The challenges of software for process systems engineering.

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KSEE Seminar, Kongsberg, 14th June 2023

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Our design challenge

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Process Systems Engineering

Chemical engineering with computers

- A term first proposed in conjunction with a conference in Kyoto in 1982.
- Process systems engineering is all about the development of systematic techniques for process modelling, design and control.
- Core elements:
  - System modelling and simulation.
  - Optimization.
  - Dynamics and control.
  - Process and plant design.

Pistikopoulos, E.N., Barbosa-Povoa, A., Lee, J.H., Misener, R., Mitsos, A., Reklaitis, G.V., Venkatasubramanian, V., You, F., Gani, R., 2021. Process systems engineering – The generation next? Computers & Chemical Engineering 147, 107252. https://doi.org/10.1016/j.compchemeng.2021.107252

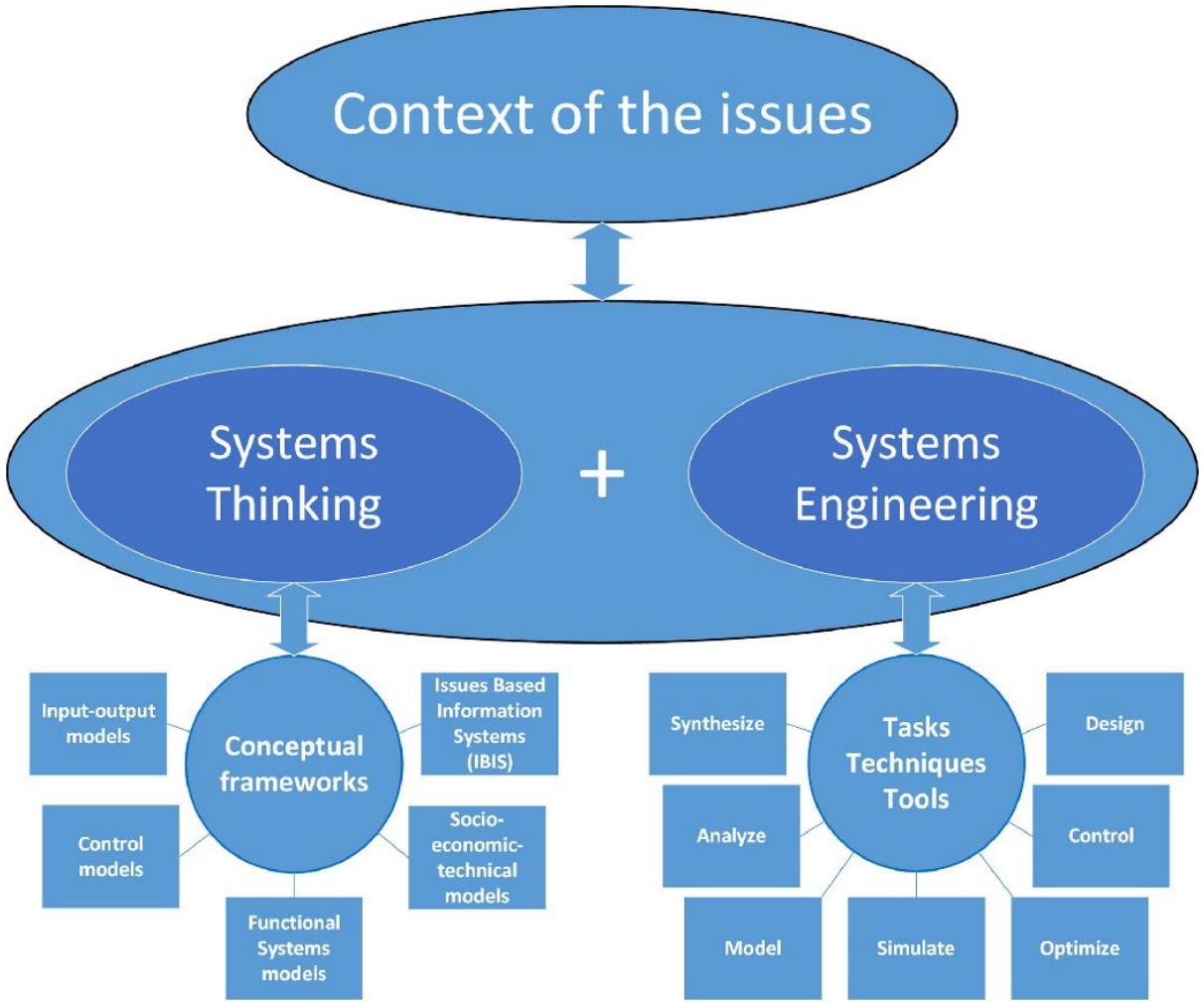
Systems engineering and chemical engineering (1961)

… systems engineering has a significant contribution to make to the practice and development of chemical engineering. The **crossing of barriers** between chemical engineering and other engineering disciplines and the **use of advanced mathematics** to study fundamental process mechanisms cannot help but be fruitful. Study of transient and dynamic behavior will undoubtedly produce radically changed design methods and results. The use of computers and the development of mathematical process simulation techniques may result in completely new methods and approaches which will justify themselves by economic and technological improvements."

T.J. Williams, Systems engineering for the process industries, McGraw-Hill, New York (1961), cited in Cameron, I.T., Engell, S., Georgakis, C., Asprion, N., Bonvin, D., Gao, F., Gerogiorgis, D.I., Grossmann, I.E., Macchietto, S., Preisig, H.A., Young, B.R., 2019. Education in Process Systems Engineering: Why it matters more than ever and how it can be structured. Computers & Chemical Engineering 126, 102–112. https://doi.org/10.1016/j.compchemeng.2019.03.036

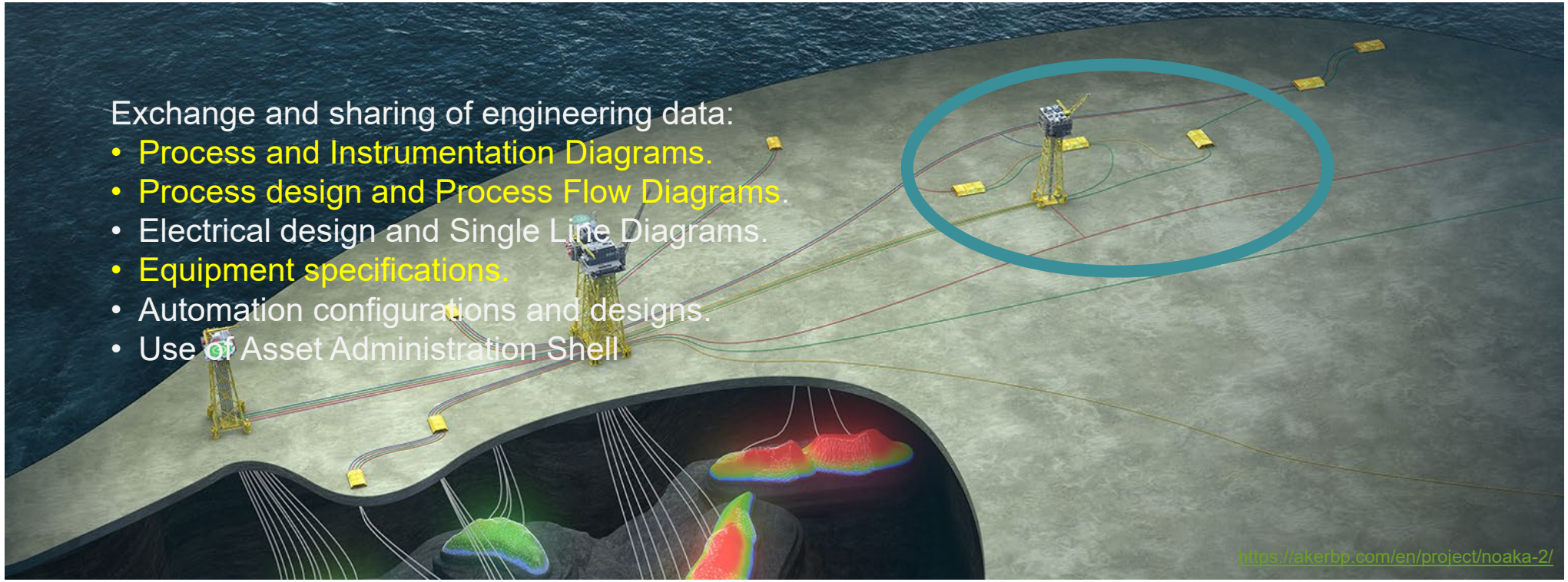
Systems engineering has a role in future education

Cameron, I.T., Engell, S., Georgakis, C., Asprion, N., Bonvin, D., Gao, F., Gerogiorgis, D.I., Grossmann, I.E., Macchietto, S., Preisig, H.A., Young, B.R., 2019. Education in Process Systems Engineering: Why it matters more than ever and how it can be structured. Computers & Chemical Engineering 126, 102–112. https://doi.org/10.1016/j.compchemeng.2019.03.036



Our Context: The NOAKA/Yggdrasil field Development

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



aibel

equinor

AkerBP

AkerSolutions

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Move from **document-centric** to **data-centric** engineering.

Use **aspect systems** to model the design information for a topside facility

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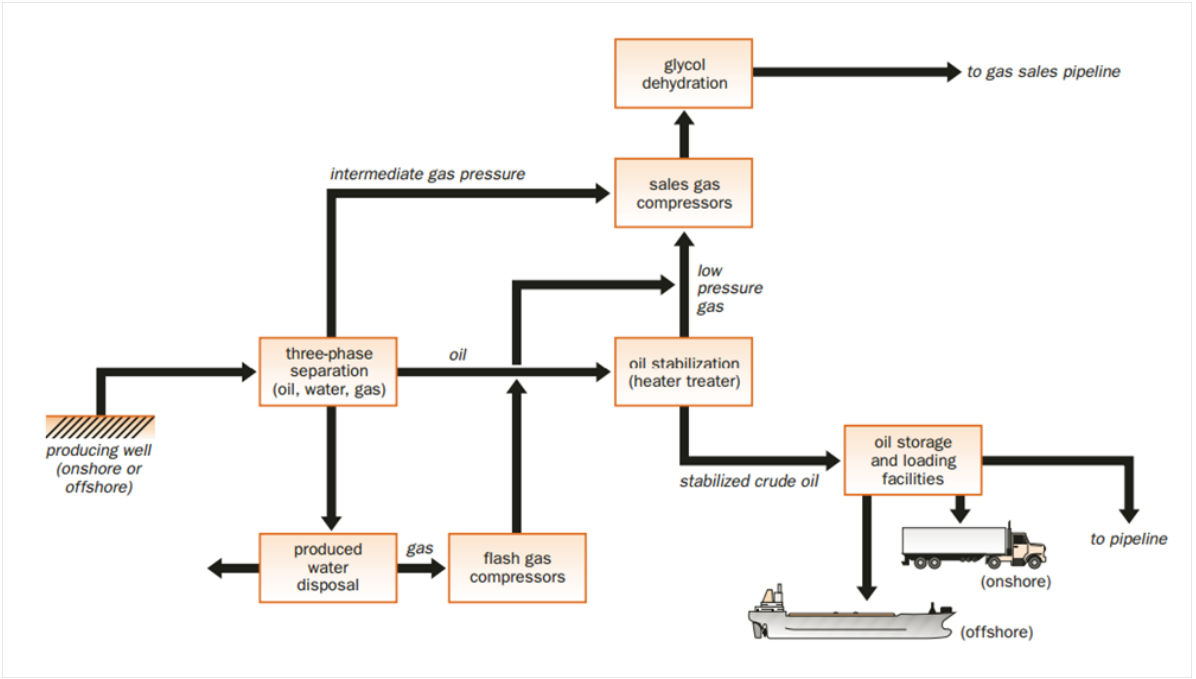
What is a system?

ISO15926-2/4, BFO

Assembly of physical things

ISO/IEC81346

INCOSE / SysML



Way of analyzing (desired) reality

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Elisabeth Sahl Jonny Engelsvoll Equinor, Grane Platform

https://www.oil-gasportal.com/upstream/petroleum-production-phase/

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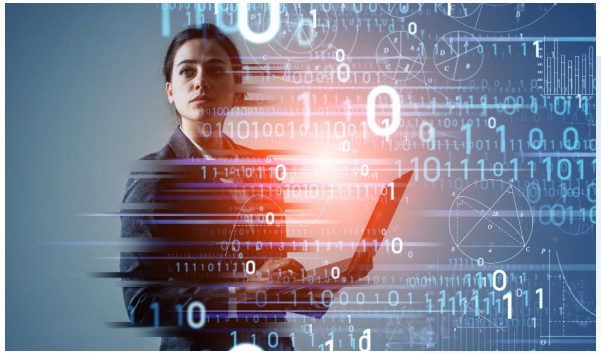
Our information models must support different concerns

Concept, Design & Construction



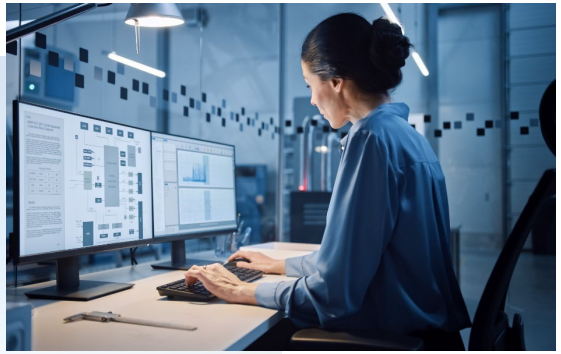
Process Design Engineer

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

Piping / Mechanical Engineer

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

Operations



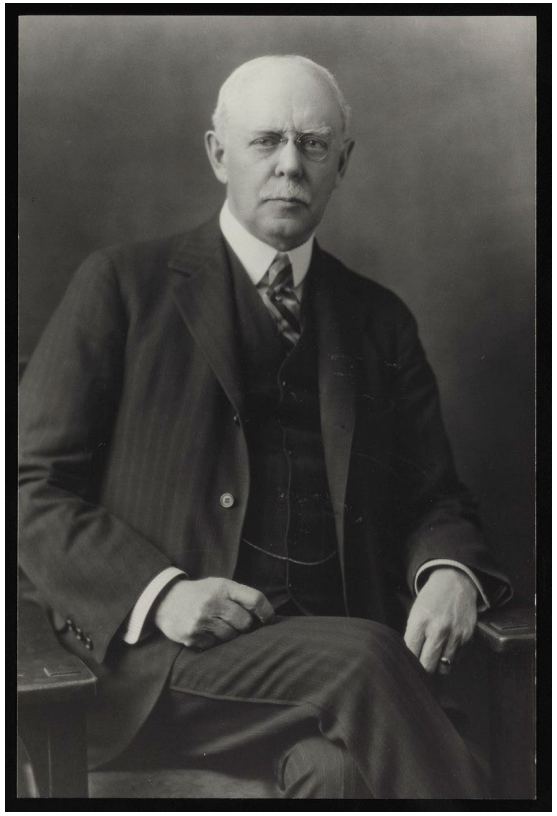
Process Engineer

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

Maintenance Engineer

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

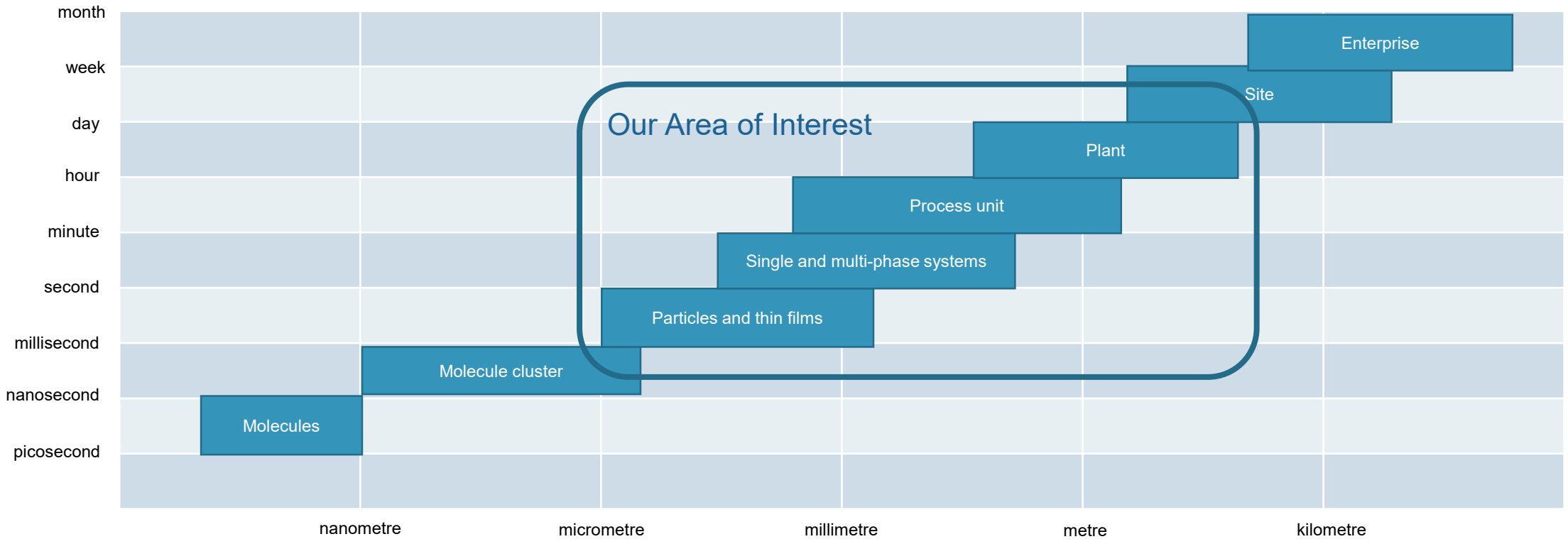
Separating process and equipment was the foundation of Chemical Engineering: the unit operation



Process Step Typed by a **verb** Specified by an adverbial phrase Activity or Role Pumping, Distilling, Separating, Regulating Flow	How much? How fast? How efficient? How near to completion? How pure?
Plant Item Typed by a **noun**. Artefact, Physical Object Pump, Process Column, Pressure Vessel, Valve	How large? How heavy? Constructed of what? Which product?

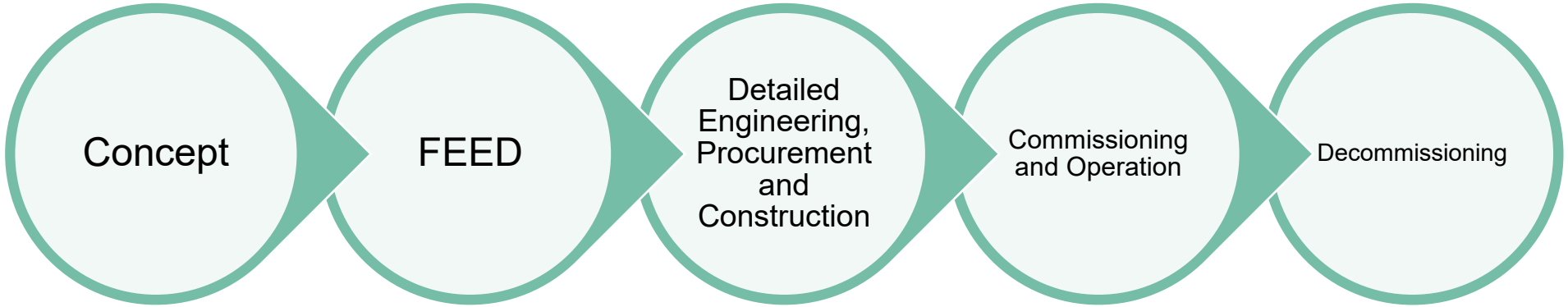
Arthur D. Little. By Science History Institute, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=79945493

Chemical Engineering Modelling



AIChE Journal, First published: 16 May 2023, DOI: (10.1002/aic.18114)

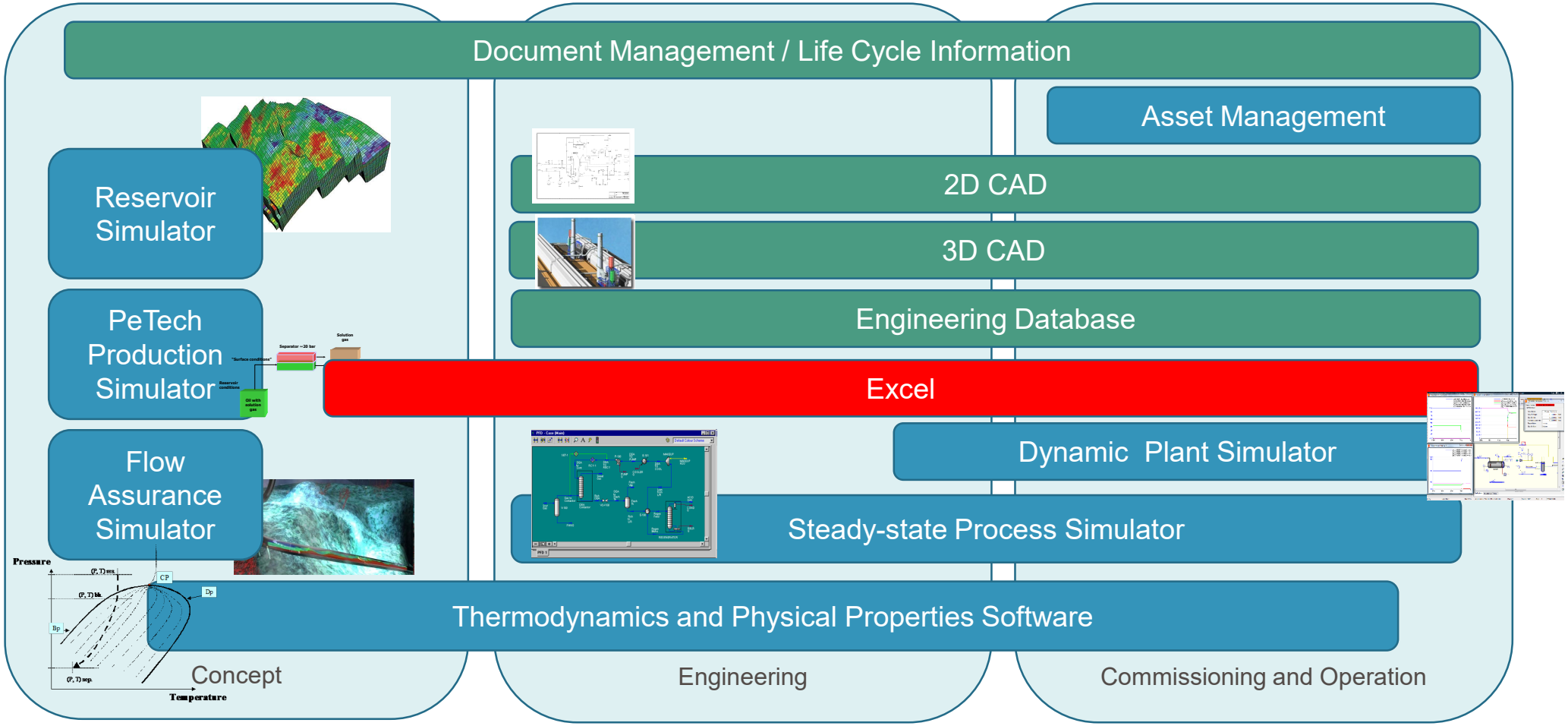
Process systems engineering in practice



ISO24748

Navigating a complex software landscape

Specialized simulation tools that are dependent on complex thermodynamic properties software



Challenges with the current software landscape

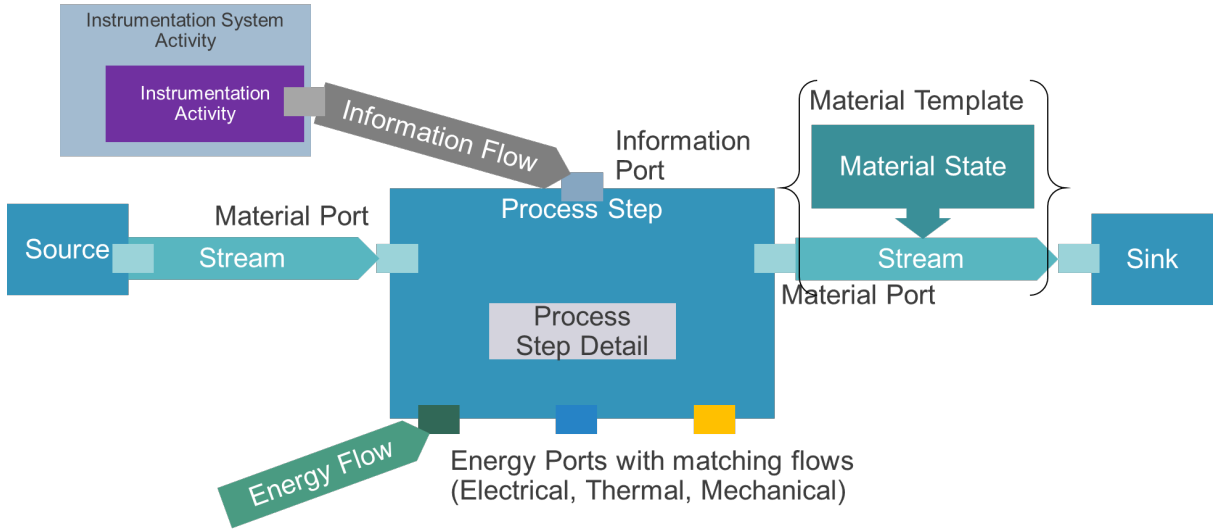
Lack of integration

- Tools are not integrated.
    - Inconsistent terminology and semantics.
    - Inconsistent data.
    - Inconsistent time-scales.
- Tools use different thermodynamic and physical property models.
- Excel is used as the primary tool for data exchange.
- No single view of truth.
    - Although Engineering Databases such as COMOS try to provide this.
- Little support for workflow.
    - Document approval is managed well.
    - Case management requires homemade systems and extensive use of Excel.
    - Requirements are not enforced by workflow system

Our attempt at a partial solution

Information Modelling Framework

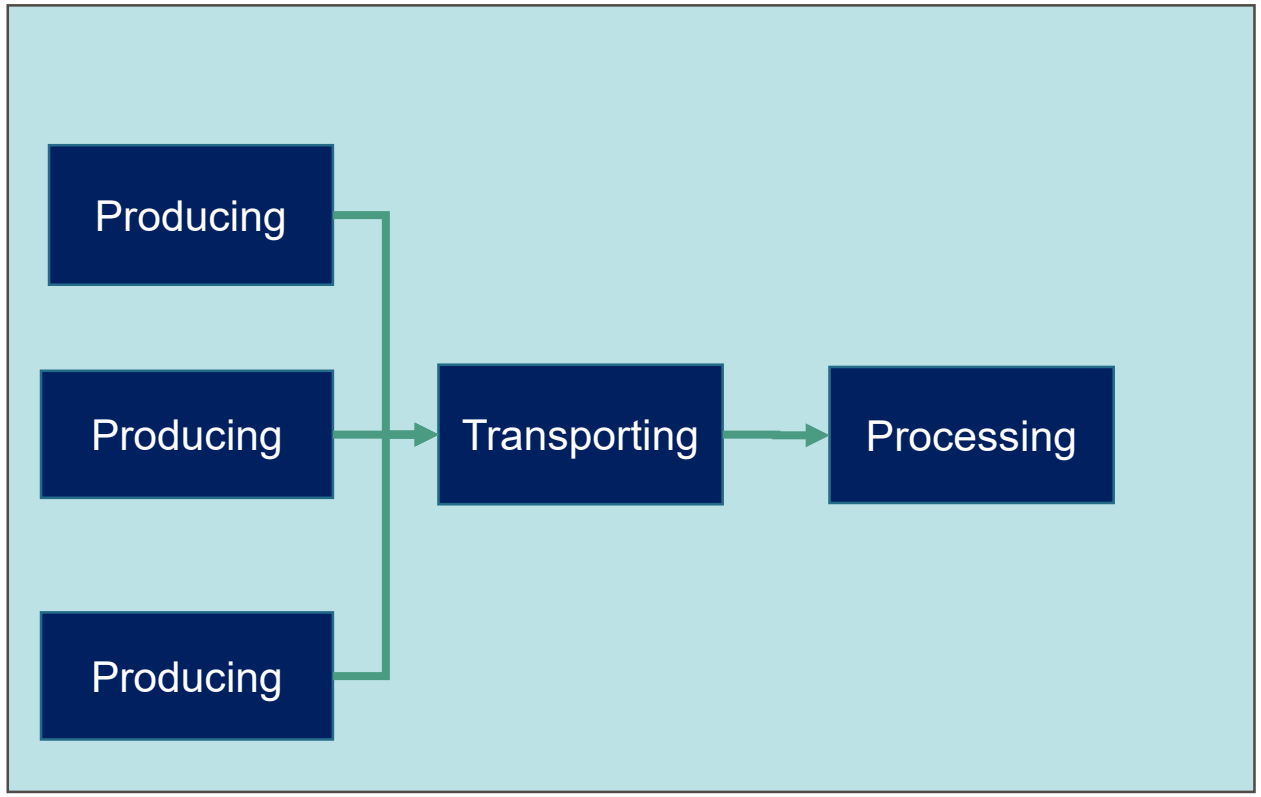
- Adopt concepts from system engineering and ISO/IEC81346
- Top-down breakdown of design into:
  - Functional systems that model the process.
  - Product systems that model the plant.
- Systems have a common structure:
  - Blocks,
  - with Ports,
  - connected by Flows
    - of Material, Energy or Information.
- This fits very nicely with SysML Block Definition Diagrams.
  - Not with Activity diagrams



- **Product systems: plant items** implement classes in DEXPI aligned with CFIHOS. Equipment types: pump, pressure vessel.
- Functional systems: process steps have been proposed standardized in DEXPI+ project. Process types: pumping, separating, measuring, exchanging thermal energy.

Concept

25 years' production from 20 wells in 3 formations



Oil export with purity specifications

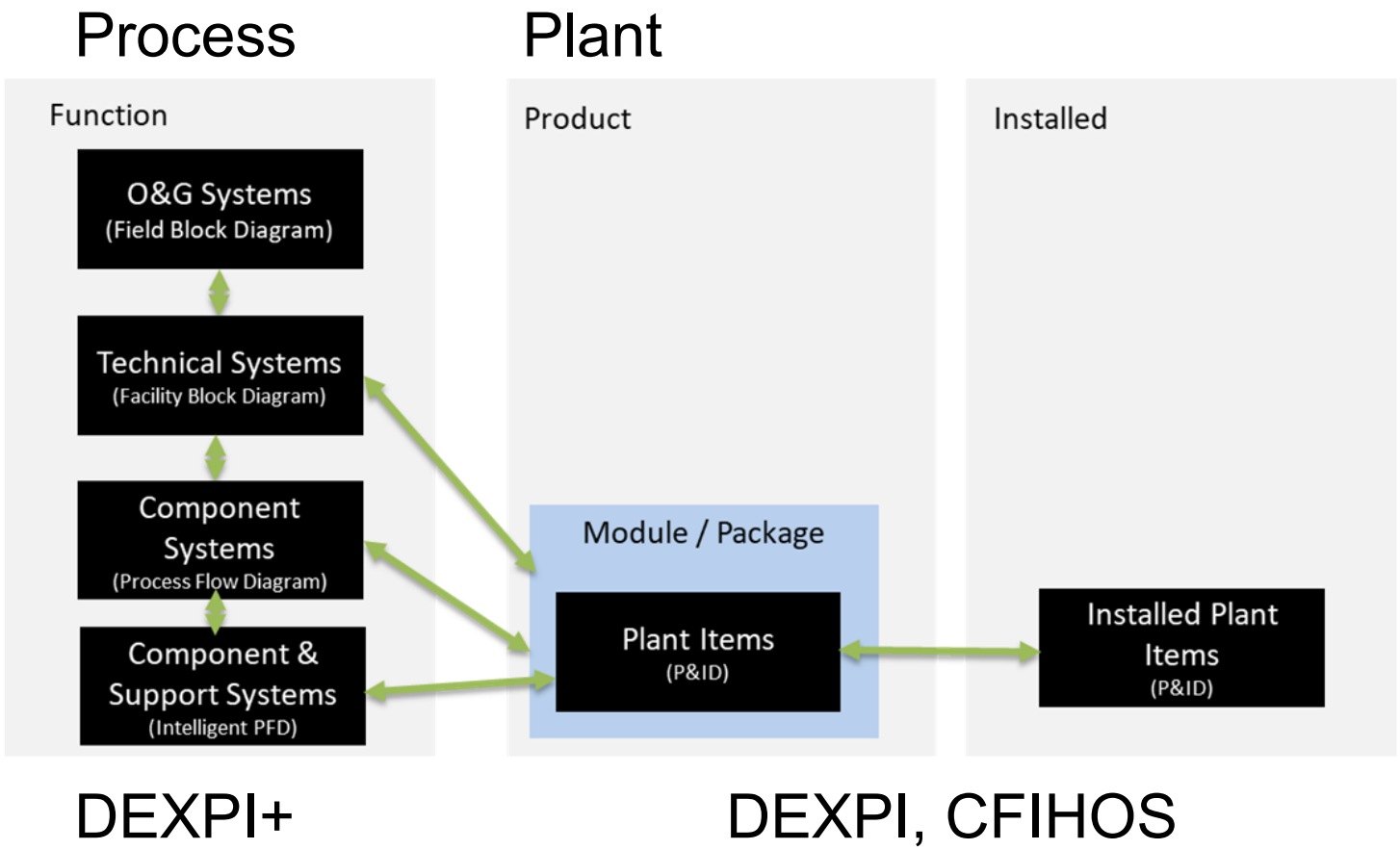
Gas export with purity specifications

Water injection with purity specifications

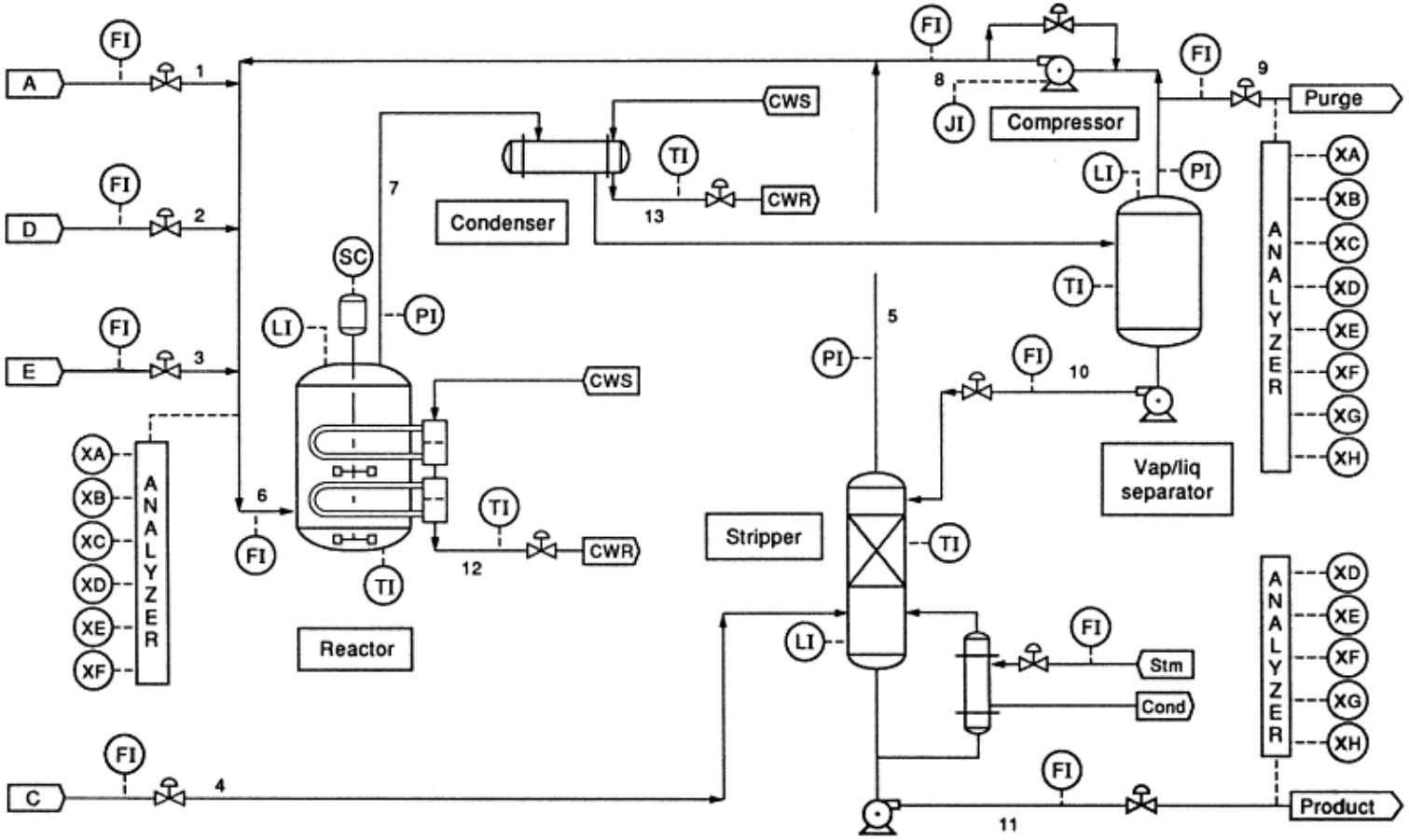
- Thermodynamics and fluid properties.
- Flow network simulation (Prosper/GAP)

FEED, Detailed Engineering, Procurement & Construction

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



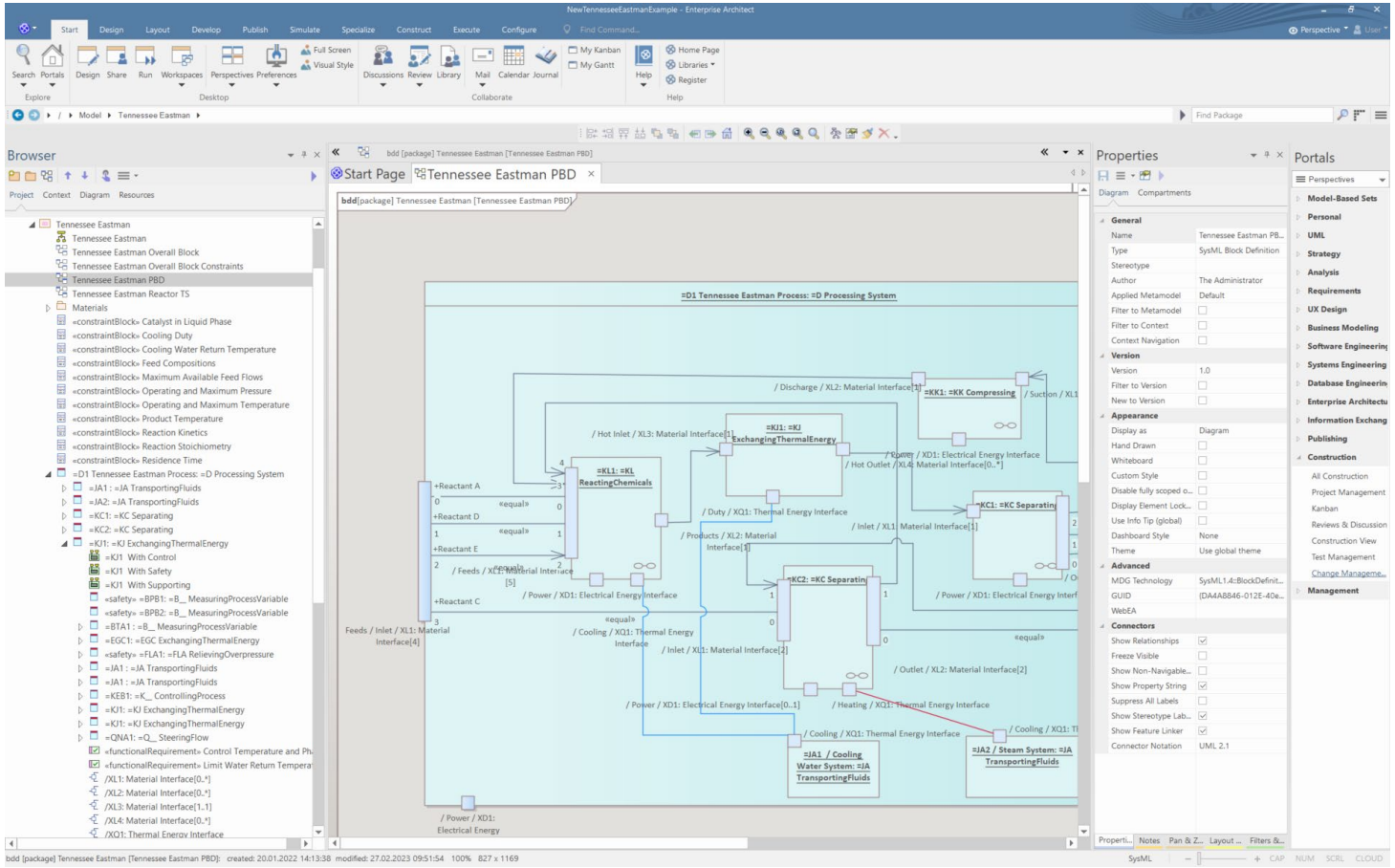
DEXPI+: An object in a Process Flow Diagram represents a Process Step



Example

A Process Flow Diagram becomes a Hierarchical Functional Model of the Facility

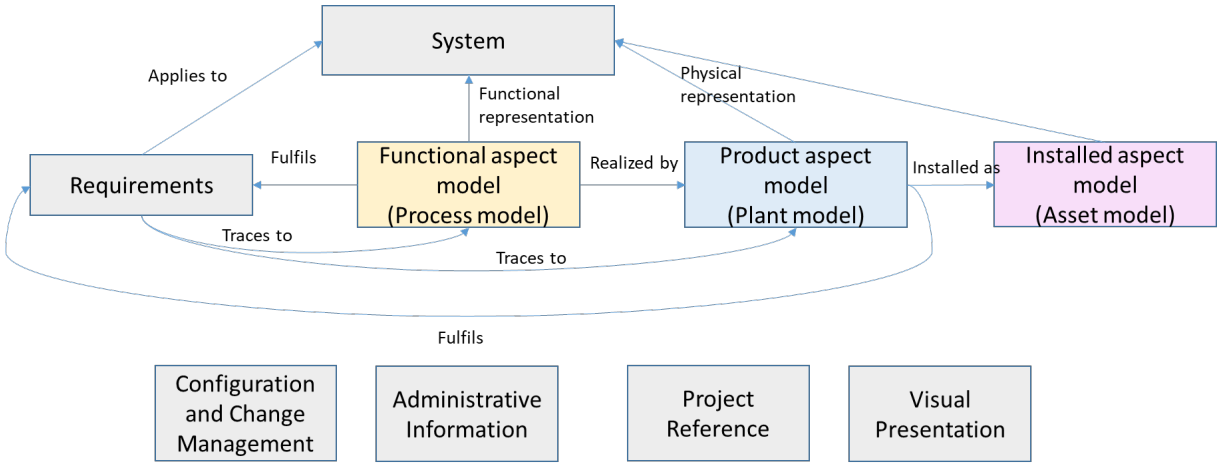
https://sws.ifi.uio.no/project/TennesseeEastmanDemonstration/



Opportunities

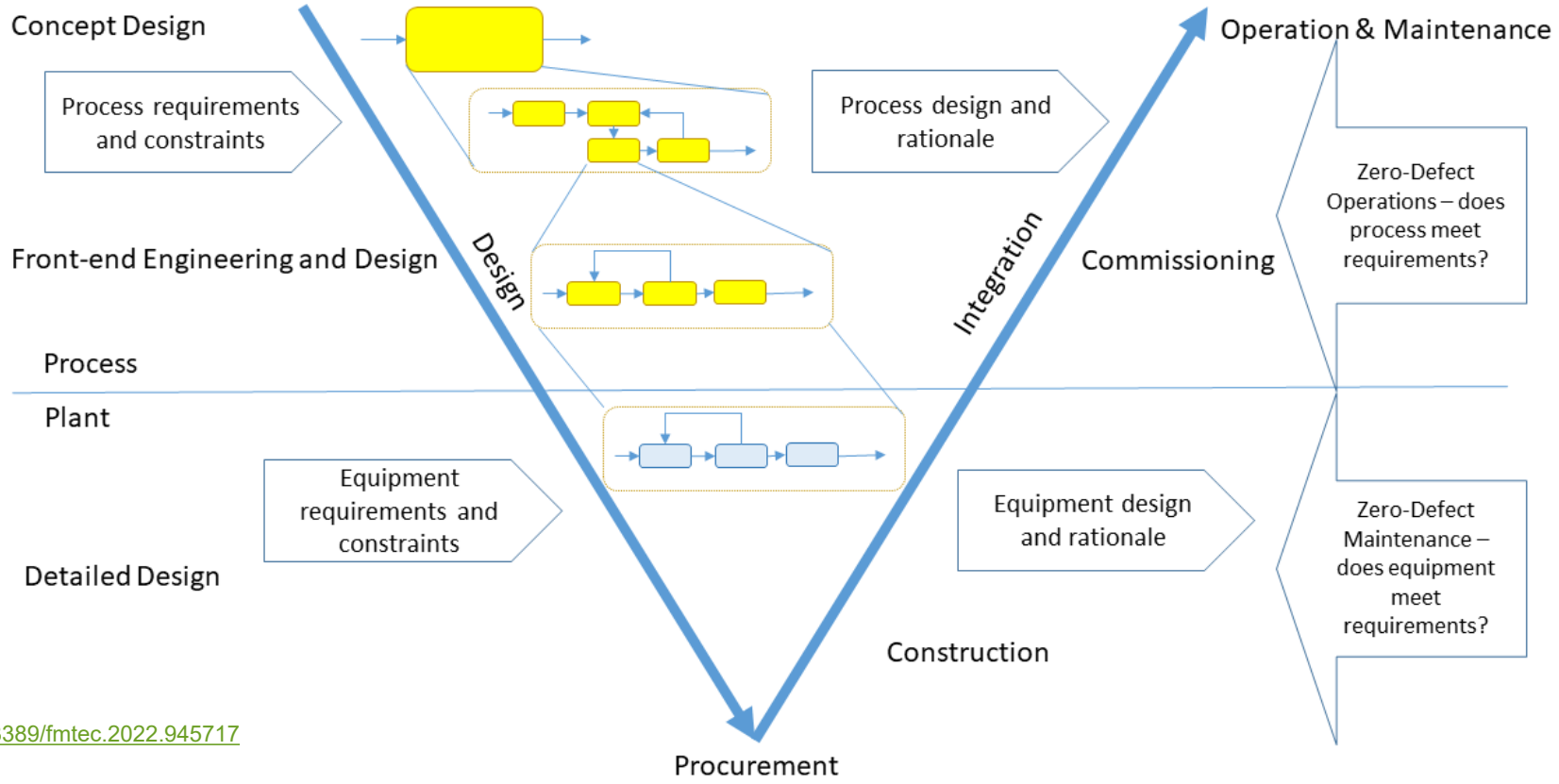
How this approach moves us towards data-centric engineering

- Referencing design parameters at the correct level of abstraction.
- Not all design information is collapsed into equipment documentation.
- We can capture process design rationale.
- We can automate design processes and quality assurance.
    - Standard libraries of Plant Items and Process Steps.
    - Templates for data sets used in the design.
    - Support for logical and numerical checking of consistency and validation.
- Process Steps map well to unit operations in steady-state process simulators.
    - Initiative underway to link DEXPI+ data model to CAPE-OPEN simulators.
- Plant Items map well to 3D CAD and dynamic simulation.
- A digital twin needs both Process Steps and Plant Items.



Process and Plant

Building a digital twin for zero-defect operations and maintenance



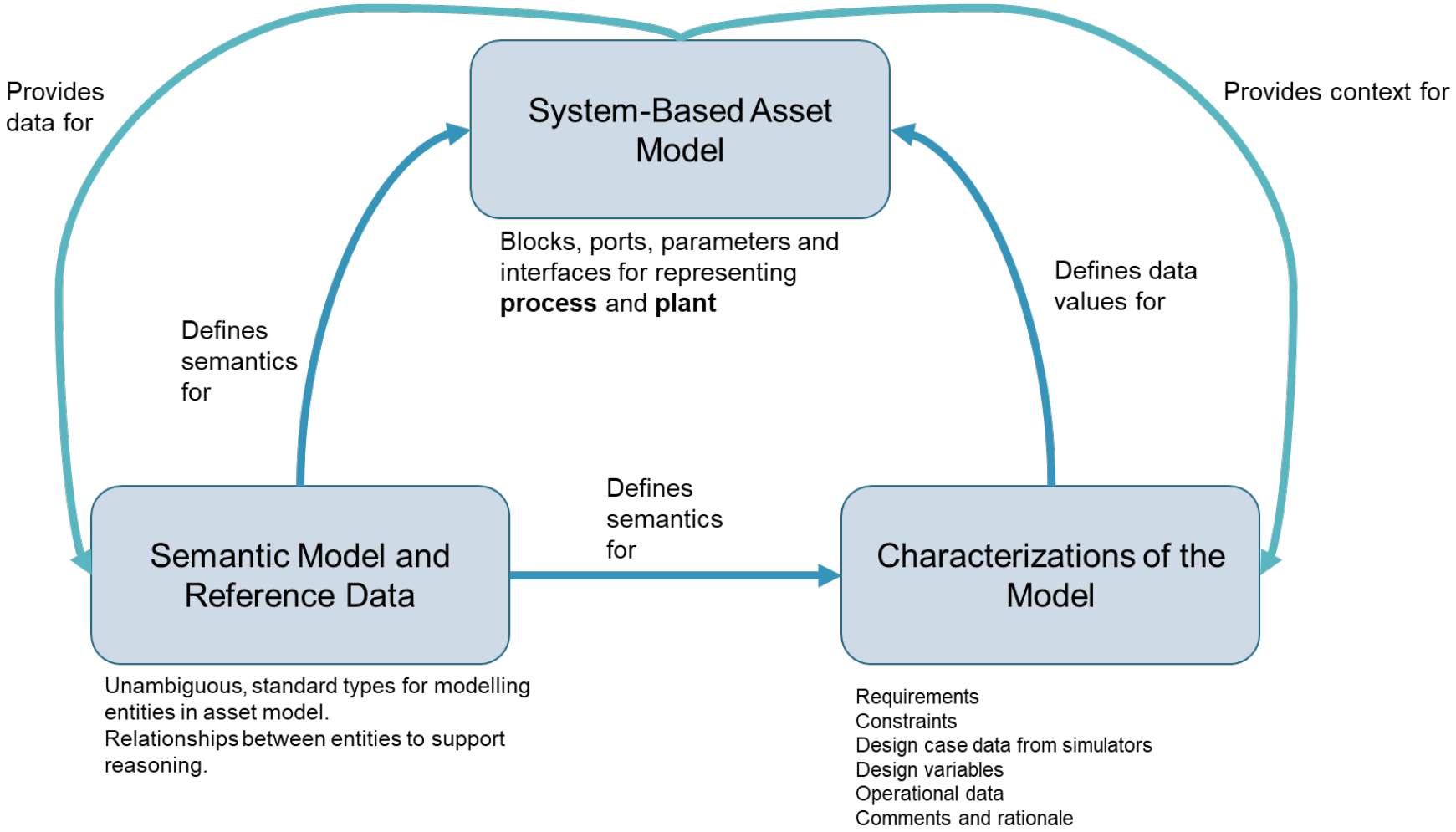
https://doi.org/10.3389/fmtec.2022.945717

Challenges

Why MBSE isn’t the solution to our problem

- SysML / UML / MBSE tools are too expensive and too complex for operational engineers.
- But building good, simpler graphical system modelling tools is hard.
- We only need to use about 10% of SysML.
    - But system engineers want us to adopt the whole approach.
- SysML is good for building a structure.
    - But awful at interoperability and data entry.
- We only have a few structures of systems
    - But many case datasets to store and check.
- Engineering databases are focused only on the equipment.
    - We need process systems to be first-class citizens in modelling.

A possible architecture for the future



Thank You!

www.sirius-labs.no

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