output signals to the selected modules and start transferring the control from process simulator to the ICSS emulator.**

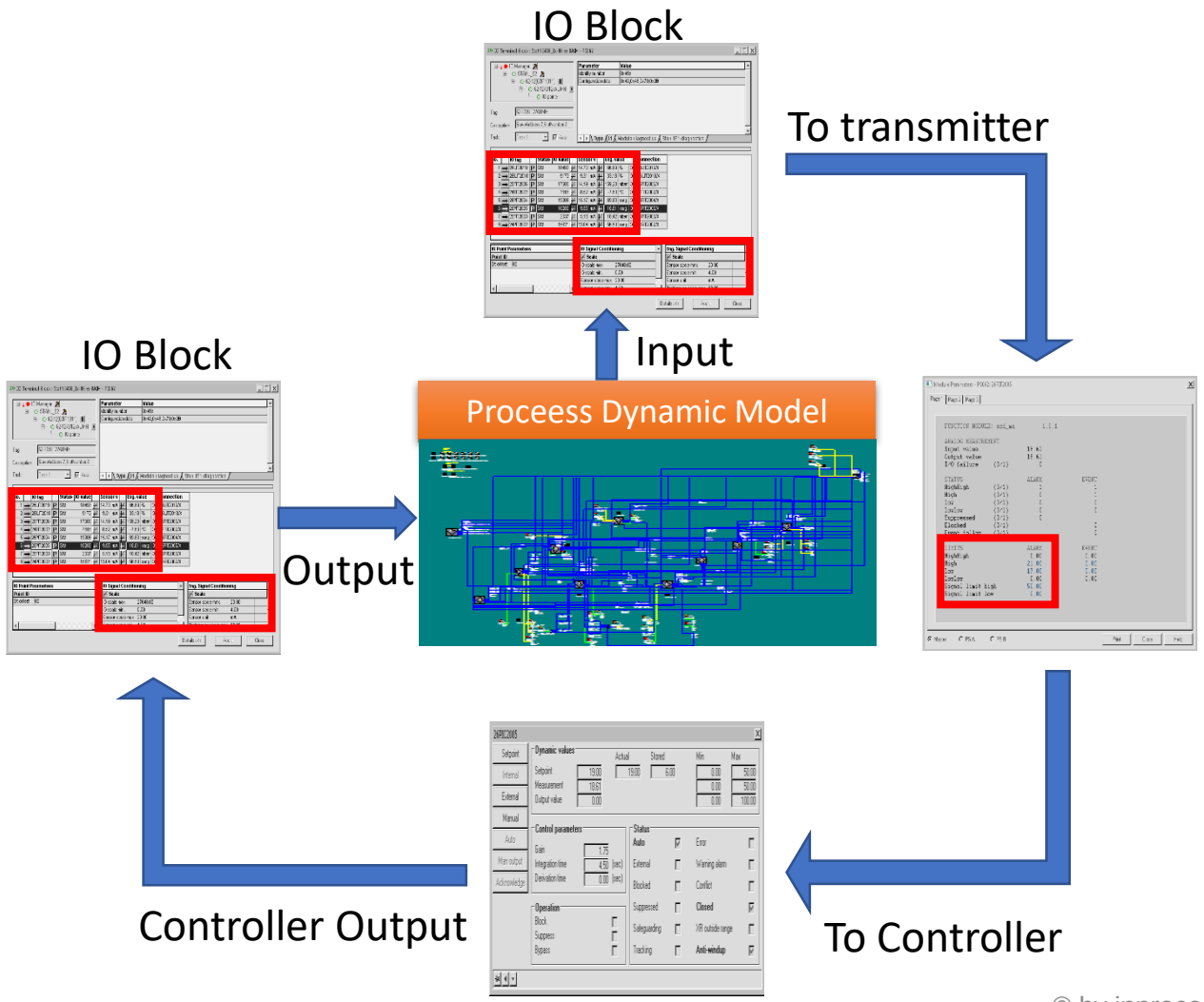


ICSS database checkout – standalone validation - benefits

Benefits of the ICSS Standalone Unit Validation

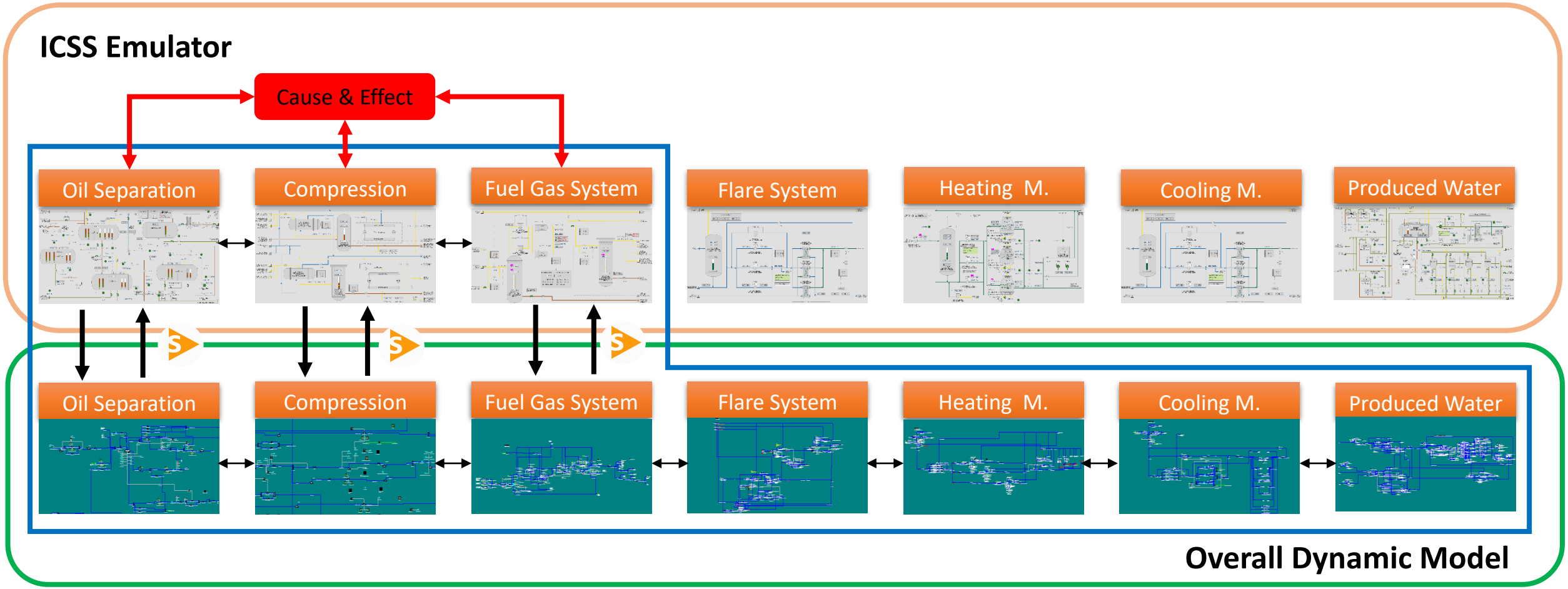
- Early Database checkout: ICSS modules don't need to be finalised to start its validation.
- Parallel Debugging: The different modules can be tested in parallel.
- IO signals and transmitters verification: Ranges, Units, Alarm & Trip settings, missing or wrong connections.
- Controllers & Logic:
  - Implementation according to the latest control philosophy
  - Controllability and operability
  - SP, PV, OP Ranges and additional functionalities

DCS Controller validation cycle



ICSS database checkout – partial integration validation

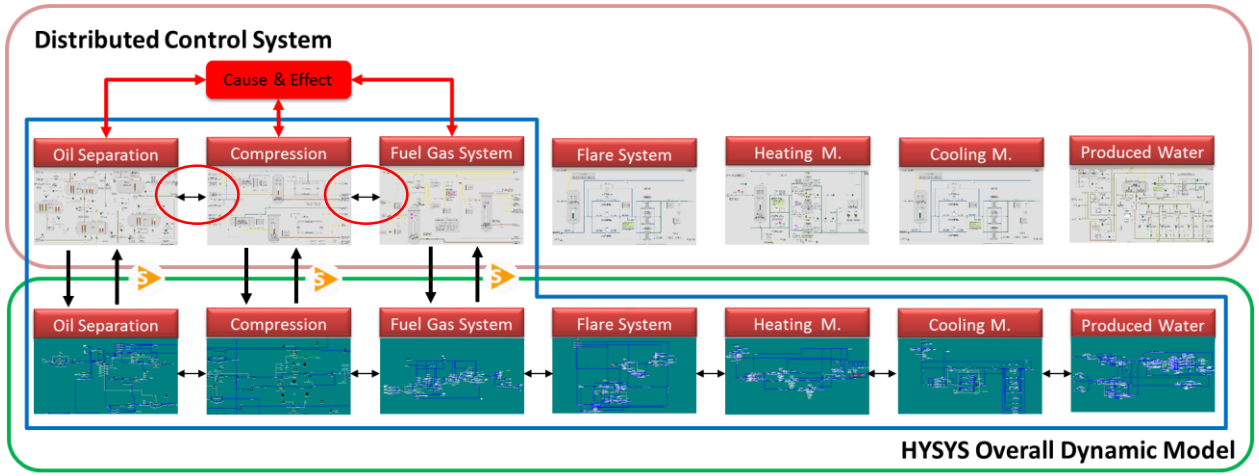
- **After performing the ICSS validation of the standalone units. The next step is connecting several units with significant interaction between them. The Cause & Effect is enabled.**

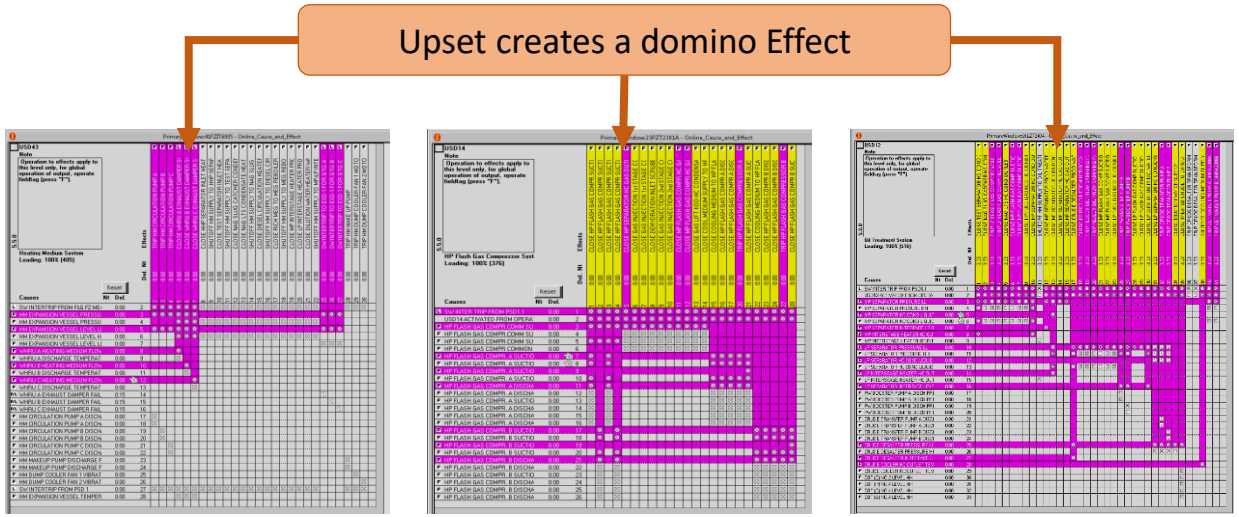


ICSS Database checkout – partial integration - Benefits

Benefits of the ICSS Partial Integration Validation

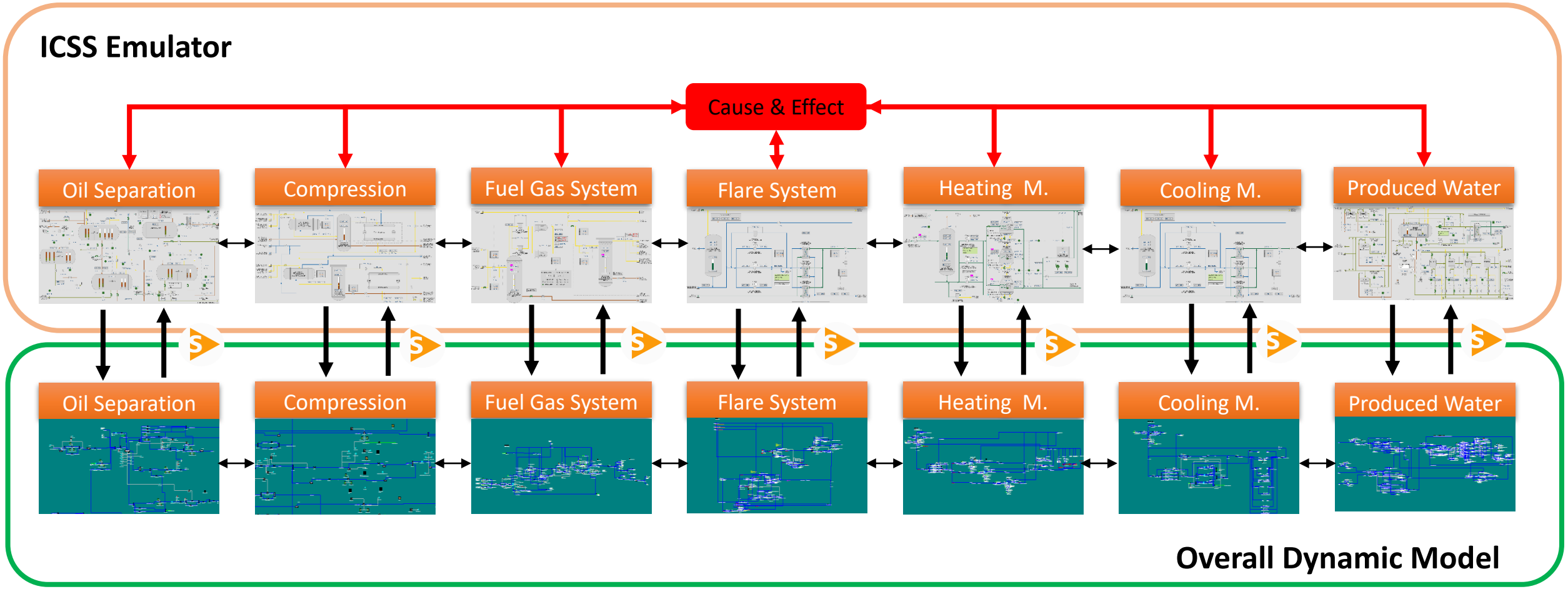
- Evaluating the performance of control loops or logic blocks which require signals from other Units.
- Prioritizing the connectivity of areas which have significant control interactions to evaluate its controllability and operability at an early stage.
- Evaluating the Unit's transient dynamics and control response due to:
  - The control interactions between the nearby units
  - The execution of sequences or specific procedures
    - Unit Start-Up
    - Unit Normal Shutdown
    - Backwash Sequences
- Evaluating the effectiveness of the cause and effect matrix to keep the plant safe during its activation:
  - Involving Several Units.
  - Analysing the possibility of domino effects





ICSS Database checkout – full connection

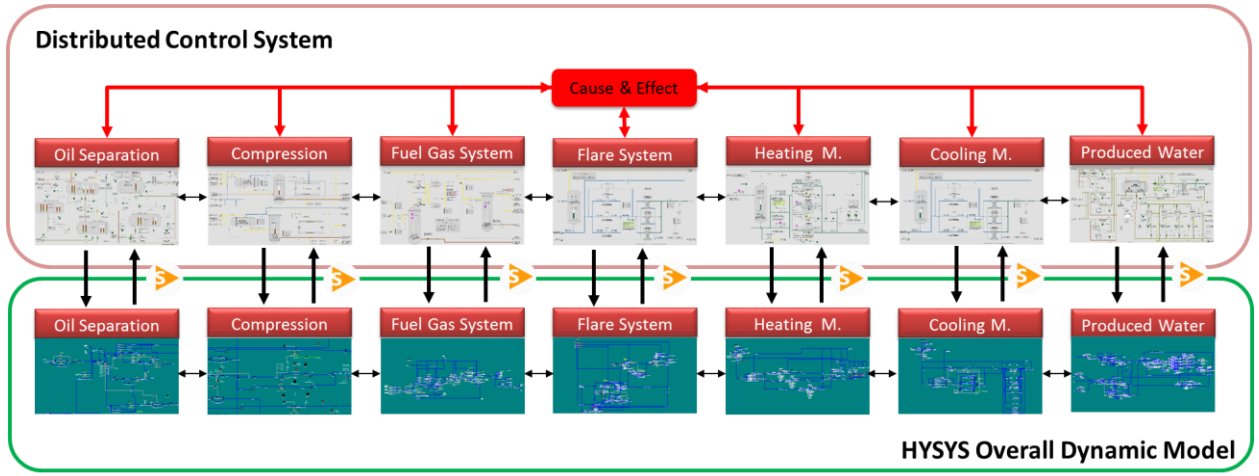
- **The final phase consists in performing a direct connect OTS solution, where the distributed control system is controlling the plant as in the real operator control room.**

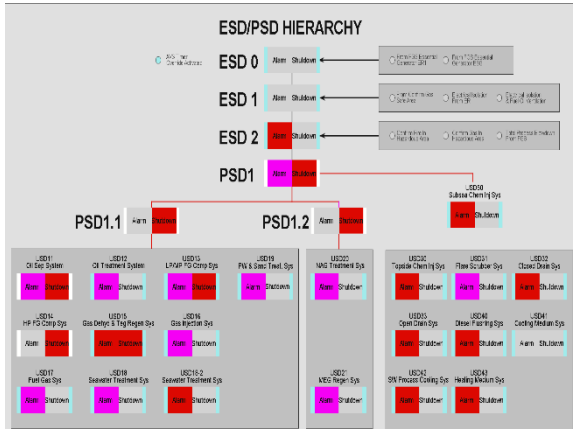


ICSS Database checkout – full connection - Benefits

Benefits of the ICSS Full Connection Validation

- Evaluating the interactions between all the control loops and logic blocks .
- Evaluating the plant's transient dynamics during the execution of specific scenarios or upset conditions.
- Evaluating all the procedures of the plant and its impact in the transient behaviour.
  - Plant Start-Up
  - Plant Normal Shutdown
  - Plant emergency shutdown
- Evaluating the effectiveness of the cause and effect matrix under all conditions.
- Operators are trained with the same control logic and functionalities they will use in the operator control room.



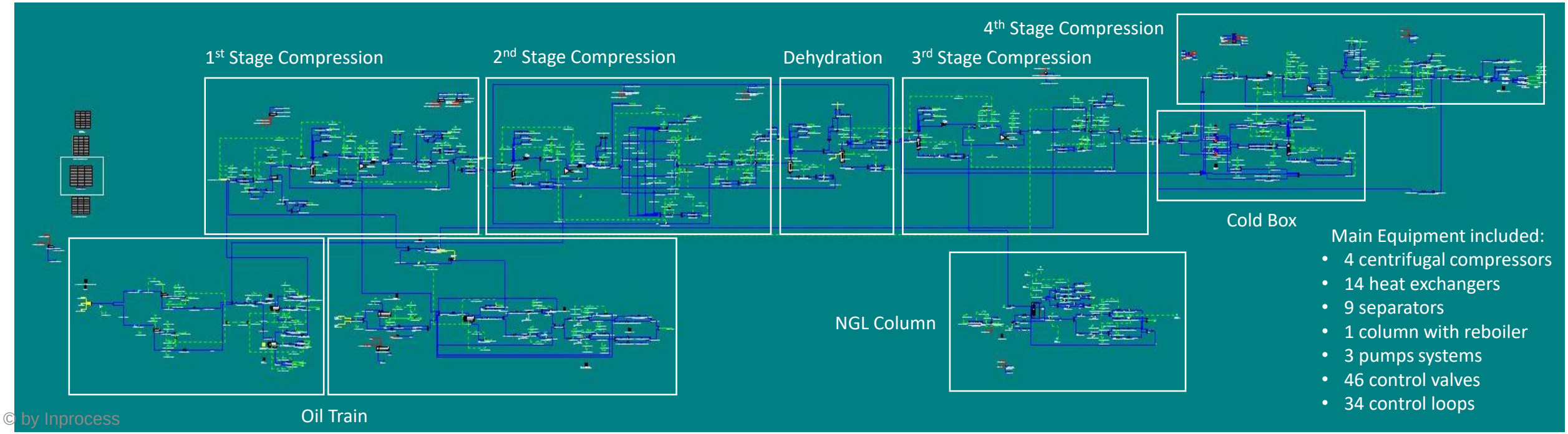


Bad Actors Detector with online Digital Twins

Case Study: Online Process Digital Twin

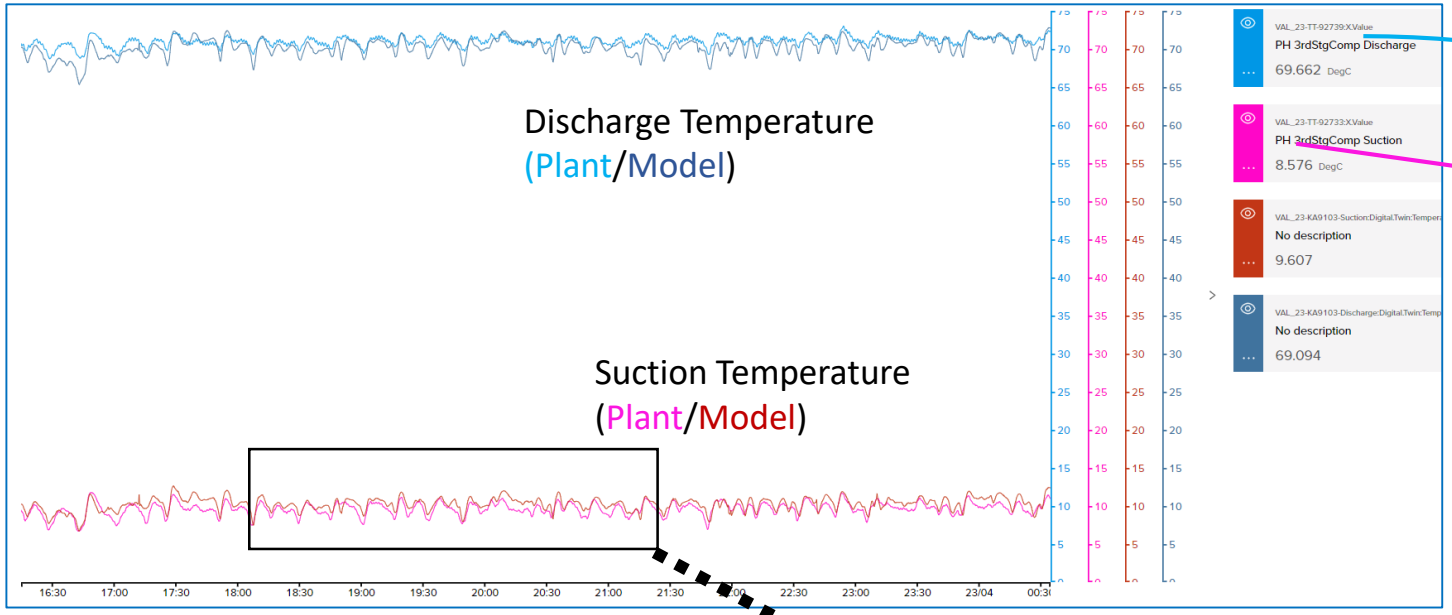
PROCESS DIGITAL TWIN

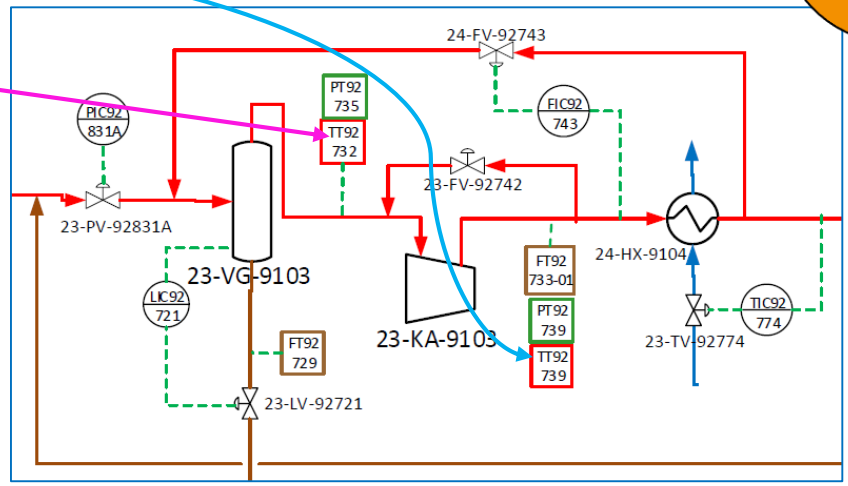
- Dynamic model replica of the asset, synchronized online with real-time plant data.
- Tracking of the asset behavior, using client's real-time database to read/write the necessary data.
- Calculation of real-time values for temperature, pressure, flow, composition where no instruments are placed, as well as for products' properties such as MW, Wobbe Index, RVP, density, etc:
  - Easy access to data through the client cloud database or Inprocess IIS.
  - No need to access the simulation case, which can be visible to the user or not.
  - Model Quality Indicators (difference between plant values and model ones).
- Historical Models Repository: Snapshots of the running dynamic model are periodically saved, allowing the DT user to pick up any past plant status and use it for post-incident analysis or What-If.



Plant Behaviour Tracking: 3rd Stage compressor

PROCESS DIGITAL TWIN

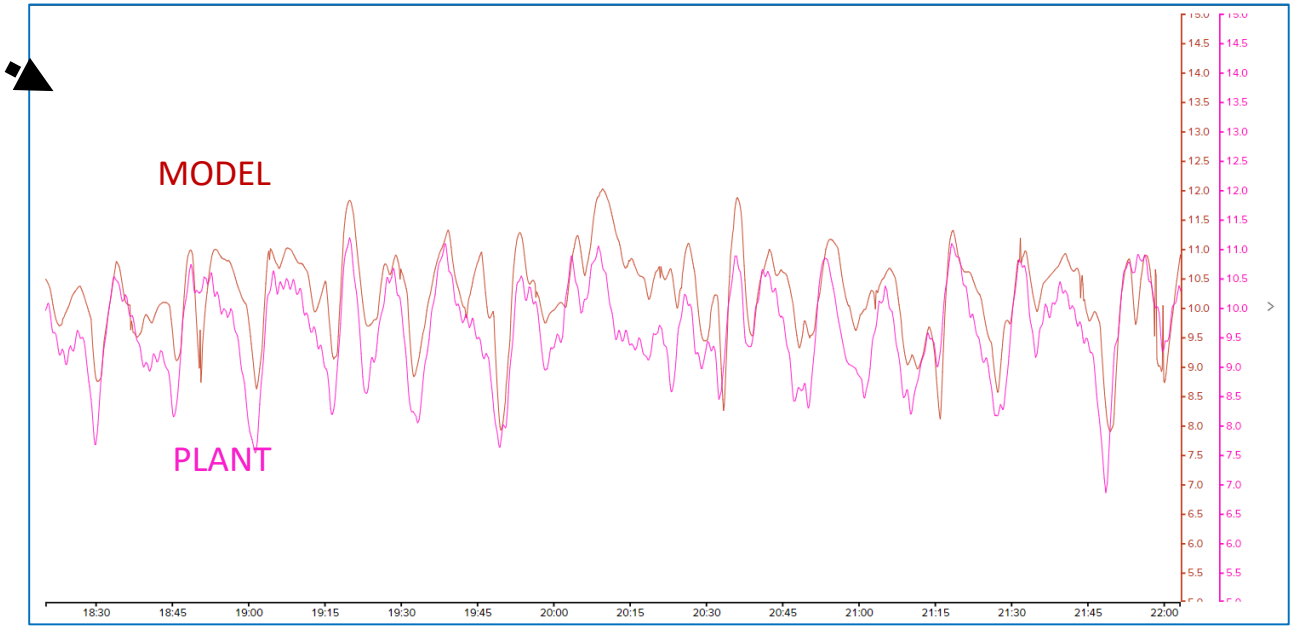




Overall, the Digital Twin is tracking the plant data relatively well, given the severe slug patterns.

Special attention should be paid to:

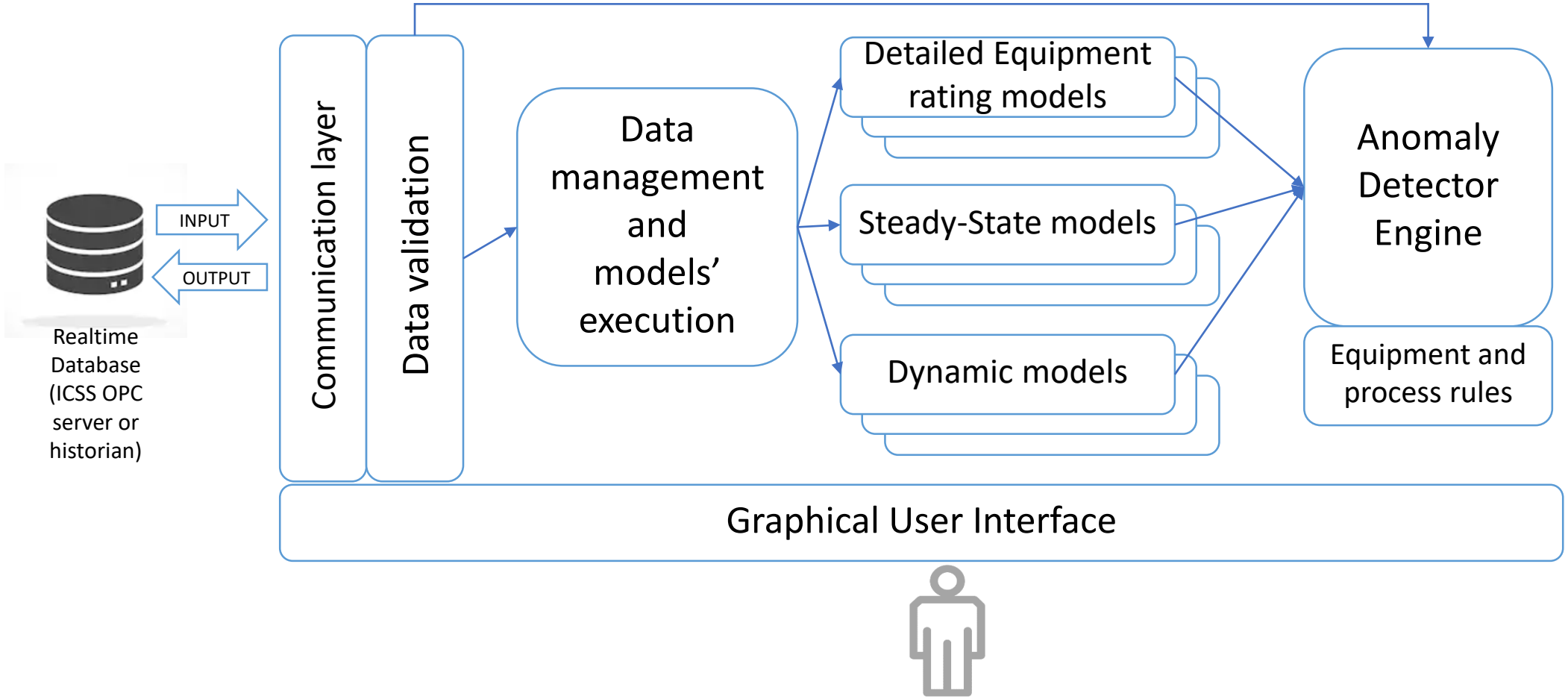
- Tuning of the ASC controllers
- Valves characterization
- Location of instruments
- Pipe volumes
- Feed compositions



Online Digital Twin Use Case: Bad Actor Detector

Anomalies (Bad Actors) Detection

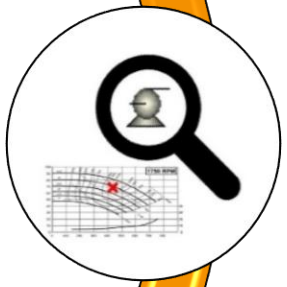
- It provides early warnings of plant anomalies based on detected discrepancies between plant instrumentation (reality) and rigorous models' results (ideality)



Process Digital Twin modules and value

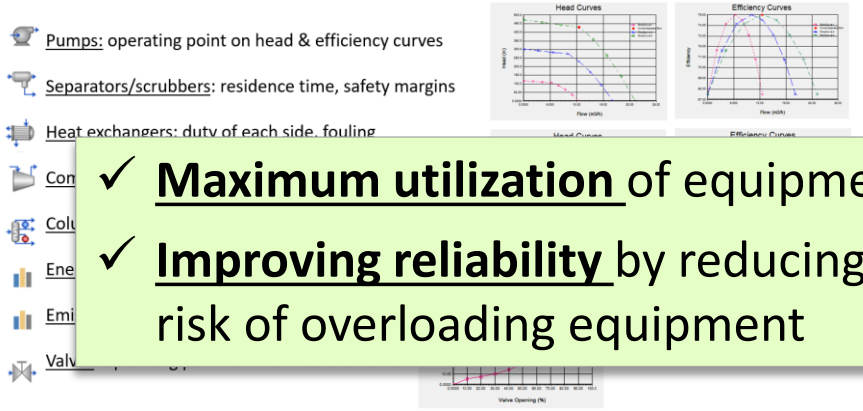
PROCESS DIGITAL TWIN

EQUIPMENT LOAD AND EFFICIENCY CALCULATOR

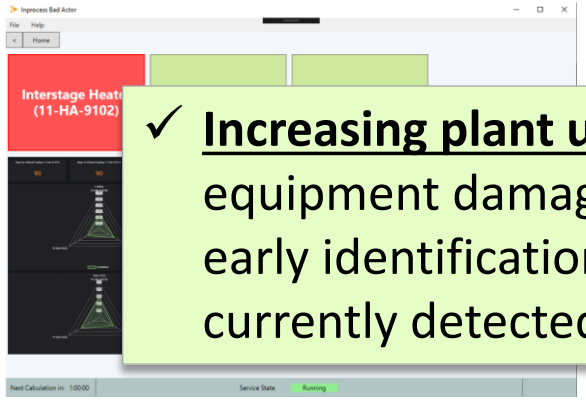


BAD ACTORS DETECTOR

WHAT-IF & LOOK-AHEAD



- ✓ **Maximum utilization** of equipment
- ✓ **Improving reliability** by reducing risk of overloading equipment



- ✓ **Increasing plant uptime:** Avoiding equipment damages or plant trips by early identification of anomalies not currently detected by ICSS alarms

- ✓ **Safer operation**:

  Improved pre-action analysis
- ✓ **Better root-causes understanding**: Improved post-incident analysis

Benefits, references and Inprocess added value

Economic benefits for FPSOs

Estimating the economic benefits is a challenging task since it depends on the specific FPSO complexity and project methodology, but it can be categorized in three areas of value:

Corrections and solved issues in PROCESS DESIGN

- Avoided production bottlenecks
- Avoided equipment damages

Start-Up: From few days to several weeks (i.e.: change/repair injection compressor)

Normal Operation: Limit max production

Corrections and solved issues in OPERATING PROCEDURES, CONTROL NARRATIVES, ICSS DATABASE

- Avoided commissioning and start-up delays
- Avoided equipment damages

~13 production days

(13MM$ net cash for a 100kbpd FPSO)

Average saving Norwegian O&G is 18 days

Quality training of CRO´s /Engineers Diagnose/Operation support tools

- Avoided Operation human errors
- Avoided equipment damages

~2 Unplanned Shutdowns less
~2 days shorter Planned Shutdowns

Average Norwegian O&G is 3 saved SD and 2.2 days

Source: *Economic benefits of training simulators.* World Oil December 2012

Lifecycle Digital Twins in FPSOs – Inprocess projects

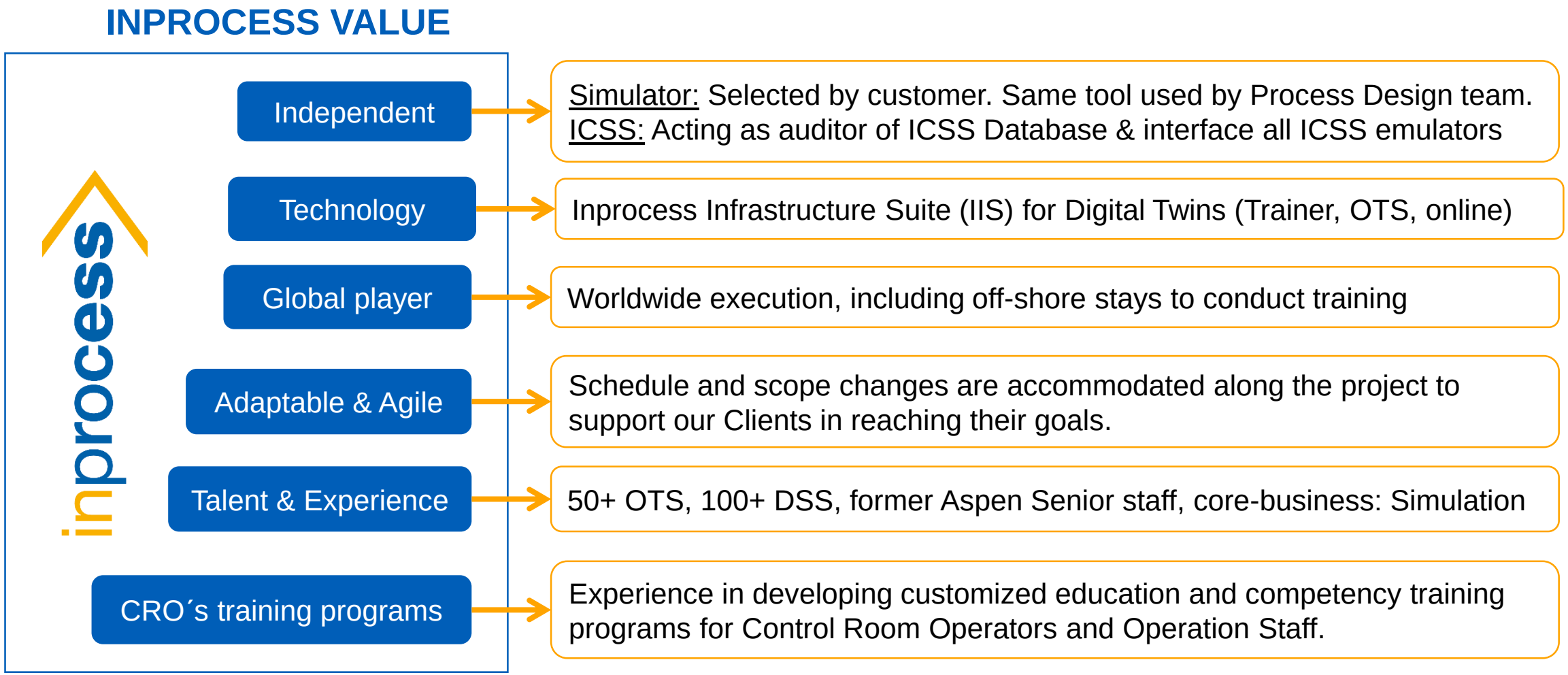
		Inprocess Lifecycle Digital Twin Method				
AWARDED	FPSO Location	Dynamic Simulation Studies	Early-OTS Process Trainer	ICSS Checkout	Full Direct Connect OTS	Operation Support & Training
2011	Norway	■				■
2012	Brazil	■	■		■	■
2013	Brazil	■				
2014	Ghana	■	■			
2015	Brazil	■	■		■	■
2016	Ghana	■				
2016	Brazil	■	■	■	■	■
2018	Ghana	■	■	■	■	■
2019	Brazil				■	
2019	Brazil				■	
2019	Brazil	■	■	■	■	■
2019	Brazil	■	■	■	■	■
2019	Mexico	■				
2020	Brazil	■	■	■	■	■
2020	Malaysia	■				
2020	Brazil	■	■	■	■	■

"I understand better how control loops are link and interact with each other, compressor limits are more clear, transitions procedures were understood and we were able to optimize them"
FPSO CRO

"The preparations through the simulator exercises and pre-tuning of the controllers really seems to pay off – basically the operators have been running everything in auto since the start-up ☺. Thank you very much for your effort and dedication to the simulator! Well done!".
FPSO Production Manager

Inprocess added value

Customers chose Inprocess as the company to fully exploit Lifecycle Dynamic Modelling for their projects



Your takeaways

Your takeaways

Originally appeared in World Oil® NOVEMBER 2017 issue, pgs 33-38. Posted with permission.

SPECIAL FOCUS: ADVANCES IN PRODUCTION

FPSO lifecycle modeling adds benefits to development offshore West Africa

In a recent FPSO development project offshore West Africa, a lifecycle modeling approach project, ending in a direct-connect Operator Training System with Aspen HYSYS Dynamics, was used for process

Yinson Production Pte Ltd (Yinson) recently converted a double-hull, very large crude carrier (VLCC) oil tanker to a Floating Production Storage and Offloading (FPSO) vessel for its development project offshore West Africa. In this project, the dynamic models from the engineering phase have been re-used for process design

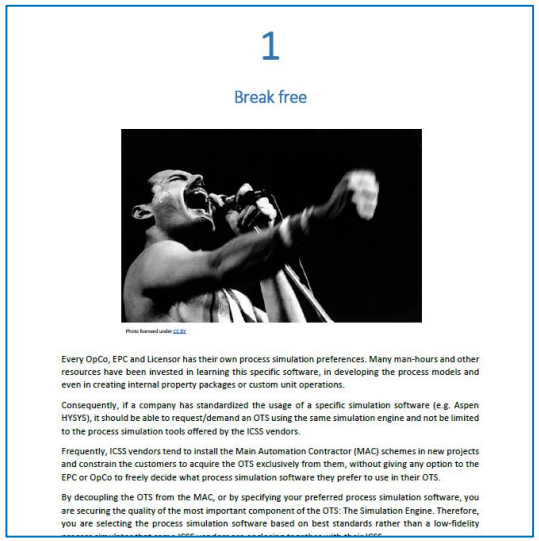
- Is the primary protection designed properly for the planned operational conditions?
- Will the safety system perform well?
- How will the vendor packages control system interface with the integrated control & safety system (ICSS)?

World Oil article about applying Lifecycle modelling to Yinson JAK FPSO in Ghana

Visit our virtual stand in this congress, our webpage, or Google

FPSO lifecycle modelling

Yinson OTS HYSYS



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Break free

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Every OpCo, EPC and Licensor has their own process simulation preferences. Many man-hours and other resources have been invested in learning this specific software, in developing the process models and even in creating internal property packages or custom unit operations.

Consequently, if a company has standardized the usage of a specific simulation software (e.g. Aspen HYSYS), it should be able to request/demand an OTS using the same simulation engine and not be limited to the process simulation tools offered by the ICSS vendors.

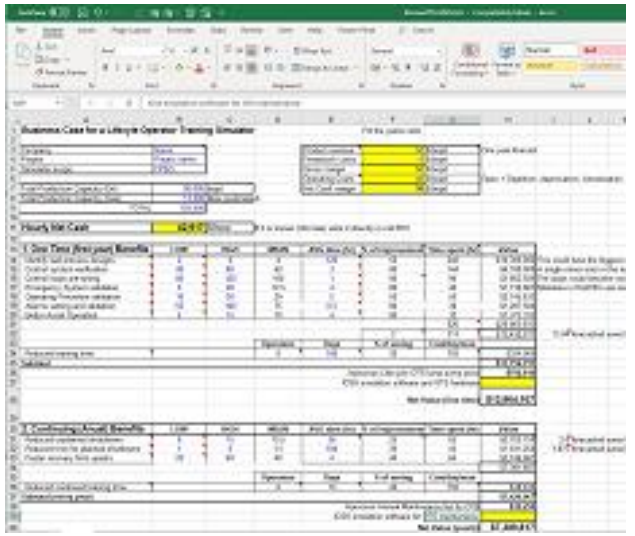
Frequently, ICSS vendors tend to install the Main Automation Contractor (MAC) schemes in new projects and constrain the customers to acquire the OTS exclusively from them, without giving any option to the EPC or OpCo to freely decide what process simulation software they prefer to use in their OTS.

By decoupling the OTS from the MAC, or by specifying your preferred process simulation software, you are securing the quality of the most important component of the OTS: The Simulation Engine. Therefore, you are selecting the process simulation software based on best standards rather than a low-fidelity

Easy to read whitepaper about Best Practices to request and exploit Lifecycle OTSs

Visit our virtual stand in this congress, our webpage, or Google

request lifecycle OTS



Excel file with a configurable business case to justify a lifecycle Digital Twin investment

Send email to: josemaria.ferrer@inprocessgroup.com

Thank you!

Q&A

JoséMaría Nougues

JoséMaría Ferrer

www.inprocessgroup.com