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A Systems Approach to Asset Design Interoperability.

David Cameron
THTH Spring Webinar 2023

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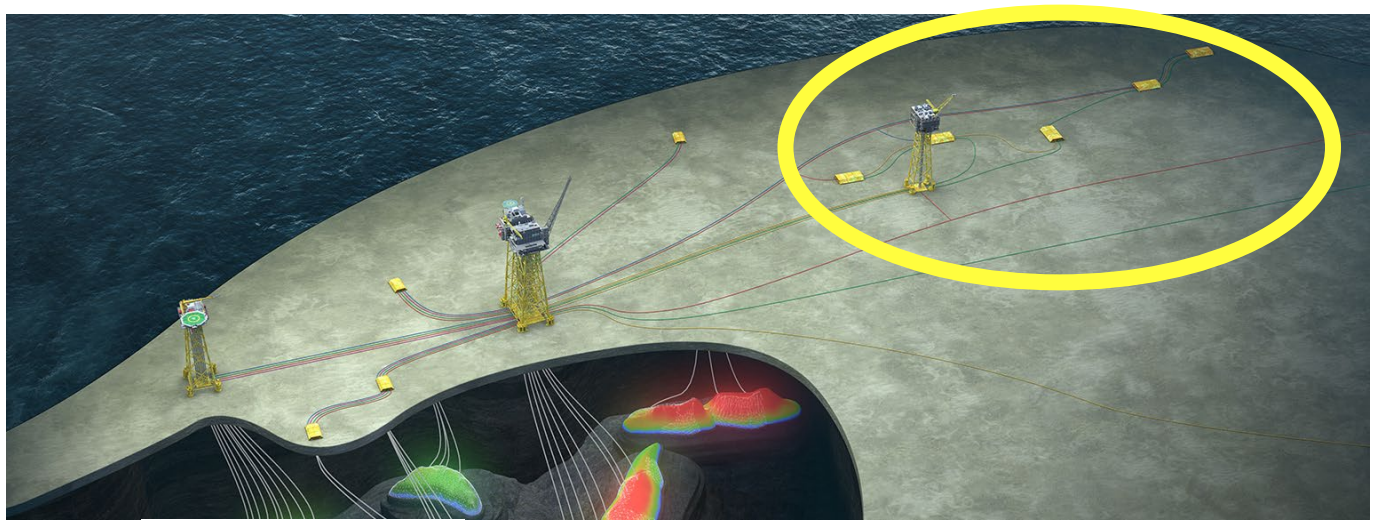
SIRIUS

Our Context: The NOAKA/Yggdrasil field Development

Two Operating Companies and Two EPC Contractors with a Coordinated, Interlinked Development

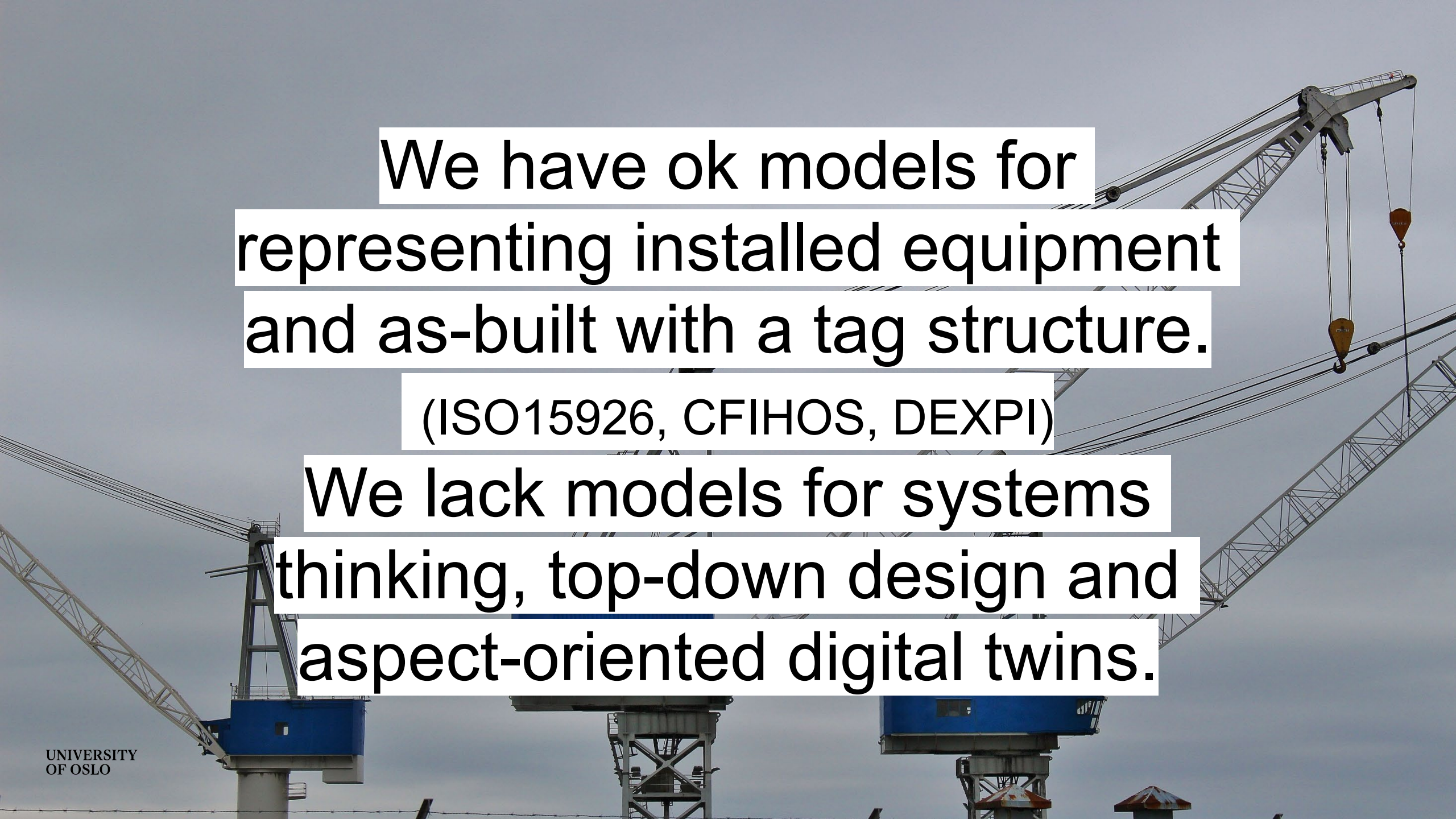


https://akerbp.com/en/project/noaka-2/

Weasel words

- Product
- Function
- Process
- Process Step
- Stream
- System
- Activity
- Functional Object
- Location
- Functional Location
- Tag

Credit: iStock, vndrpttn


We have ok models for representing installed equipment and as-built with a tag structure.
(ISO15926, CFIHOS, DEXPI)
We lack models for systems thinking, top-down design and aspect-oriented digital twins.
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What is a system?

ISO15926-4, BFO

Assembly of physical things

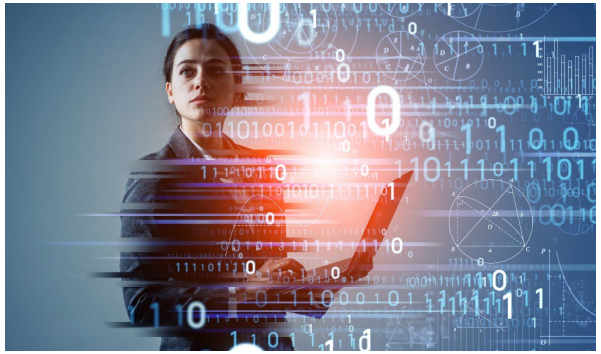
ISO/IEC81346

INCOSE / SysML

Way of analyzing (desired) reality

Different Aspects – Different Concerns

Design & Construction



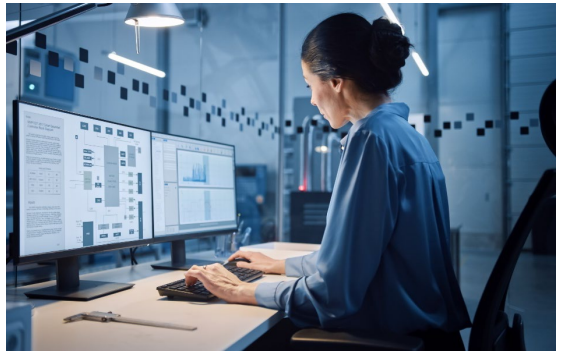
Process Design Engineer

What is the **process** we need to build?

Piping / Mechanical Engineer

What is the **equipment** we need to build to realise the process?

Operations



Process Engineer

How can we optimize and troubleshoot the **process**?

Maintenance Engineer

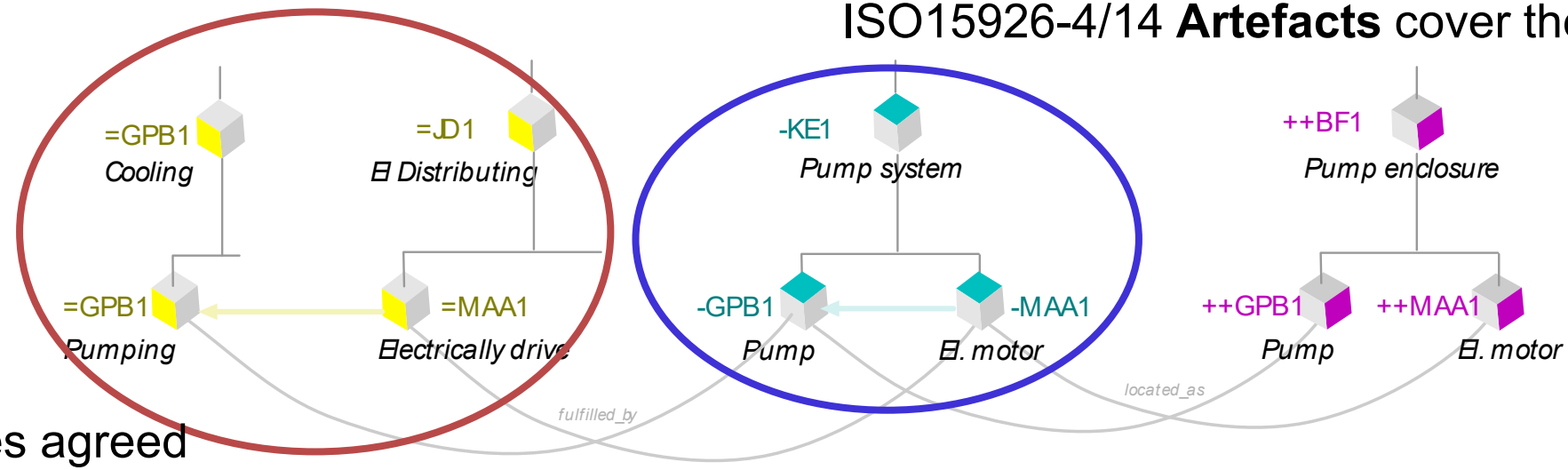
How do we ensure the **equipment** is running as it should?

The **Information Modelling Framework** allows us to apply Systems Engineering principles to our information

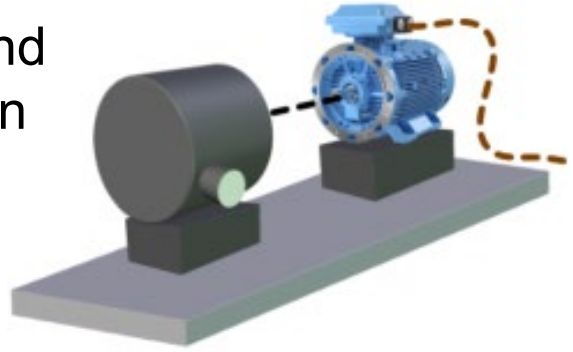
- Based on the **ISO/IEC81346** standard series.
- Complex **systems** are broken down into sub-systems along different but agreed **aspect** trees.
- Systems and sub-systems are typed using a **Reference Designation System**.
  - An RDS has been developed for oil and gas, that is easily extendable to the process and energy industries.
- Separates **function** from the physical object (**product**) and its **installed** object.
- Allows us easier access to “why” questions in our digital twins.
- Allows us easier **abstraction** of relevant information.
- Integrates the “old” tag-based & product-based approach in the **product** aspect.
  - Without being locked into the limitations of the old approach.
  - Without overloading plant item objects with hundreds of requirements.

IMF uses aspects to separate function from equipment: for example a pump

ISO15926-4/14 **Artefacts** cover the product aspect



IMF gives agreed functional systems and break-down structures. Typed by **Activities**



Requirements	Specifications	Req's and spec's
e.g. - Shaft power req'd - Start torque req'd - Speed req's - Voltage & Hz req'd	e.g. - Motor power input - Motor power output - Rated speed - Rated voltage - Enclosure type - Insulation class	e.g. - Dimensional specs - Positional spec's plus part of area req's - Noise limitation - Ingress protection - Explosion protection
FUNCTION	PRODUCT	LOCATION

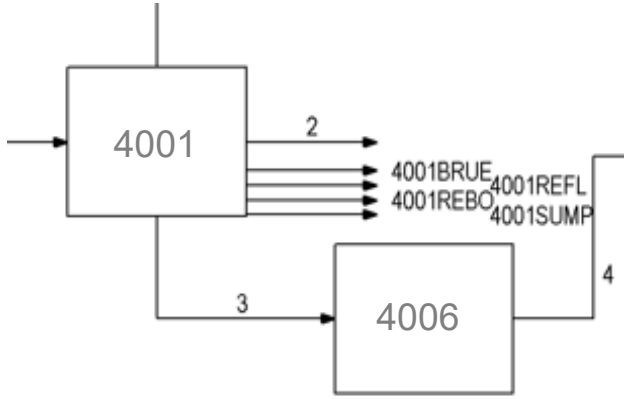
(credit: Arild Waaler, Erlend Fjøsna and IMF team)

DEXPI and the ENPRO lifecycle model

DEXPI Data Exchange in the Process Industry

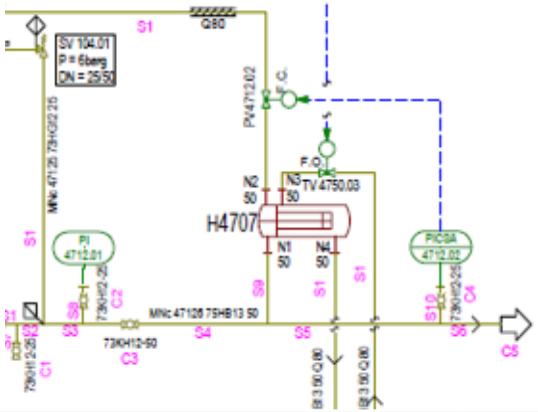
The plant lifecycle is separated into four aspects with three underlying data structures

Functional Requirements



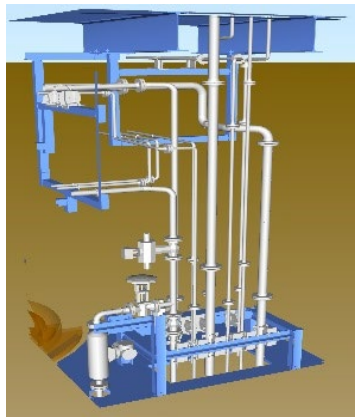
Process Structure

Functional Design



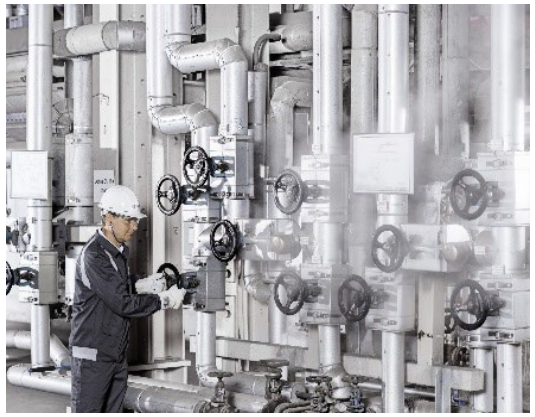
Plant Structure

Plant Specification



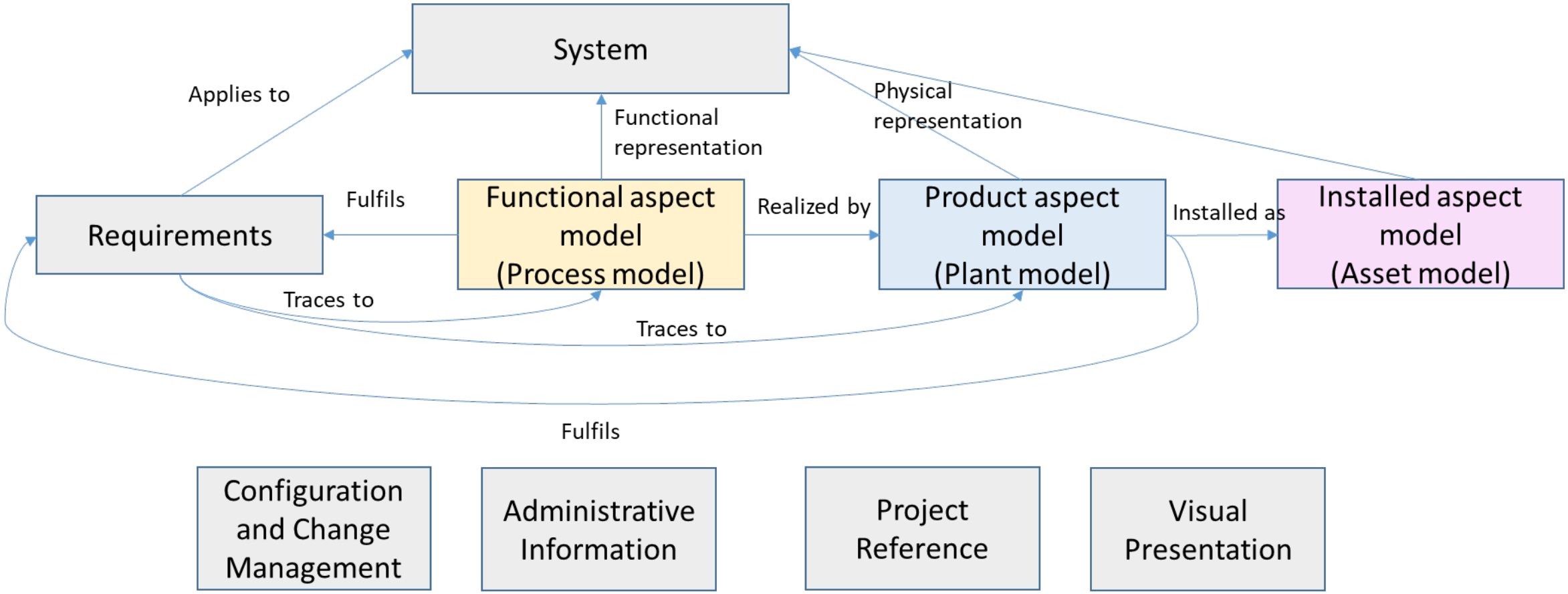
Plant Structure

Plant in Operation



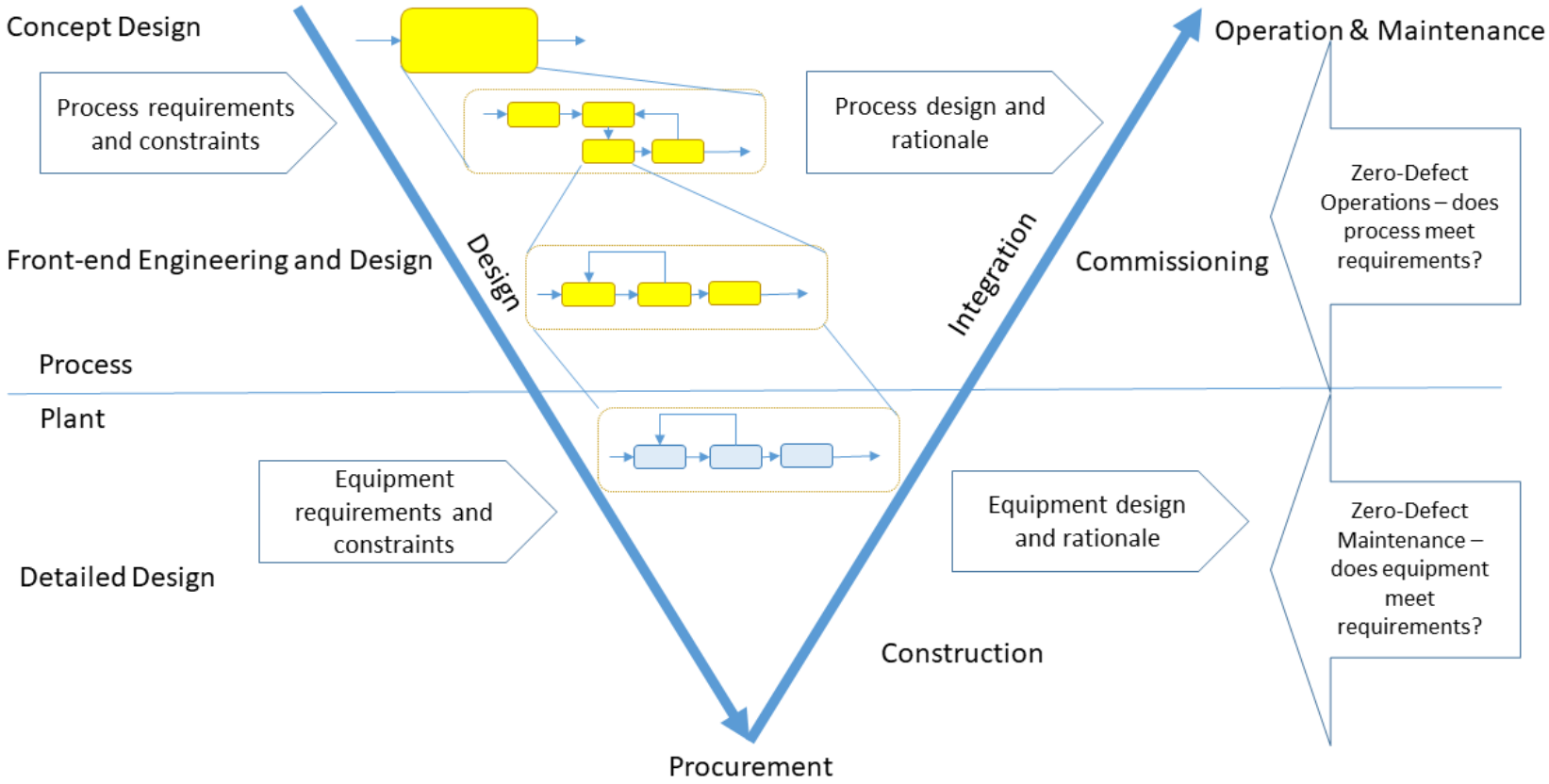
Some Background of Our Modelling Approach

Conceptual Model of an Asset Information System



Process and Plant

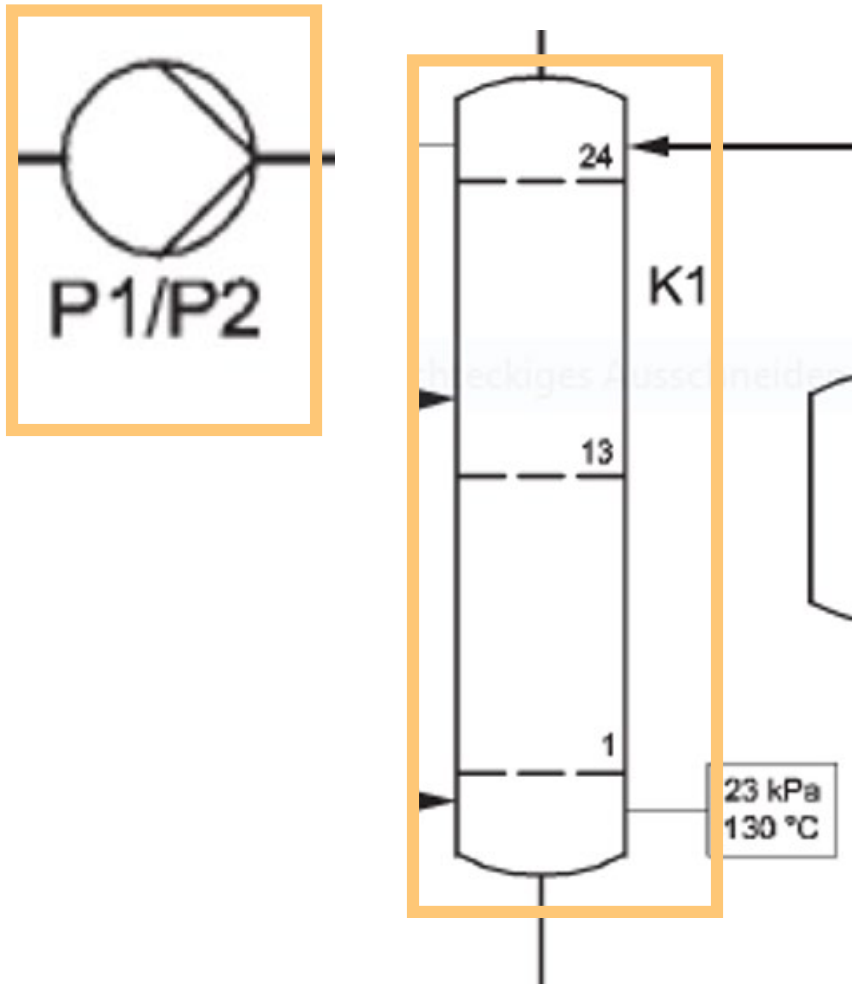
Conceptual Model of an Asset Information System



A gap in the standards exists

DEXPI Data Exchange in the Process Industry

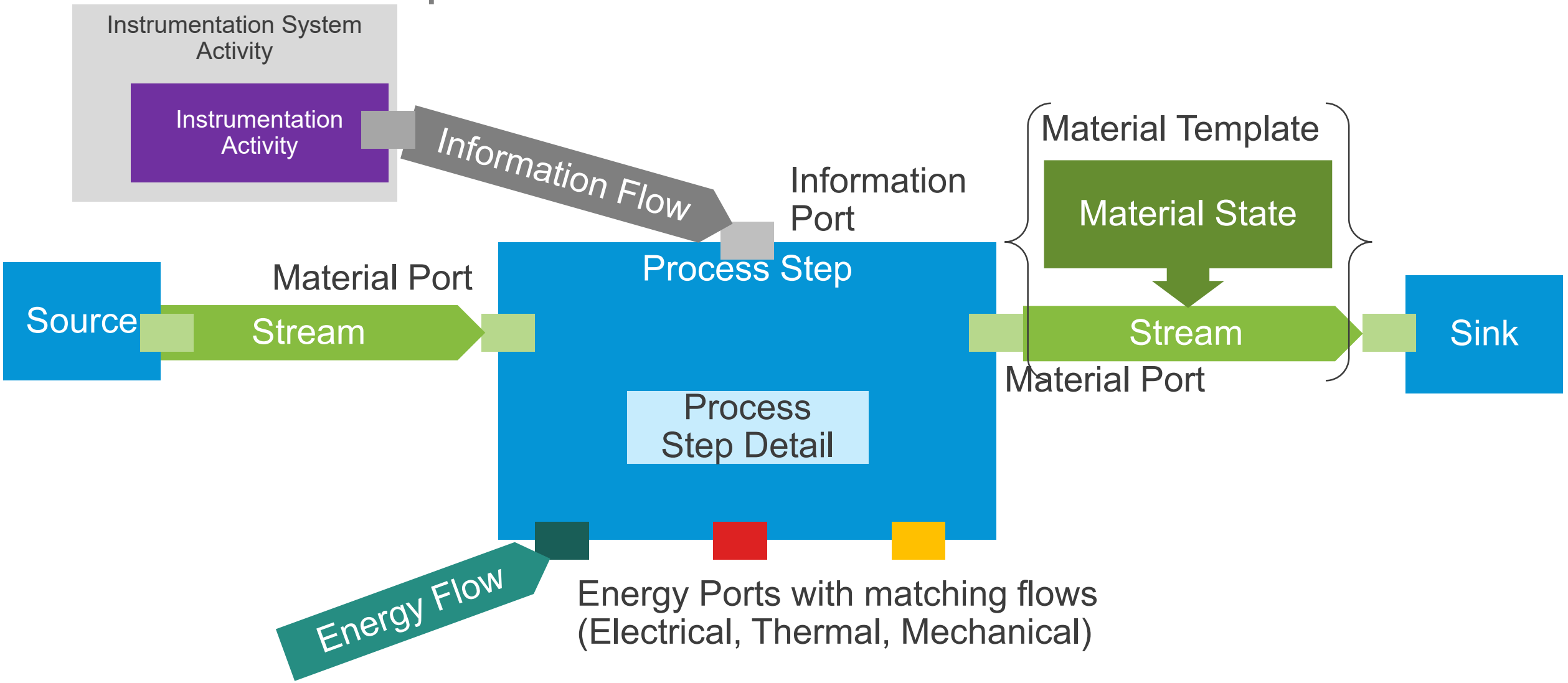
What does a symbol in a BFD or PFD represent?



- Symbols in these diagrams represent equipment only indirectly.
- The symbol actually represents a **system** that performs a **process.**
- When we are doing the design needed to specify a BFD and PFD we are looking at
  - Process requirements.
  - Process constraints.
  - Functional systems.
- We are not looking at a distillation column, we are looking at a system for separation by distillation.
- The system is ***always*** more than the column itself.

The DEXPI+ core objects

Connected blocks and parameters



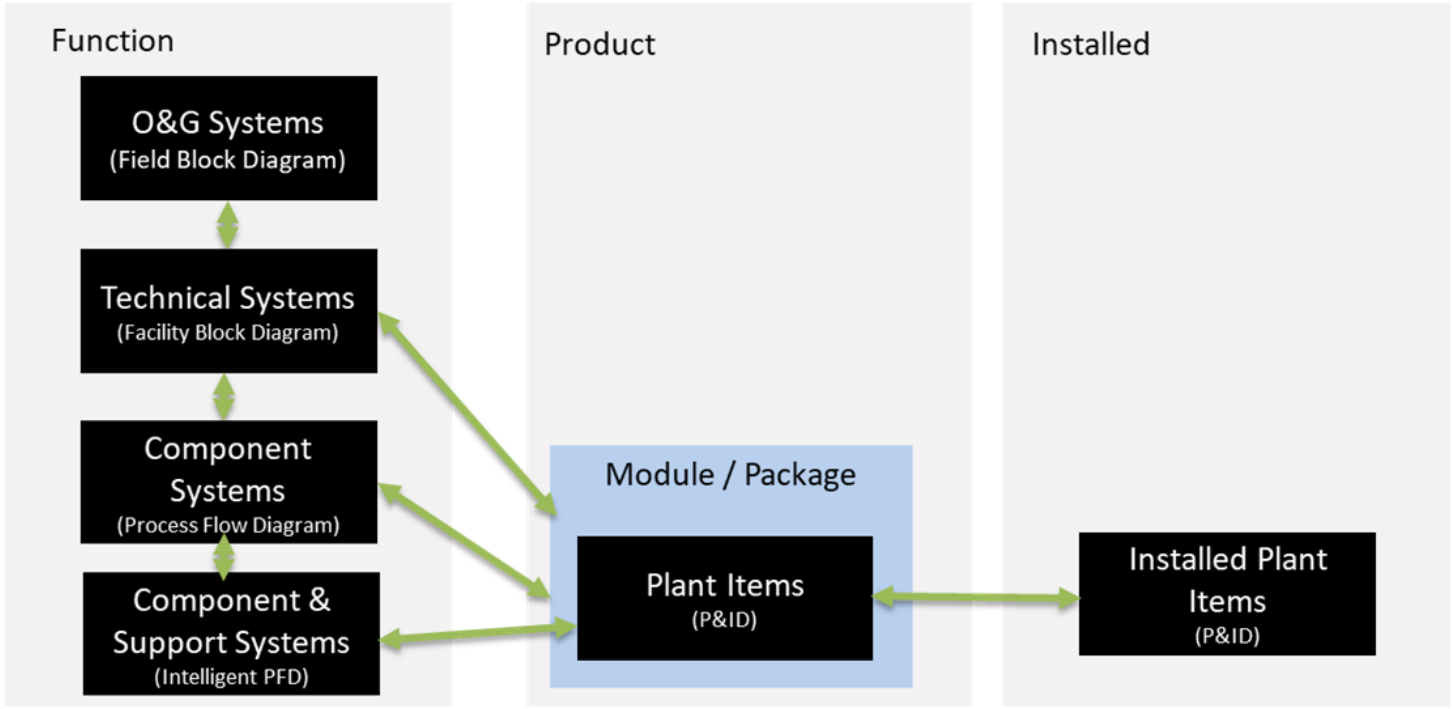
Design of a Heat Exchanger

Source: Evonik, ENPRO Project (2015).

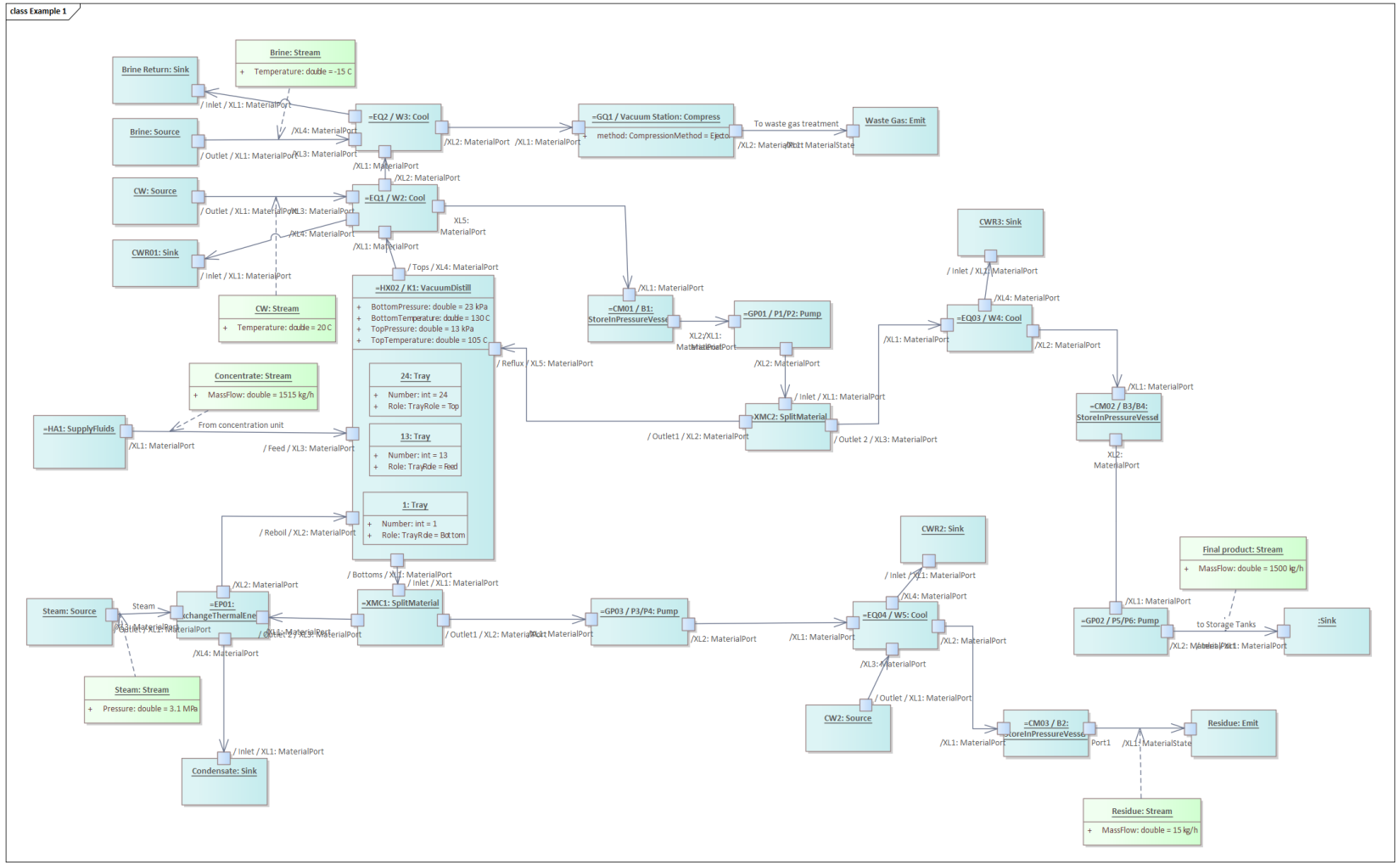
Heat Exchanger			
Functional Requirement	Functional Design	Equipment Design	Equipment in Operation
Process description	Simulation with explicit functions	P&ID **with surroundings of the equipment**	As built documents
Simulation without defined function	Calculation of thermodynamic interpretation	3D with surroundings of the equipment	Commissioning documents
Simulation with generic function	Process data sheet. Describing the **function** of the equipment.	Technical specification	Plant maintenance
PFD without type defintion (PBD)	PFD with type definition	Tender, Purchase	Operational data
	3D model of conceptual design	Production, Implementation	Test and quality protocols

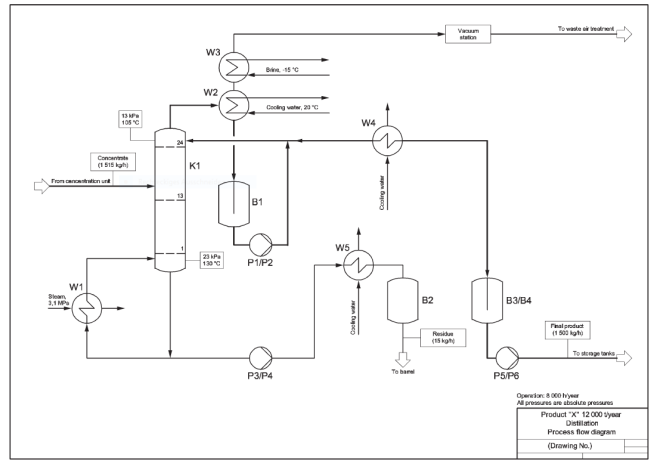
Building a model during design

Process Steps realized by Plant Items and delivered as Installed Plant Items



DEXPI+


class Example 1
Brine: Stream
+ Temperature: double = -15 C
Brine Return: Sink
Brine: Source
=EQ2 / W3: Cool
=GQ1 / Vacuum Station: Compress
method: CompressionMethod = Ejector
To waste gas treatment
Waste Gas: Emit
CW: Source
=EQ1 / W2: Cool
CWR01: Sink
CW: Stream
+ Temperature: double = 20 C
=HX02 / K1: VacuumDistill
+ BottomPressure: double = 23 kPa
+ BottomTemperature: double = 130 C
+ TopPressure: double = 13 kPa
+ TopTemperature: double = 105 C
=CM01 / B1: StoreInPressureVessel
=GP01 / P1/P2: Pump
CWR3: Sink
=EQ03 / W4: Cool
=CM02 / B3/B4: StoreInPressureVessel
Concentrate: Stream
+ MassFlow: double = 1515 kg/h
24: Tray
+ Number: int = 24
+ Role: TrayRole = Top
13: Tray
+ Number: int = 13
+ Role: TrayRole = Feed
1: Tray
+ Number: int = 1
+ Role: TrayRole = Bottom
=HA1: SupplyFluids
From concentration unit
=XMC2: SplitMaterial
Final product: Stream
+ MassFlow: double = 1500 kg/h
CWR2: Sink
=EQ04 / W5: Cool
=GP02 / P5/P6: Pump
to Storage Tanks
:Sink
Steam: Source
Steam
=EP01: HeatExchangeThermalEnergy
=XMC1: SplitMaterial
=GP03 / P3/P4: Pump
Steam: Stream
+ Pressure: double = 3.1 MPa
Condensate: Sink
CW2: Source
=CM03 / B2: StoreInPressureVessel
Residue: Emit
Residue: Stream
+ MassFlow: double = 15 kg/h


Vacuum station
To waste air treatment
W3
Brine, -15 °C
W2
Cooling water, 20 °C
13 kPa
105 °C
W4
Concentrate
(1 515 kg/h)
From concentration unit
24
K1
13
B1
1
23 kPa
130 °C
P1/P2
Cooling water
W5
W1
Steam,
3,1 MPa
B2
B3/B4
Cooling water
Residue
(15 kg/h)
To barrel
Final product
(1 500 kg/h)
To storage tanks
P3/P4
P5/P6
Operation: 8 000 h/year
All pressures are absolute pressures
Product "X" 12 000 t/year
Distillation
Process flow diagram
(Drawing No.)

DEXPI+ integrates existing standards

DEXPI Data Exchange in the Process Industry

SysML, OntoCAPE, ISO10209, ENPRO, READI, IMF, NOAKA, ISO15926-14

- SysML and IDEFx.
  - **Blocks** with **ports**.
- OntoCAPE.
  - **Process Steps**, **Aspects** (Functional, Equipment).
- ENPRO.
  - **Lifecycle** with clear distinction between process, plant and asset structure.
- ISO15926.
  - Set of **activities** that can be used to characterize DEXPI+ Blocks.
- ISO/IEC81346.
  - **System engineering approach** with aspects, technical systems and component systems.
- DIN6779-14.
  - ISO/IEC81346 **breakdown for process engineering.**
- READI project.
  - ISO/IEC81346 Reference Designation System for oil & gas (and process!).
- Information Modelling Framework and NOAKA collaboration.
  - Library of objects for modelling **processes** and **equipment**, aligned across ISO/IEC81346, DEXPI and CFIHOS.
  - Application to modelling of Krafla / Munin platform (all BFD and PFD).
  - Open Demonstration of method with Tennessee Eastman Process.

A hierarchy of process steps

DEXPI Data Exchange in the Process Industry

Characterized by reference data for *activities,* verbs, not things, nouns.

- Generating Flow: Compressing and Pumping.
- Mixing.
- Splitting.
- Transporting Material and Energy.
- Storing
- Supplying Materials and Energy.
- Supplying Exchange of Thermal Energy.
  - Heating, Cooling, Exchanging of Heat.
- Separating.
  - Phase separation, Thermal processes, Filtering, Electromagnetics, Physical Processes.
- Processing solids.
  - Reducing size, Increasing size, Forming material.
- Reacting Chemicals.
- Packaging.

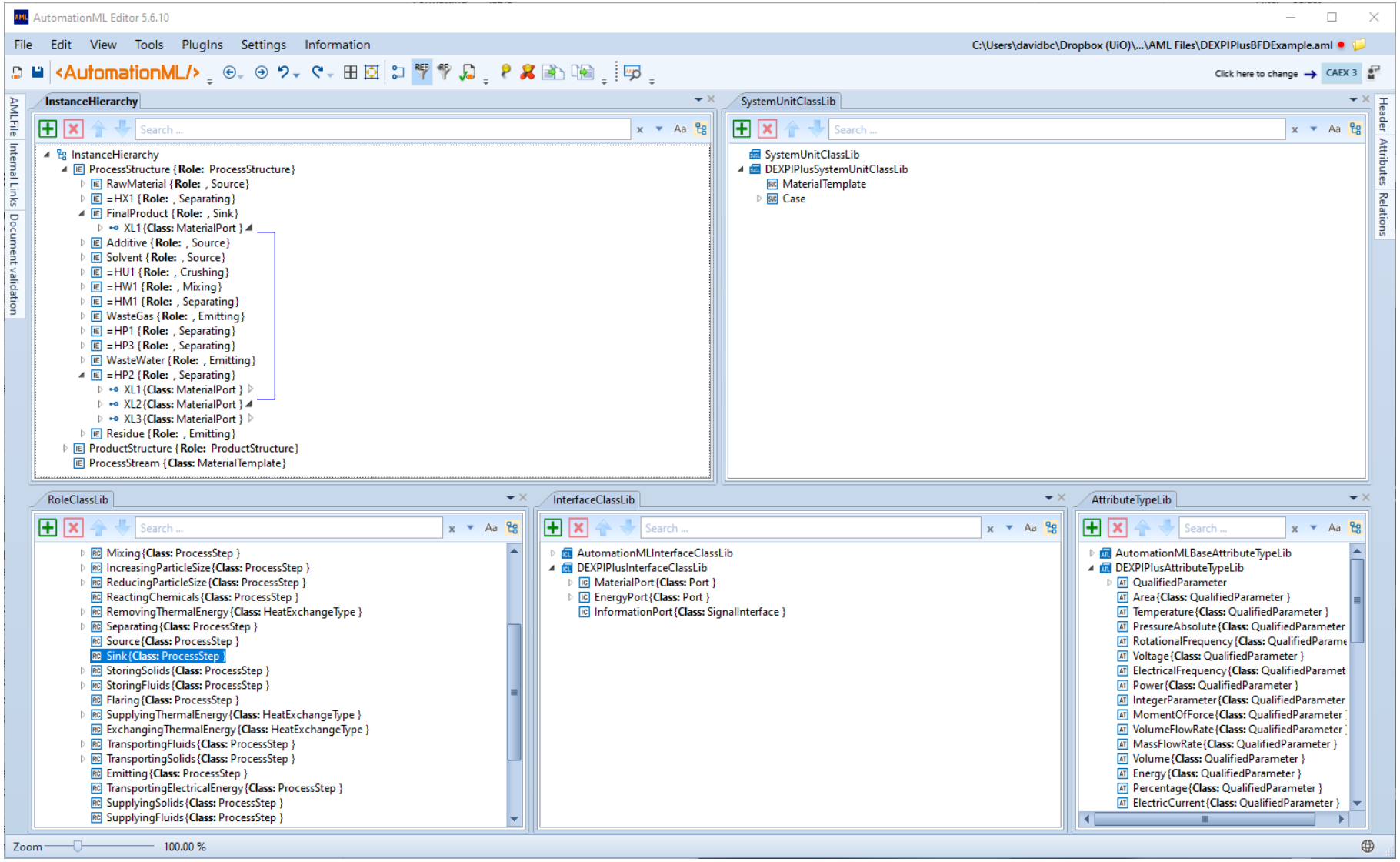
PROCESS STEP /
Technical Systems

What must be done?
Separate, Transport, Compress...

Unit Operations /
Component Systems

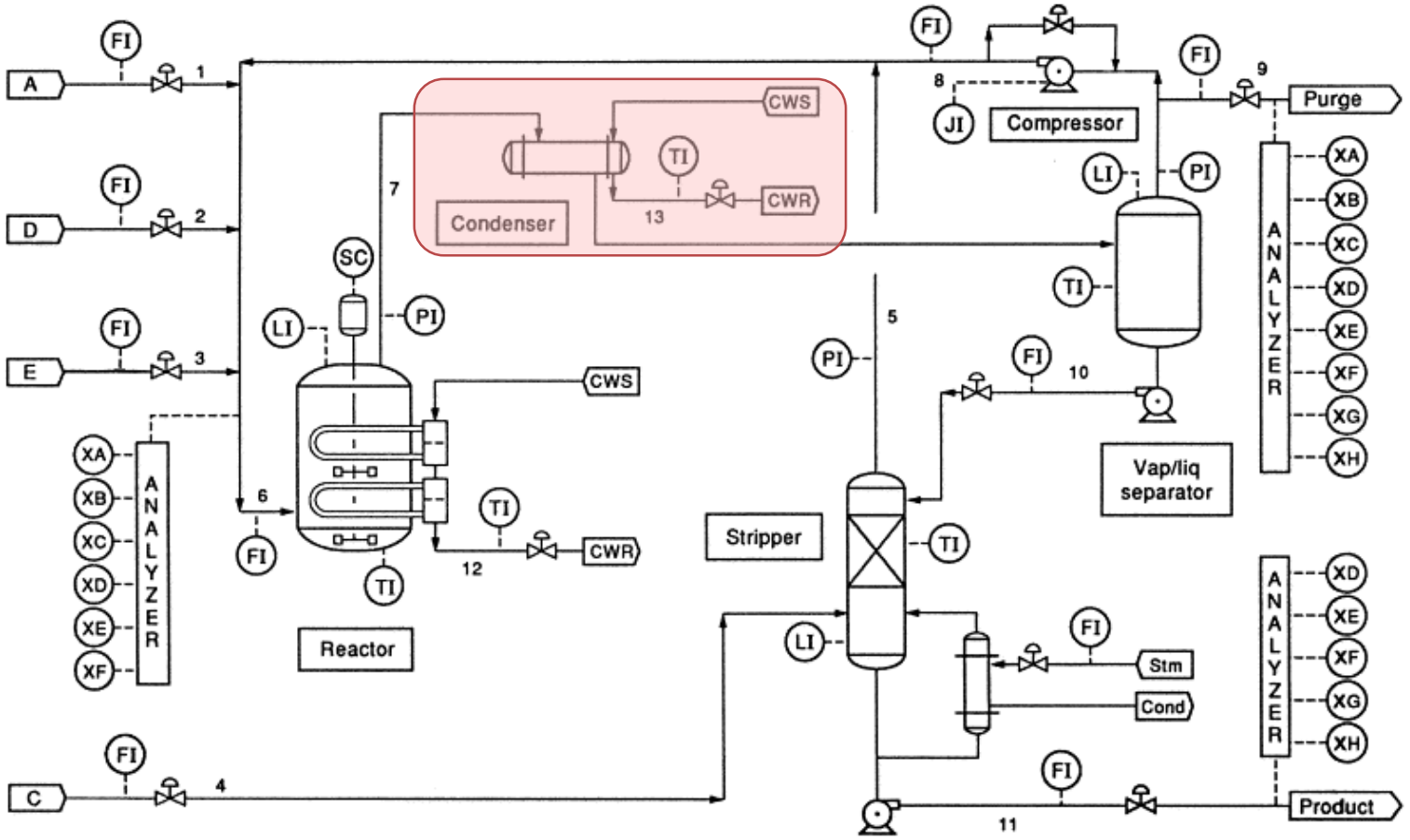
What must be done?
How?
Separate by distillation, Transport in piping, Compress by centrifugal motion

DEXPI+ can be implemented as AML (exploiting AML semantics)



The Tennessee Eastman Process

A Published, Non-Trivial Process Description for Use in Research and Technology Development



Resources for the Case Study

Free, open source and in need of further development

- Paper describing the case
  - https://doi.org/10.3389/fmtec.2022.945717
- Static website for browsing
  - https://sws.ifi.uio.no/project/TennesseeEastmanDemonstration/
- Enterprise Architect Model file
  - https://www.dropbox.com/s/o7h0qvqwk4vlbof/TennesseeEastmanExample.eapx?dl=0
- XMI 2.1 Export file for import in other tools (and conversion to RDF?)
  - https://www.dropbox.com/s/heuu5xpa5rp5zxx/TennesseeEastmanExample.xml?dl=0
- XMI 1.1 Export file for import in other tools
  - https://www.dropbox.com/s/adpks1rhqo0dgmy/TennesseeEastmanExampleXmi11.xml?dl=0