Engineering Automation

Petri Solanti, Siemens EDA

INSIDE Connect 2025

3-4 September
Malaga

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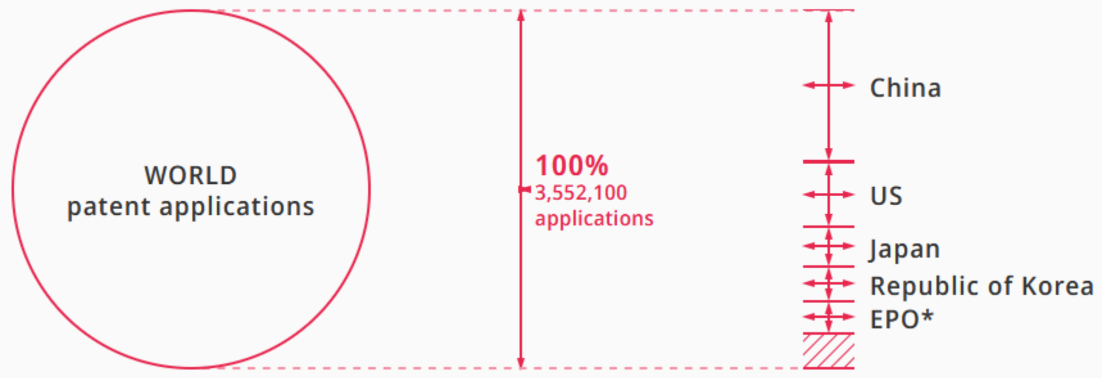
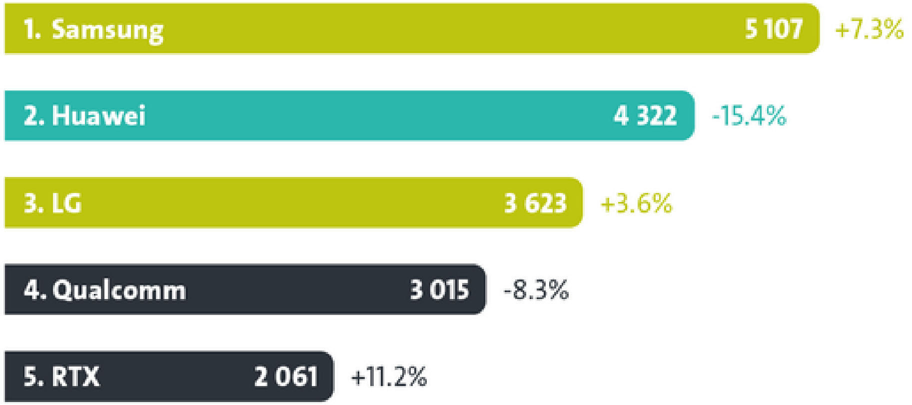
Europe is Lagging in Innovation

Europe is behind other regions in research and innovation:

- International patent applications *Source: WIPO Statistics Database
    - China 47,2%
    - USA 16,8%
    - Japan 8,4%
    - Korea 6,8%
    - EPO 5,6%



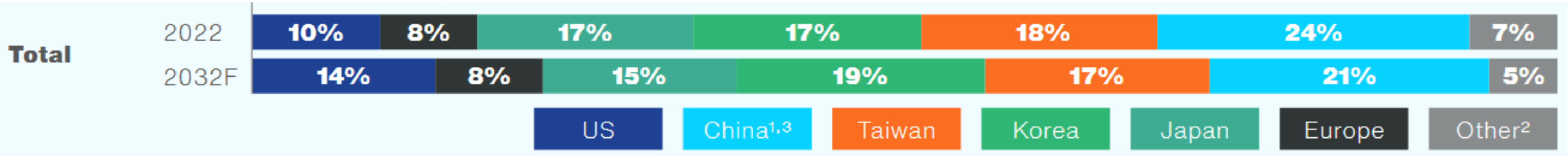
- European patent applications : Top 5 applicants *Source: EPO
    - Samsung
    - Huawei
    - LG
    - Qualcomm
    - RTX
    - Siemens



Europe is Lagging in Semiconductors

Europe is behind other regions in semiconductors:

- Semiconductor revenue growth in 2024 *Source: www.semiconductors.org
  - Americas +44,8%
  - China +18,3%
  - APAC +12,5%
  - Japan -0,4%
  - Europe -6,4%
- Global wafer fabrication capacity *Source: www.semiconductors.org



- Semiconductor industry value-add in 2022 *Source: www.semiconductors.org

Europe is Lagging in Design Automation

Europe is behind other regions in Design Automation:

- Global Electronic Design Automation (EDA) market 2025 *Source: www. intellectualmarketinsights.com
  - North America 45%
  - APAC 30%
  - Europe 15%
  - Rest of the World 10%
- Design automation industry is ~50bn$ industry with 30% R&D investment
  - USA dominated
  - Europe is practically non-existent
  - China has initiated its own EDA industry
- European universities focus on open source and freeware
  - Graduates have no knowledge in commercial tool flows
  - Publications do not reflect the rapid improvement of the commercial tools *
  - Bad experiences cause reluctance to adopt new design methodologies

* S. Lahti, T. D. Hämäläinen: *High-Level Synthesis for FPGAs—A Hardware Engineer's Perspective*, IEEE Access vol 13, 2025
10.1109/ACCESS.2025.3540320

Why do we need Engineering Automation?

Other problems Europe is facing

- Skills gap
  - MINT subjects are not attractive to the students
  - Microelectronics, specially design of large digital ASICs offered by few universities
  - Electronics engineers getting retired, missing 75.000 engineers in 2030 (Efecs 2024)
  - Adoption of new design methodologies is far behind the other regions
- Fragmented industry
  - European semiconductor vendors are small
    - No EU companies in WW top 10 *Source: https://companiesmarketcap.com/
  - Many small design facilities, 21% of WW design facilities *Source: www.semiconductors.org
  - Very few design engineers, only 4% of design engineers WW *Source: www.semiconductors.org
    - USA 32%
    - China 28%
    - India 19%
- Conclusion: European engineers must be much more productive to be competitive

Potential Methodologies to Increase Productivity

- Raising abstraction level
  - Model based system level engineering with automatic code generation
- Standardize methodologies and model exchange
  - SySML, semantics and standards
- Verification shift-left and automating design steps
  - Digital twinning and copiloting
- Manage product development, manufacturing and support
  - Engineering over the lifecycle
- Supporting infrastructure
  - Open source and the ecosystem

Introductions

- Systems Engineering and where is Model Based Systems Engineering leading us?
  - Maarten Bonnema, University of Twente
- SysML, Semantics & Standards: Semantic Integration in Cyber-Physical Environments
  - Torbjorn Holm / Carl Borngrund, Lulea University
- Digital Twinning & Copiloting
  - Pál Varga, Budapest University of Technology and Economics
- Engineering the future: Addressing system complexity in high-tech equipment
  - Benny Åkesson, TNO
- Why you should consider open source in your ecosystem
  - Boris Baldassari, Eclipse Foundation
- Open discussion & closing remarks

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Systems Engineering
and
Where is Model Based Systems Engineering leading us?

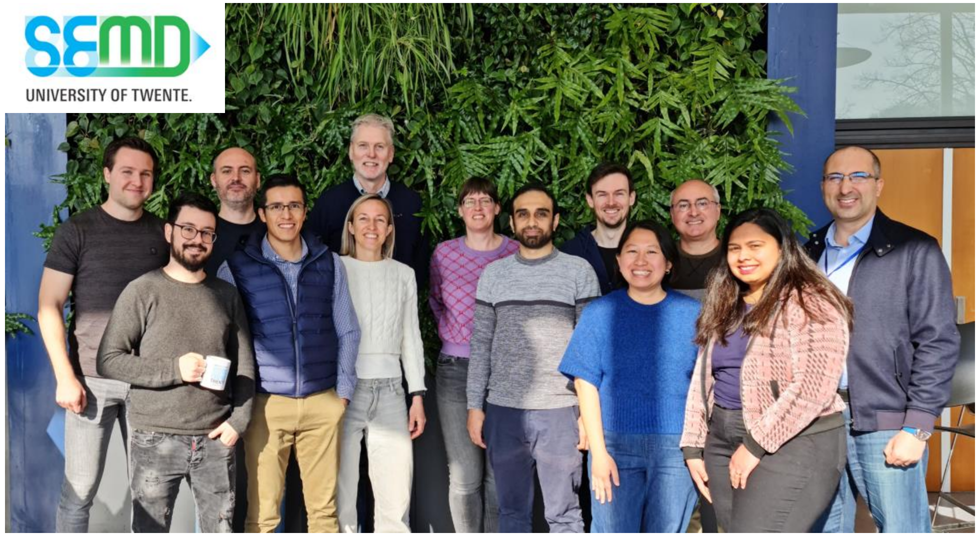
Maarten Bonnema

Inside Connect, Malaga, 20250904

SYSTEMS ENGINEERING & MULTIDISCIPLINARY DESIGN (SEMD)

Who is Maarten Bonnema

- Full Prof in Systems Engineering and Multidisciplinary Design - SEMD
- MSc in Electrical Engineering
- EngD in Technical Systems (Mechatronics & Mechanical Engineering)
- PhD in Systems Architecting
- Industrial Experience as Systems Engineer at ASML
- Collaboration with, and consulting for high-tech companies
- INCOSE Fellow
  (International Council On Systems Engineering)



What is Systems Engineering?

INCOSE definition:

"a transdisciplinary and integrative approach to enable the successful realization, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods."

https://www.incose.org/about-systems-engineering/system-and-se-definition/systems-engineering-definition, accessed 20230626

Noah's Ark, Roman Aquaducts & Road System

1960s: MIT course on SE by Arthur Hall

1966: USAF SE Handbook

1969: STD-499 Military Standard: SE Management

1990: National Council on Systems Engineering, renamed in 1995 INternational: INCOSE

1995: NASA SE Handbook

1996: The Art of Systems Architecting by Maier and Rechtin

1998: INCOSE SE Handbook v.1

2009: CNN Money calls Systems Engineer "the best job in the world"

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"…**the systems engineer resembles an architect**, who must generally have adequate substantive knowledge of building materials, construction methods, and so on, to ply his [or her] trade. Like architecture, **systems engineering is in some ways an art as well as a branch of engineering**. Thus, aesthetic criteria are appropriate for it also. For example, such essentially aesthetic ideas as **balance**, **proportion**, **proper relation of means to ends**, and **economy of means** are all relevant in a systems-engineering discussion."

Hendrick Bode in a 1967 report for the US House of Representatives

https://nap.nationalacademies.org/read/21281/chapter/6

What is Systems Engineering? – a practical description

1. The *System perspective*;
2. Separate the *what* and *how much*, from the *how*;
3. Focus on the *interfaces*;
4. *Uncertain* and *incomplete information* in taking far-reaching decisions;

- Relying on *Communication* in a context of *Multi-disciplinarity*.

1. The System Perspective:

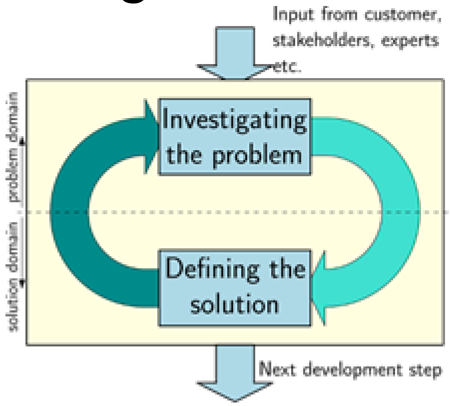
- Zooming in to relevant details
- Zooming out to the context and environment
- Zooming in and out in Hierarchy and Time

- One person's system is another person's subsystem

What is Systems Engineering? – a practical description

2. Separate the *what* and *how much*, from the *how*

- Fundamental to SE
- Distinguish the Function from the Solution
- Define what is good *enough*



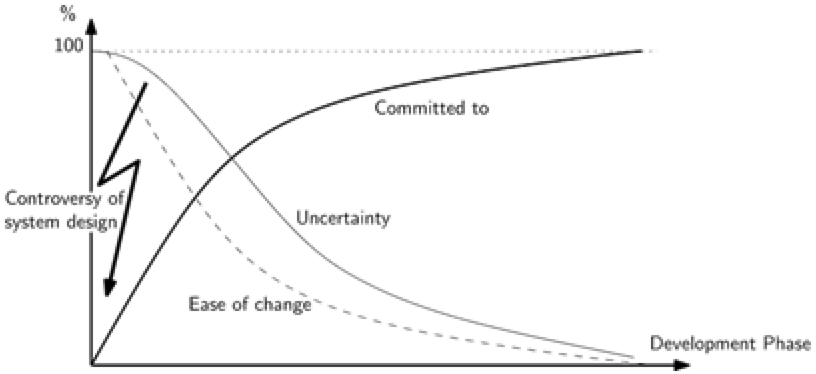
3. Focus on the *interfaces*

"There are two kinds of Systems Engineers: those that look at the interfaces and amateurs"

Robert Halligan - PPI

What is Systems Engineering? – a practical description

4. Uncertain **and** ***incomplete information*** **in taking far-reaching decisions**



"If a man will begin with certainties, he shall end in doubts; but if he will be content to begin with doubts he shall end in certainties"

Sir Francis Bacon

+ Relying on ***Communication*** **in a context of** ***Multi-disciplinarity***

- Different disciplines use different languages
- Integration and consistency is not easily checked
- SE looks at the big picture and across disciplines

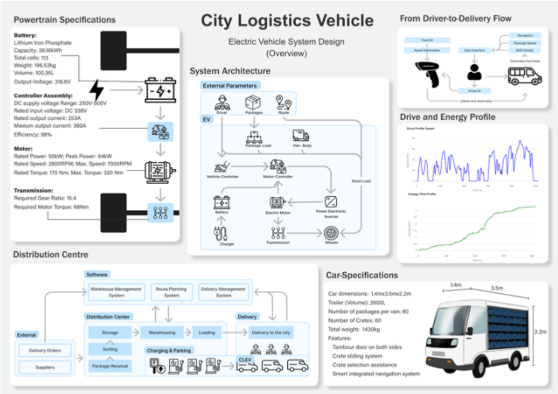
The SE uses many "simple" diagrams to acquire, manage and show very diverse types of information and knowledge

Picture source: Bonnema, G. M., K. T. Veenvliet and J. F. Broenink (2016). Systems Design and Engineering: facilitating multidisciplinary development projects. Boca Raton, FL, CRC Press.

Transition from “Paper & document based” to “Model based”

Paper & document based SE

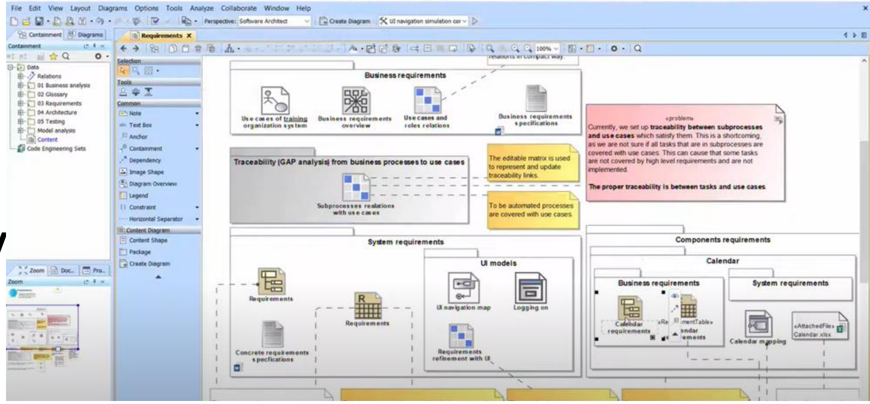
- The “truth” is in reviewed and accepted documents
- “baselines”
- Widespread use of pictures and diagrams (“model supported”)
- A3 Architecture Overviews help to focus



Students’ work, see https://www.mdpi.com/3457318

Model Based SE (MBSE)

- The “truth” is in an interlinked set of models
- Documents (snapshots) can be generated automatically
- Tooling essential to maintain consistency



Source https://www.keonys.com/catia-magic

MBSE

- Philosophy
  (Long&Scott: “thought process”)
- Method
- Tool(s)
- Facilitated by a language

INCOSE: MBSE is the “formalized application of modeling to support system requirements, design, analysis, verification and validation, beginning in the conceptual design phase and continuing throughout development and later life cycle phases”

- Language (e.g. SysML) and tool without method or philosophy is no SE
- Philosophy or method without tool and language is impractical and unstable

Long, D. and Z. Scott (2011). A Primer for Model-Based Systems Engineering. Blacksburg, VA, USA, Vitech Corporation.

INCOSE Wiki: https://incosewiki.info/Model_Based_Systems_Engineering/index.php?title=MBSE_Definitions retrieved 20250829

Promises of MBSE

2007

MBSE enhances the ability to capture, analyze, share, and manage the information associated with the complete specification of a product, resulting in the following benefits:

- Improved communications among the development stakeholders
- Increased ability to manage system complexity
- Improved product quality
- Enhanced knowledge capture and reuse
- Improved ability to teach and learn SE fundamentals

Friedenthal S, Griego R, Sampson M. INCOSE model based systems engineering (MBSE) initiative. Paper presented at INCOSE 2007 Symposium, San Diego, CA, USA, 2007. https://www.researchgate.net/publication/267687693_INCOSE_Model_Based_Systems_Engineering_MBSE_Initiative retrieved 20250829

2020

48 benefits claimed

Improved system quality
Increased rigor
Increased traceability
Reduce errors
Reduce cost
Reduce risk
Improved risk analysis
Improved system design
Increased effectiveness
Improved deliverable quality
Better requirements generation
Increased accuracy of estimates
Improved predictive ability
Better analysis capability
Improved capability
More stakeholder involvement
Strengthened testing

Reduce time
Improved consistency
Increased capacity for reuse
Easy to make changes
Reduce rework
Reduce waste
Increased productivity
Increased efficiency
Increased transparency
Increased confidence
Increased flexibility
Better requirements management
Ease of design customization
Higher level of support for integration
Increased uniformity
Increased precision
Early V&V
Reduce ambiguity

Higher-level support for automation
Reduce burden of SE tasks
Better manage complexity
Improved system understanding
Reduce effort
Better data management/capture
Better decision making
Better accessibility of information
Better knowledge management/capture
Improved architecture
Multiple viewpoints of model
Better communication/ information sharing
Improved collaboration

Henderson, K. and A. Salado (2021). "Value and benefits of model-based systems engineering (MBSE): Evidence from the literature." Systems Engineering **24(1): 51-66.**

Types of projects and MBSE suitability

Intermezzo

Greenfield

Projects start (largely) from scratch

Each project can decide on its methodology and documentation approach

Common in space and defense

(Sequential) Brownfield

Projects create evolutionary changes to existing system designs

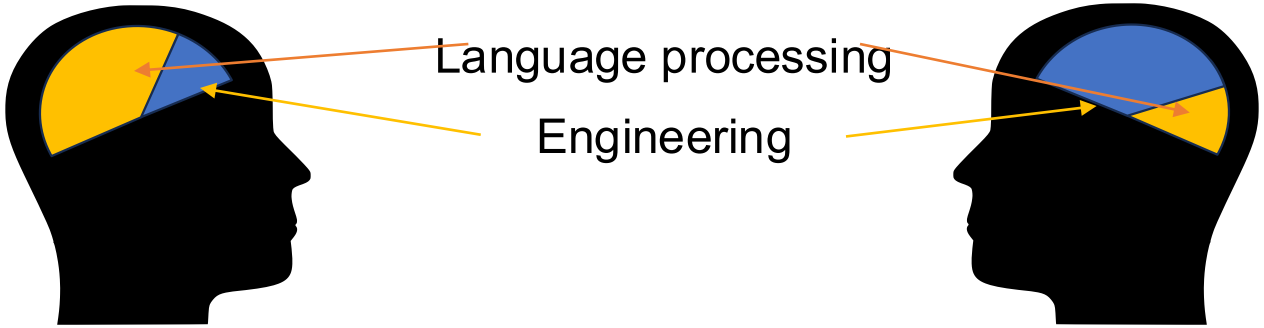
Documentation approach stable across many projects and generations

Common in High-Tech

Challenges of MBSE

- Large body of knowledge not coded in models (in particular relevant for sequential brownfield projects)
- Learning curve for tooling and language
- Cultural aspects
- Perceived value

- Actual *measured* value of MBSE unclear [Henderson&Salado]
- Proficiency in handling an abstract System Language
  - Inhibits communication to non-SE-ers
  - Mental load to handle the language

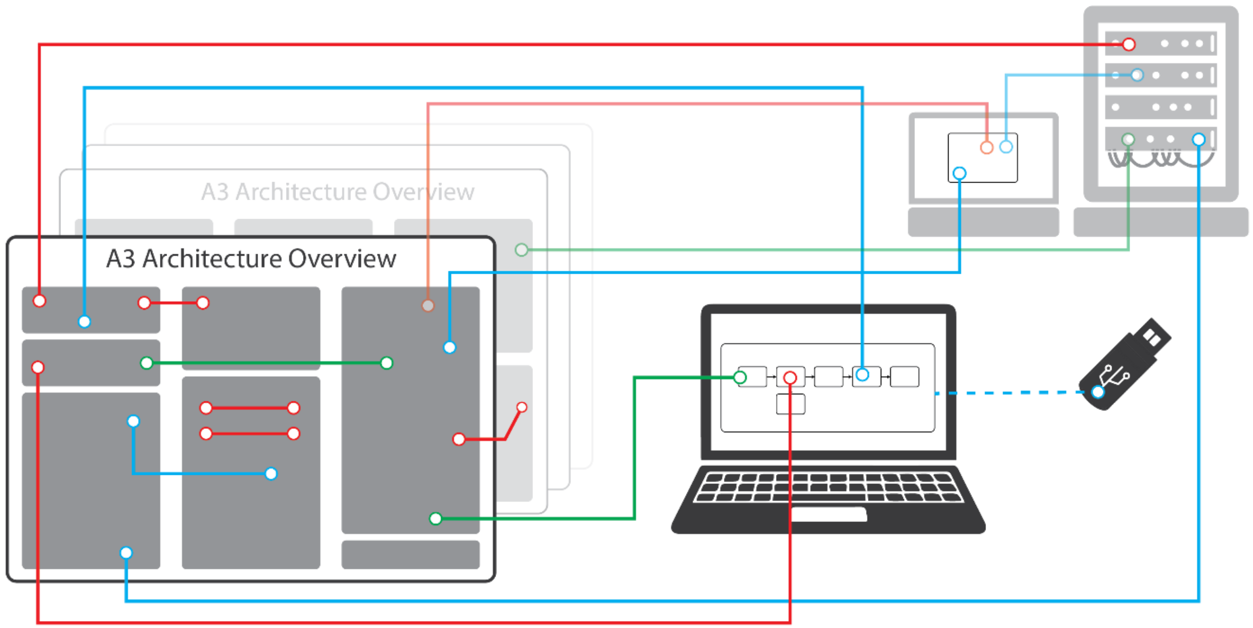


Huldt, T. and I. Stenius (2019). "State-of-practice survey of model-based systems engineering." Systems Engineering **22(2): 134-145.** <- Note that >70% of the respondents in the reported survey are from Aerospace and defense!

Henderson, K. and A. Salado (2021). "Value and benefits of model-based systems engineering (MBSE): Evidence from the literature." Systems Engineering **24(1): 51-66.**

Flavours and mixtures of Paper Based and MBSE

- From MBSE-approaches:
  - Formality
  - Error checking
  - Consistency checking
  - Single source of truth
- From paper-based approaches:
  - High info content
  - Facilitating communication
  - Tailored representations for discussions



Outlook

- Develop user-friendly tooling (ongoing)
- Bridge the gap between pictures and formal models
- Use AI to “mine” bodies of knowledge
- Teach SE to **all** engineering disciplines

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Thank you!

More information on www.utwente.nl/semd

SE in 45 minutes: https://tinyurl.com/SEin45min

Scan Me

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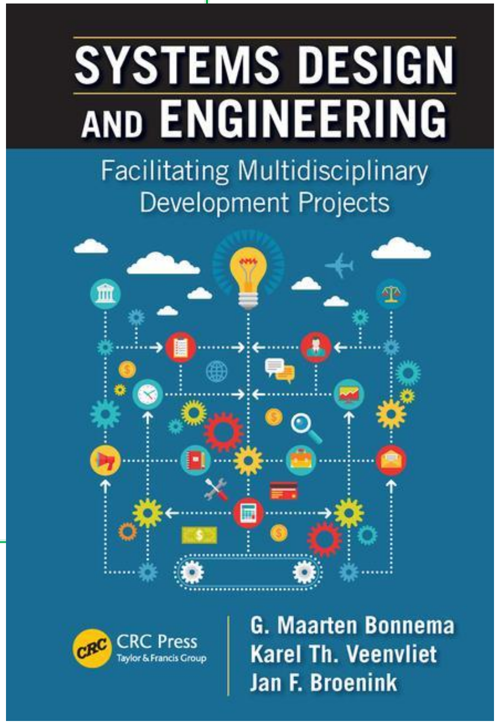
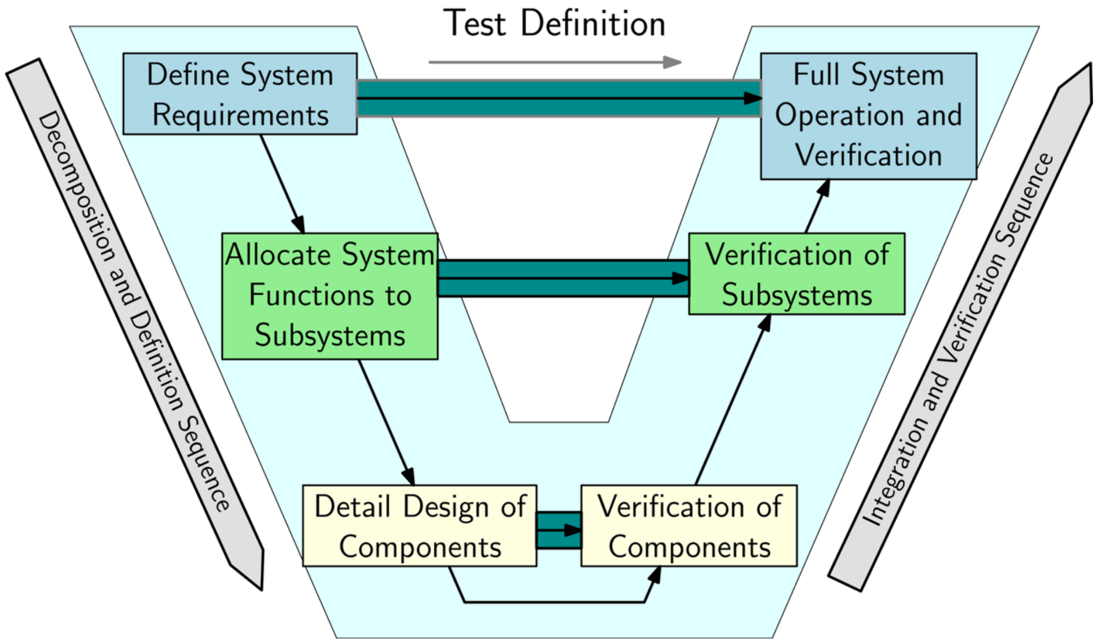
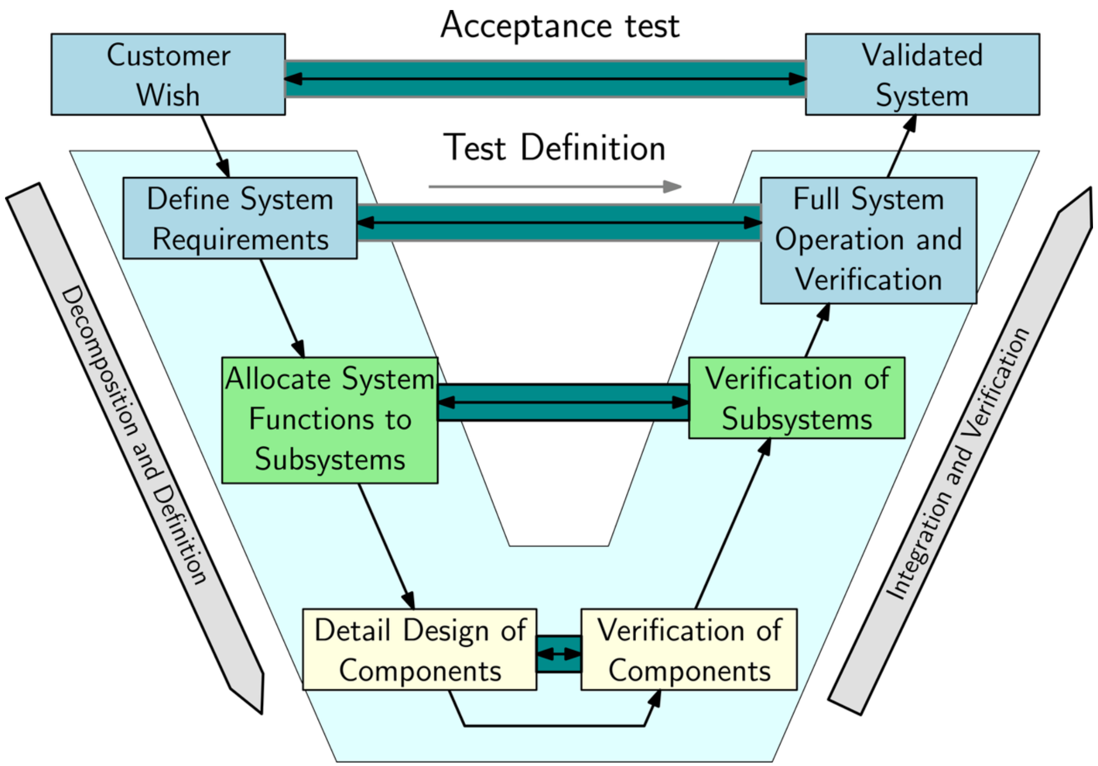


The Vee-Model





SysML, semantics & standards

Semantic Integration in Cyber-Physical Environments

From requirements to handover and operations, knowledge graphs unifying standards and technologies for a flexible product value network

Use Case 2.9 Demonstration | September 4, 2025

This research work has been funded by the European Commission, through the European H2020 research and innovation programme, KDT Joint Undertaking, and National Funding Authorities from 12 involved countries under the research project Arrowhead Tools with Grant Agreement no. 101111977 .

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Lifecycle of an artifact

Products and Production Lines: Both Are Designed, Built, and Evolved

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- Requirements
- Specification
- Design
- Build up
- Handover
- Operations

Is it possible to seamlessly integrate these phases along with their respective technologies and standards?

- The longest phase should be the operation where maintenance, failure, evolution take place until retirement

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Major Engineering standard languages

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Major standards are developed and maintained within their own contexts, each with distinct semantics and employing different modeling technologies and architectures.

→ Semantic gap → Technology gap → Architectural gap

Applied Approach to Address Shortcomings:

1. Transform lexical modeling standards into the W3C Semantic Web OWL 2 DL language, while preserving the original semantics of the standards.

2. Utilize W3C standard technologies such as SPARQL, SHACL, RDF, SKOS, etc., to support information management through knowledge graphs.

3. Unify architectural frameworks by adopting W3C technologies as a common foundation.

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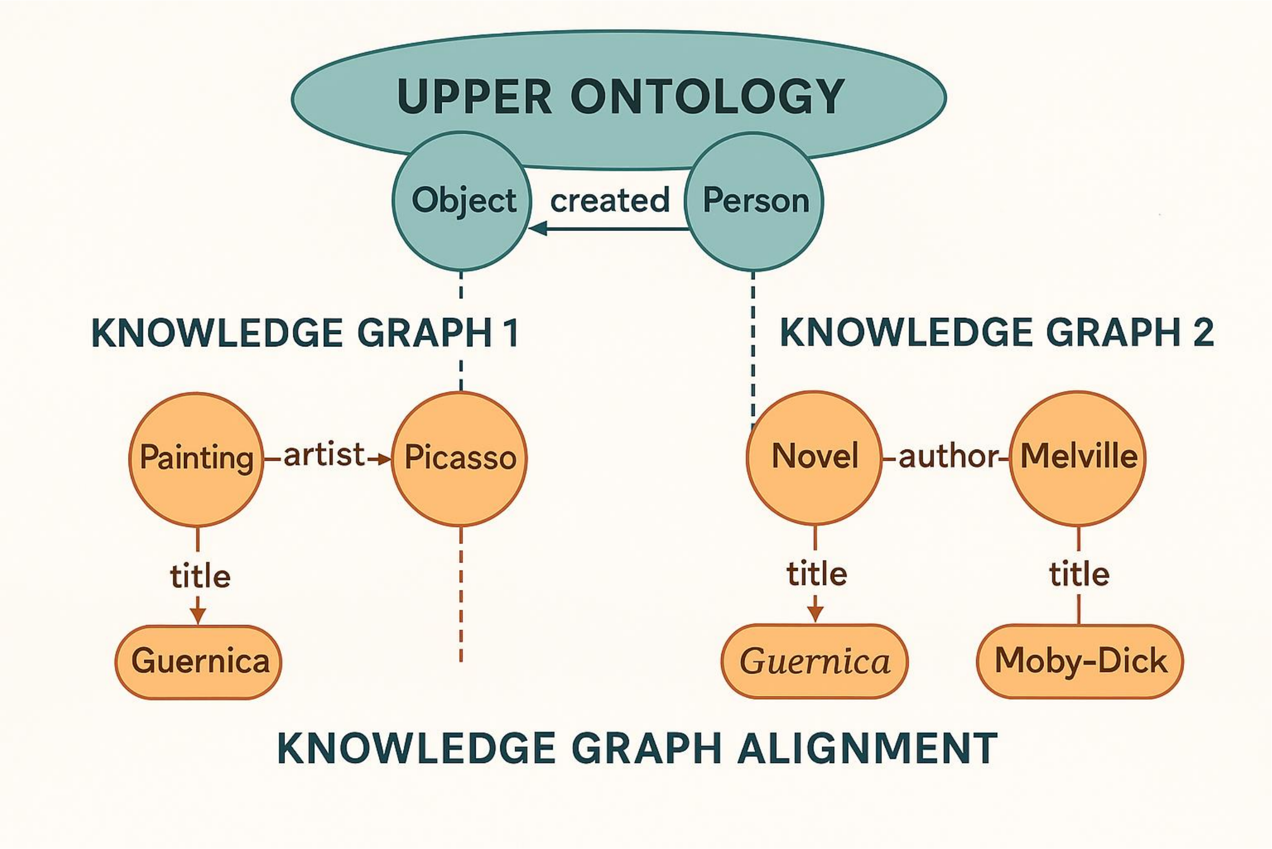
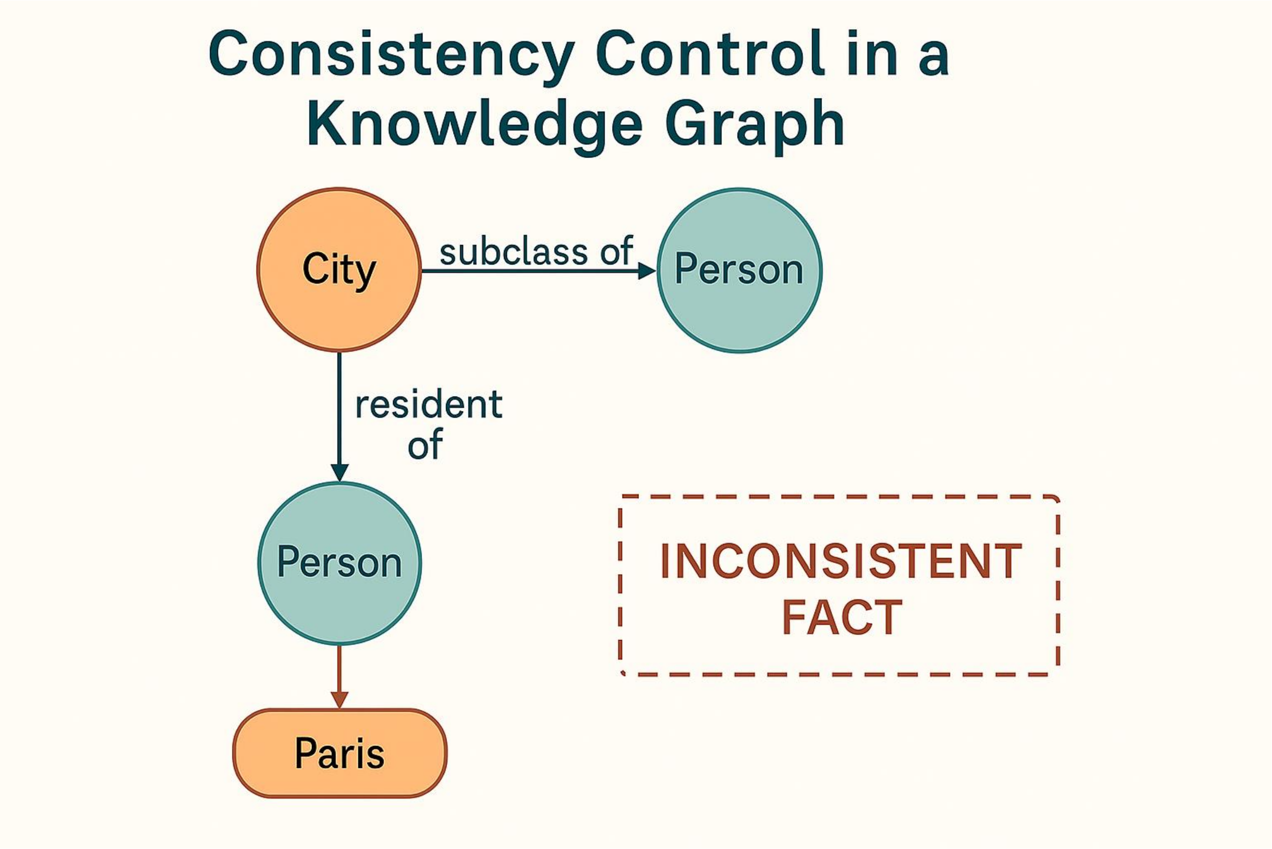
Enabled features

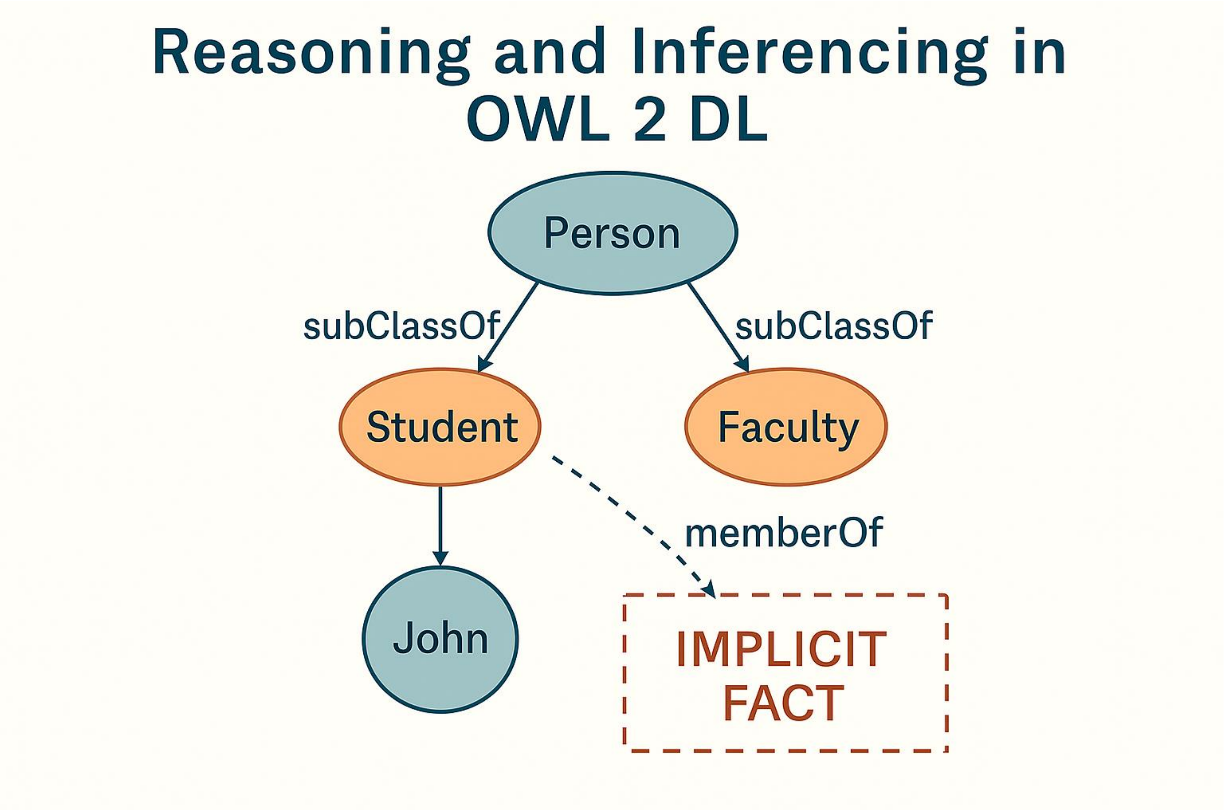
- Extendibility and flexibility (ISO 27362-3)



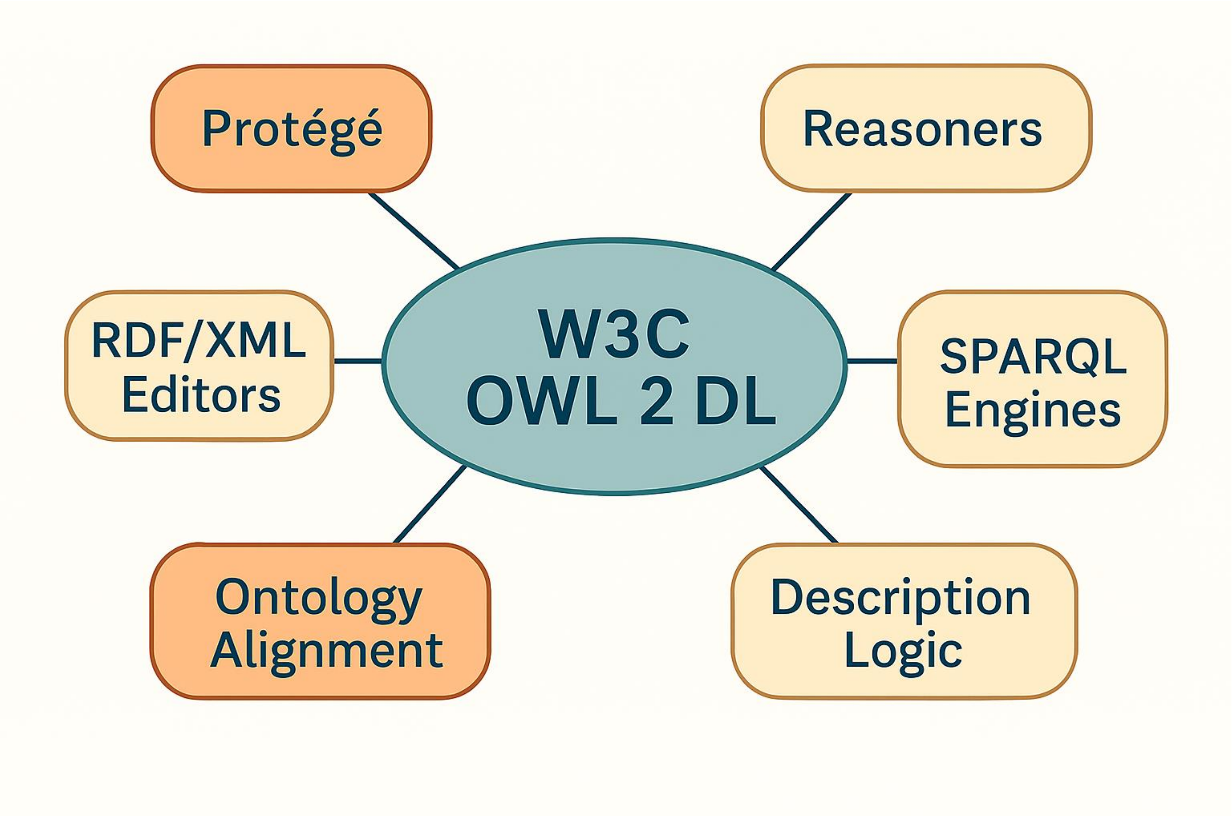
- Consistent knowledge



- Reasoning and Inferencing



- Common tools and technologies



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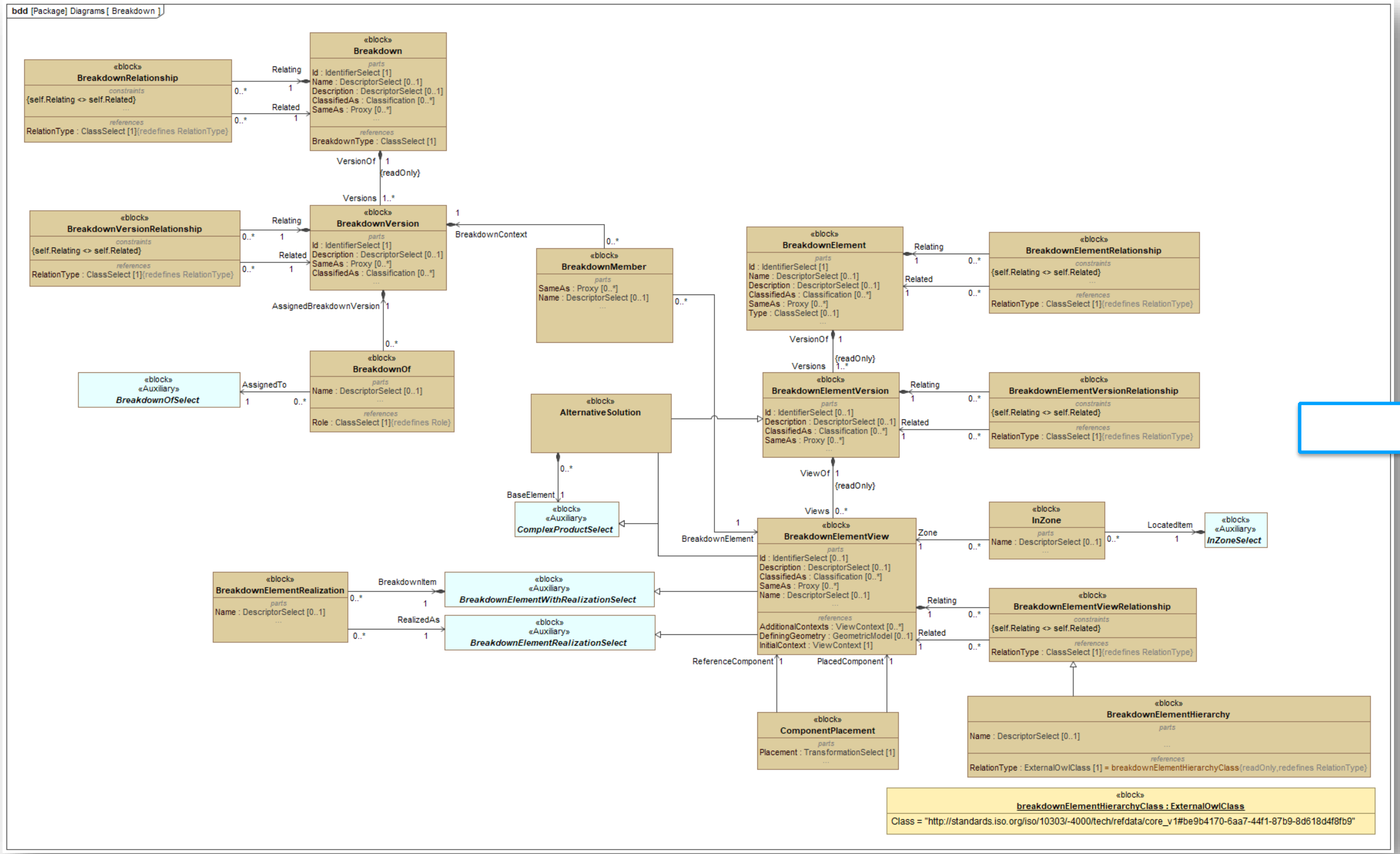
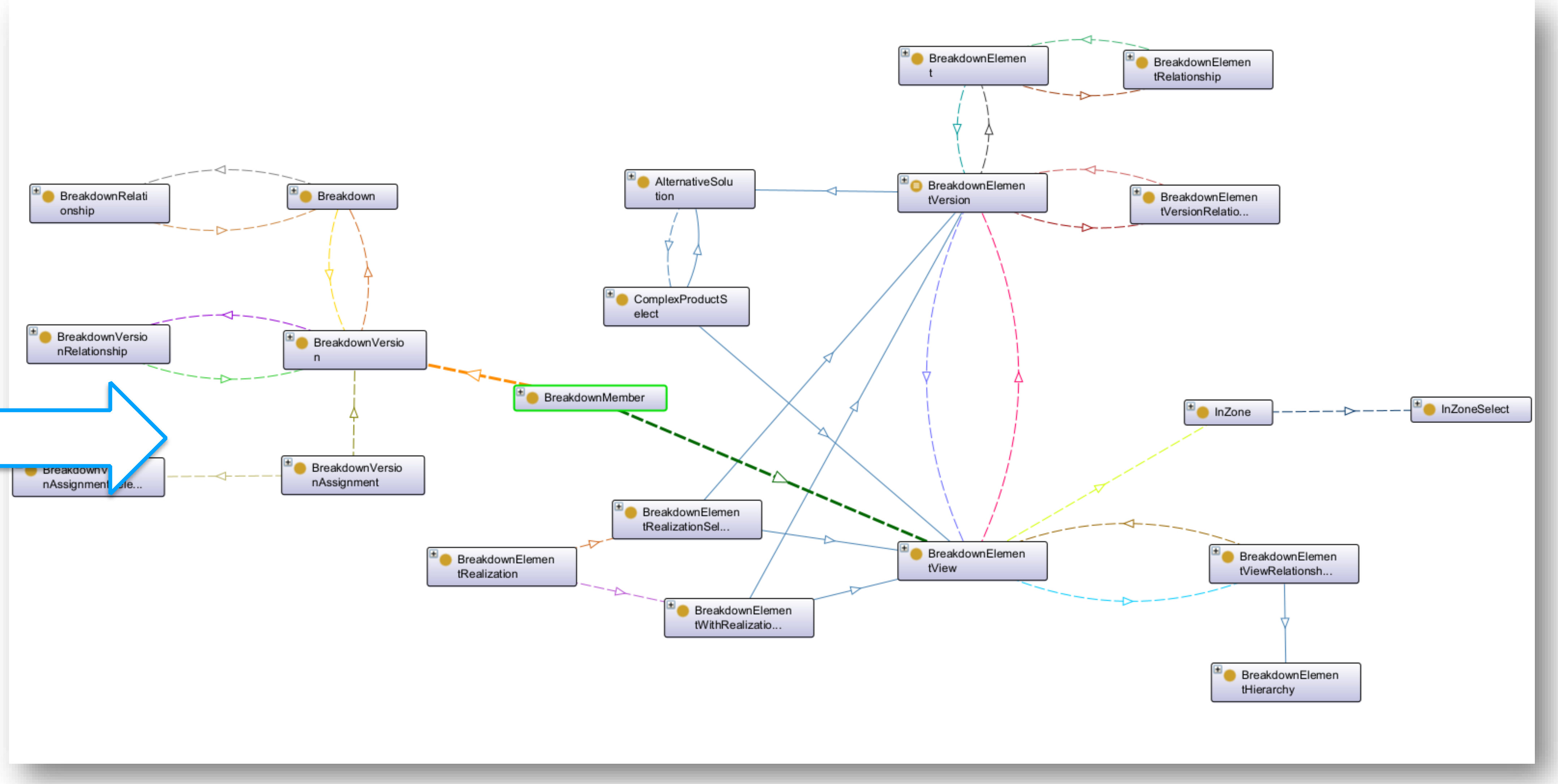
Example of transformation of standards

Mature standard with very large uptake

STEP Core model transformed to a STEP Core Ontology





100% of STEP Core (AP239 & AP242)
(Axioms 16 834 , Classes 1059)

Example of transformation of standards

New standard under introduction

SysML V2

KerML

```
// Industrial Pump Station Model
part PumpStation {
  part mainInlet: Pipe
  part inletFork1: Pipe
  part inletFork2: Pipe
  part pump1: Pump
  part pump2: Pump
  part outletJoin1: Pipe
  part outletJoin2: Pipe
  part mainOutlet: Pipe
  part controlSystem: ControlSystem
  // Inlet flow distribution
  connect mainInlet.output to inletFork1.input
  connect mainInlet.output to inletFork2.input
  // Pumps connected to inlet forks
  connect inletFork1.output to pump1.input
  connect inletFork2.output to pump2.input
  // Pumps connected to outlet join pipes
  connect pump1.output to outletJoin1.input
  connect pump2.output to outletJoin2.input
  // Outlet join pipes merge into main outlet
  connect outletJoin1.output to mainOutlet.input
  connect outletJoin2.output to mainOutlet.input
}
// Pump definition
part Pump {
  port input: FluidPort
  port output: FluidPort
```

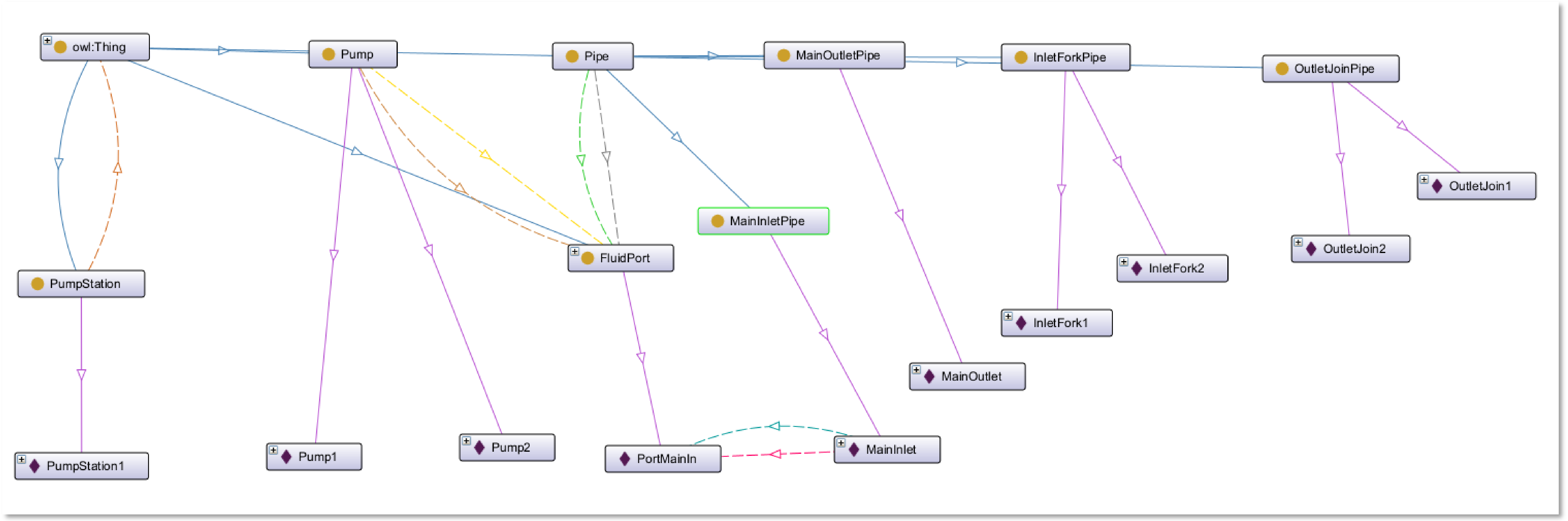
```
// Control system
part ControlSystem {
  property mode: Enum {AUTO, MANUAL}
  property status: Enum {ON, OFF}
  behavior controlLogic: ControlBehavior
}
// Control behavior
behavior ControlBehavior {
  input sensorData: SensorInput
  output commands: PumpCommand
  action evaluateStatus {
    if (sensorData.pressure > threshold) {
      commands.turnOff(pump1)
      commands.turnOff(pump2)
    } else {
      commands.turnOn(pump1)
      commands.turnOn(pump2)
    }
  }
}
// Sensor input
part SensorInput {
  property pressure: Real
  property flowRate: Real
}
// Pump command interface
interface PumpCommand {
  action turnOn(p: Pump)
```

Transformation

OWL 2 DL

```
Ontology: <http://example.org/pumpstation>
Class: PumpStation
  SubClassOf:
    hasPart some MainInletPipe,
    hasPart some InletForkPipe,
    hasPart some Pump,
    hasPart some OutletJoinPipe,
    hasPart some MainOutletPipe,
    hasPart some ControlSystem
Class: Pipe
Class: MainInletPipe
  SubClassOf: Pipe
Class: InletForkPipe
  SubClassOf: Pipe
Class: OutletJoinPipe
  SubClassOf: Pipe
Class: MainOutletPipe
  SubClassOf: Pipe
Class: Pump
  SubClassOf:
    hasInput some FluidPort,
    hasOutput some FluidPort,
    hasFlowRate exactly 1 xsd:float
Class: FluidPort
  SubClassOf:
    hasPressure exactly 1 xsd:float,
    hasFlow exactly 1 xsd:float
Class: ControlSystem
```

```
Class: ControlBehavior
  SubClassOf:
    receivesInput some SensorInput,
    sendsCommand some PumpCommand
Class: SensorInput
```




```
ObjectProperty: sendsCommand
ObjectProperty: executesAction
DataProperty: hasFlowRate
  Range: xsd:float
DataProperty: hasPressure
```

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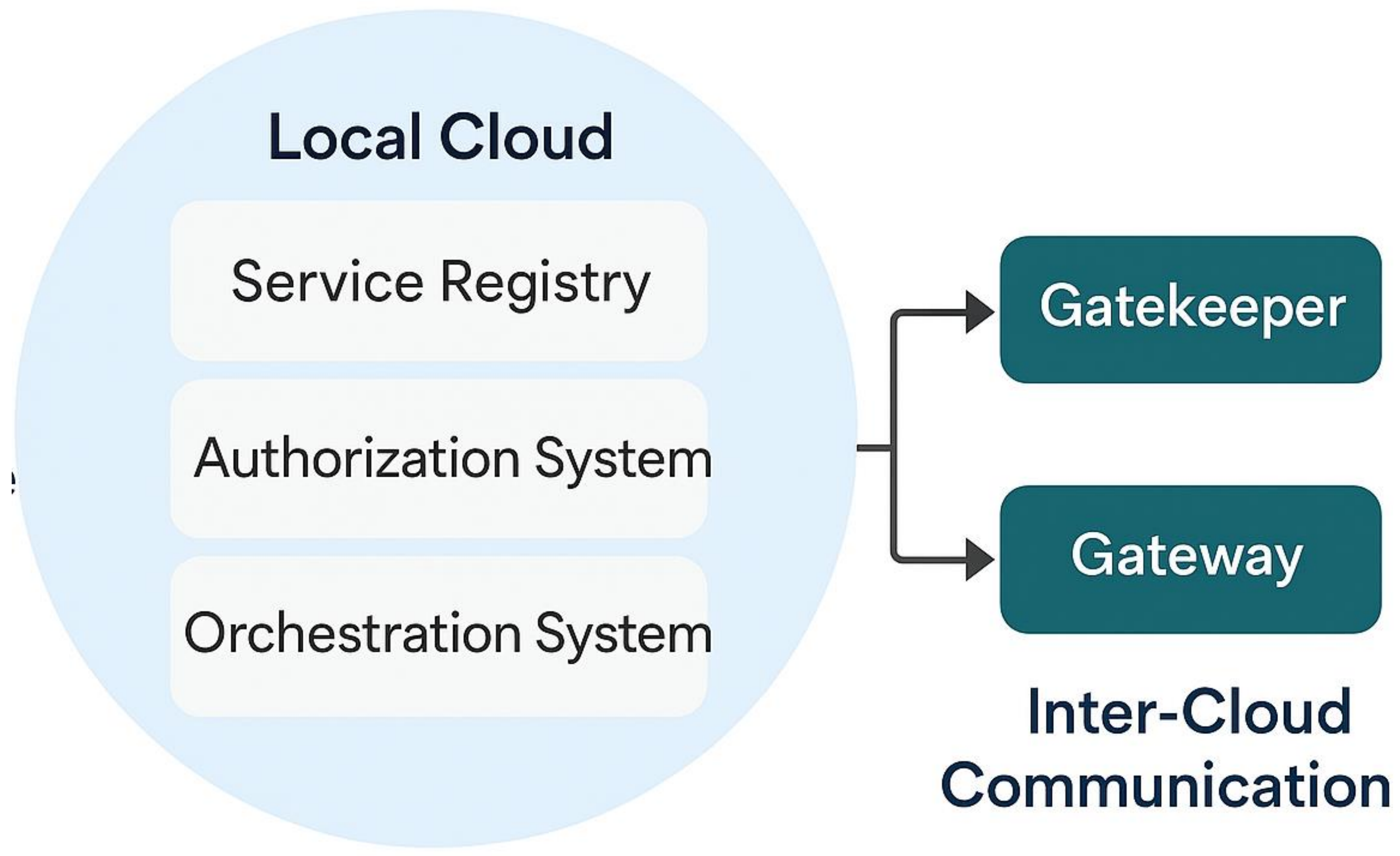
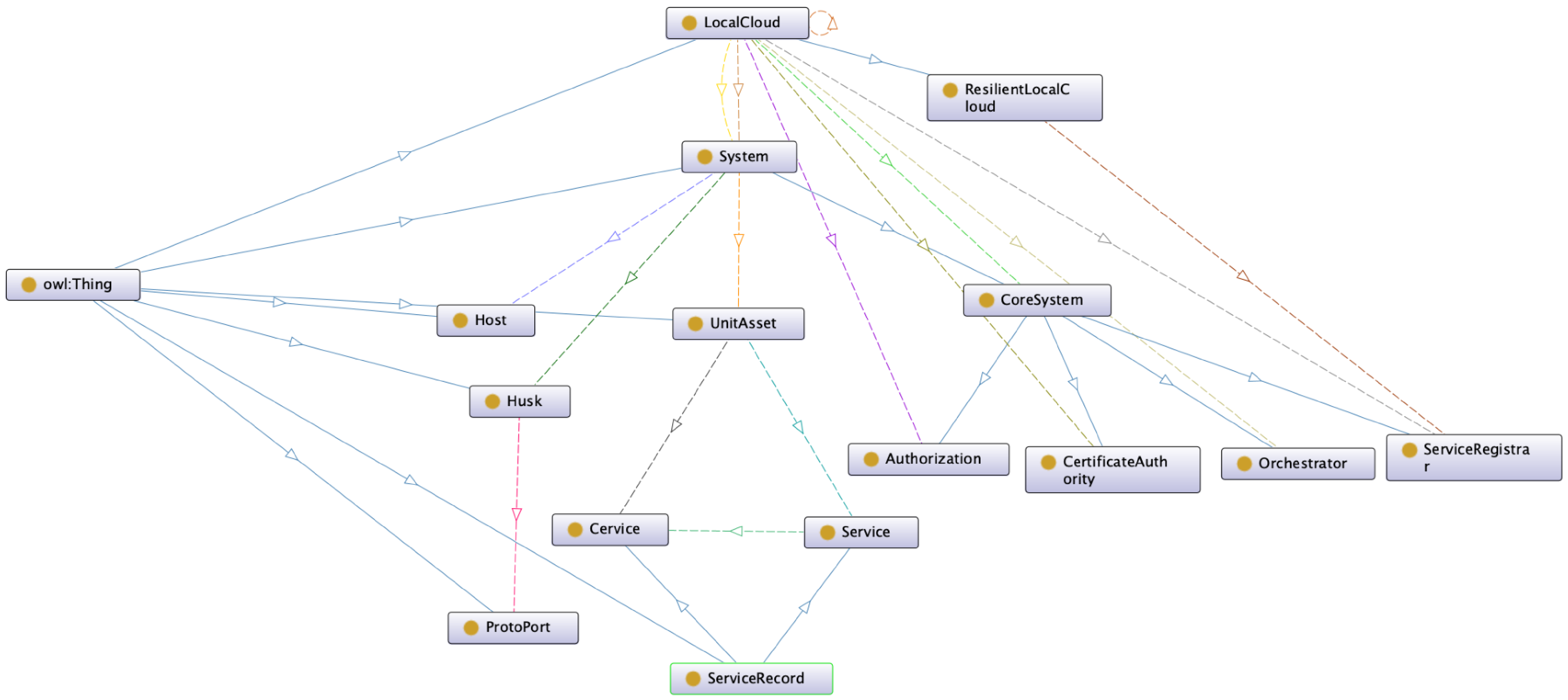
Implementation eco-system

Utilizing the Arrowhead framework for flexible implementation



Arrowhead Software Architecture



Arrowhead Framework Ontology

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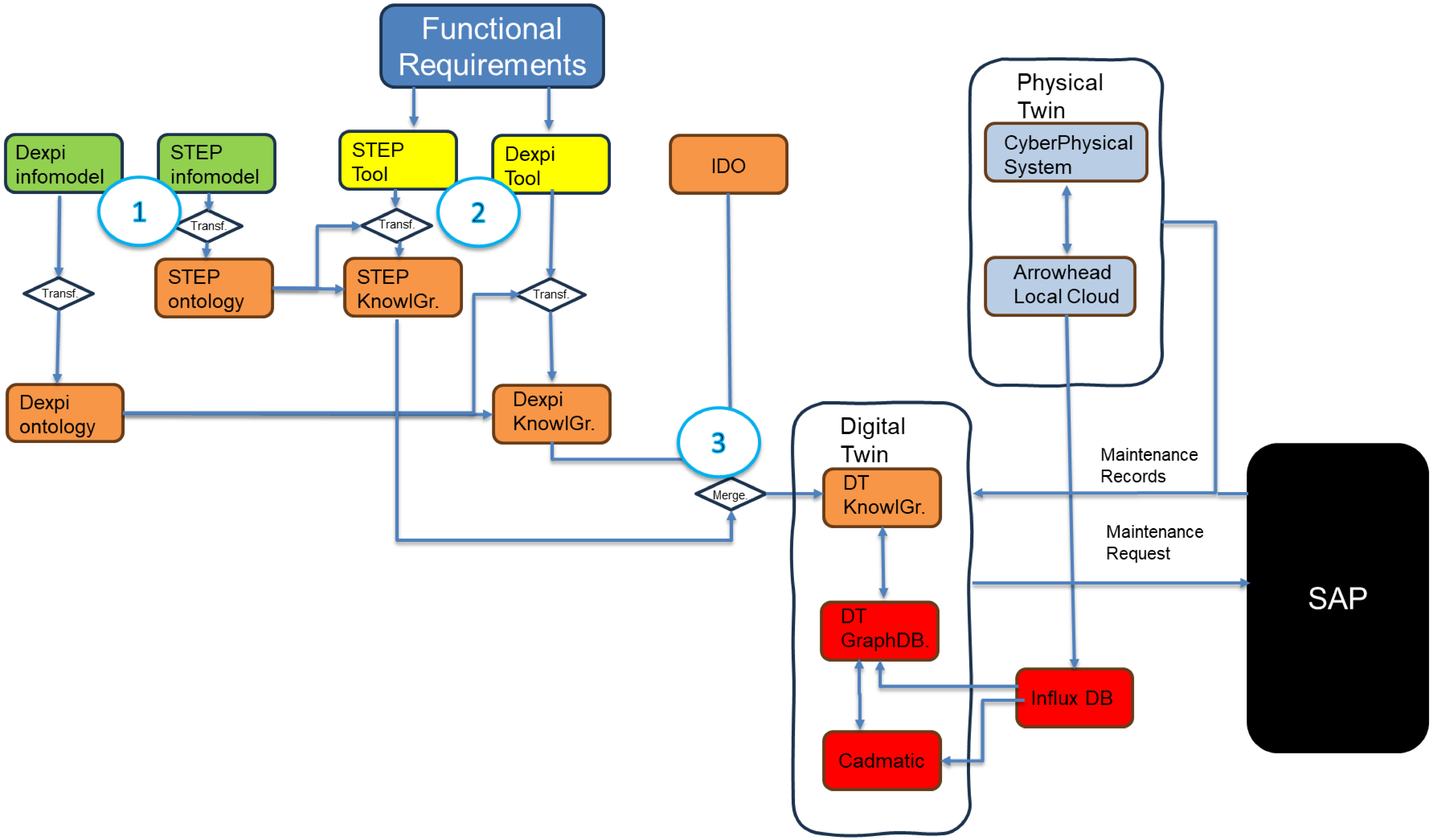
Arrowhead fPVN use case 2.9

Knowledge Graph Based Life Cycle Digital Twin



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Proof of concept

A pump station

- Pipe & Instrumentation Diagram
- Transformation P&ID to DEXPI standard
- Transformation of STEP & DEXPI to OWL 2
- Cyber Physical Systems integration for computerized operation

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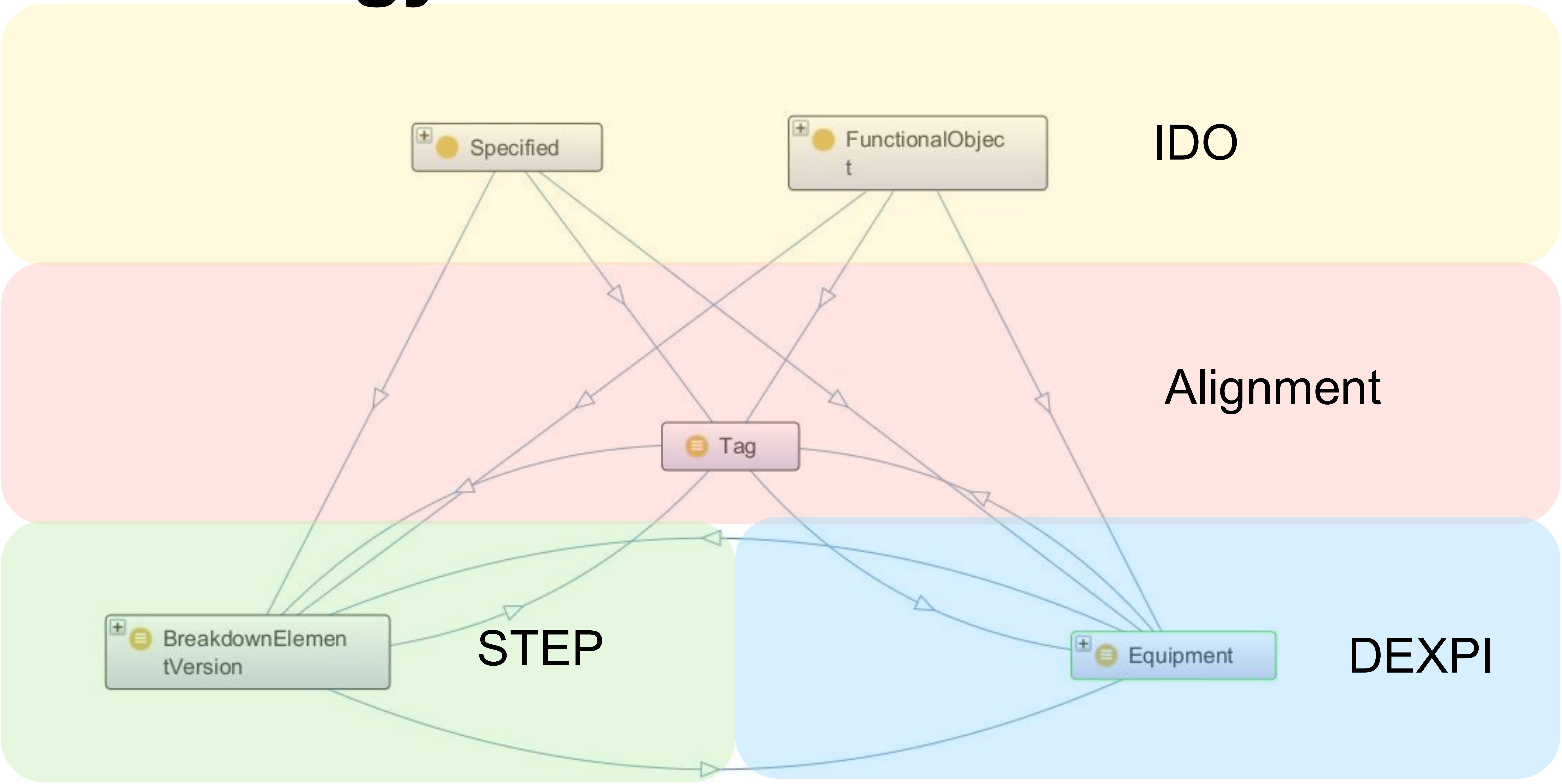
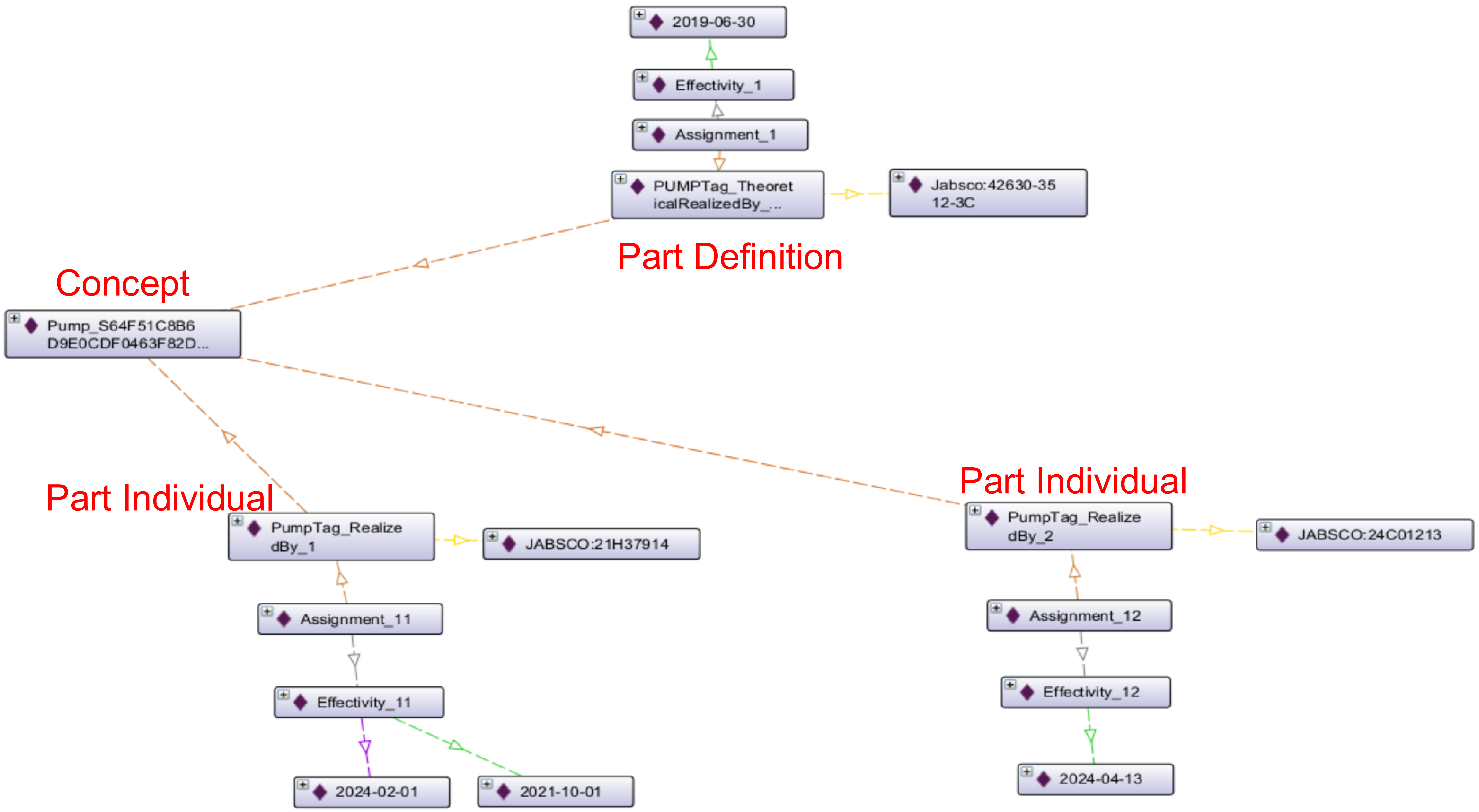
Knowledge graph alignment using W3C technology and standards



Instance data of a pump lifecycle

Utilizing DEXPI, STEP & IDO as constraints



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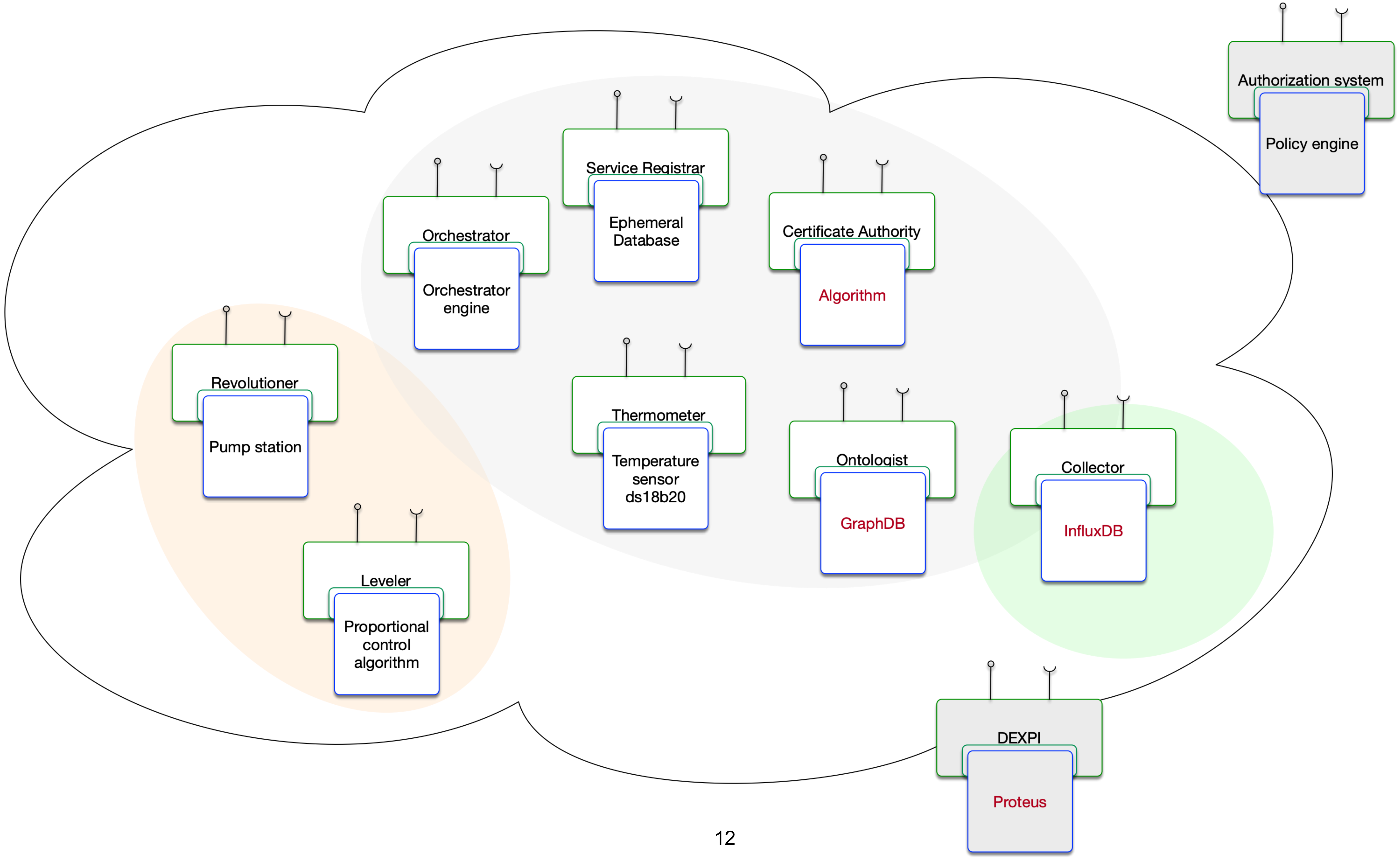
The demonstration during operations

Distributed System of Systems



Conclusion

Seamless integration of data models

Bridging the Communication Gap Across Technologies and Engineering Phases

Applying alignment between different knowledge graphs – using Alignment of chosen classes and IDO

Common “technology” to reduce system costs and training etc.

Perfect fit with service-oriented architectures

There is no need to discard existing systems
Instead, we enable seamless integration by transforming fragmented information into actionable knowledge supporting reasoning and consistency control

INSIDE Connect
Málaga, 04.09.2025

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Digital Twinning and Copiloting

by Pal Varga

Budapest University of Technology and Economics
Department of Telecommunications and AI

BME TMiT

HOLA

I am interested in

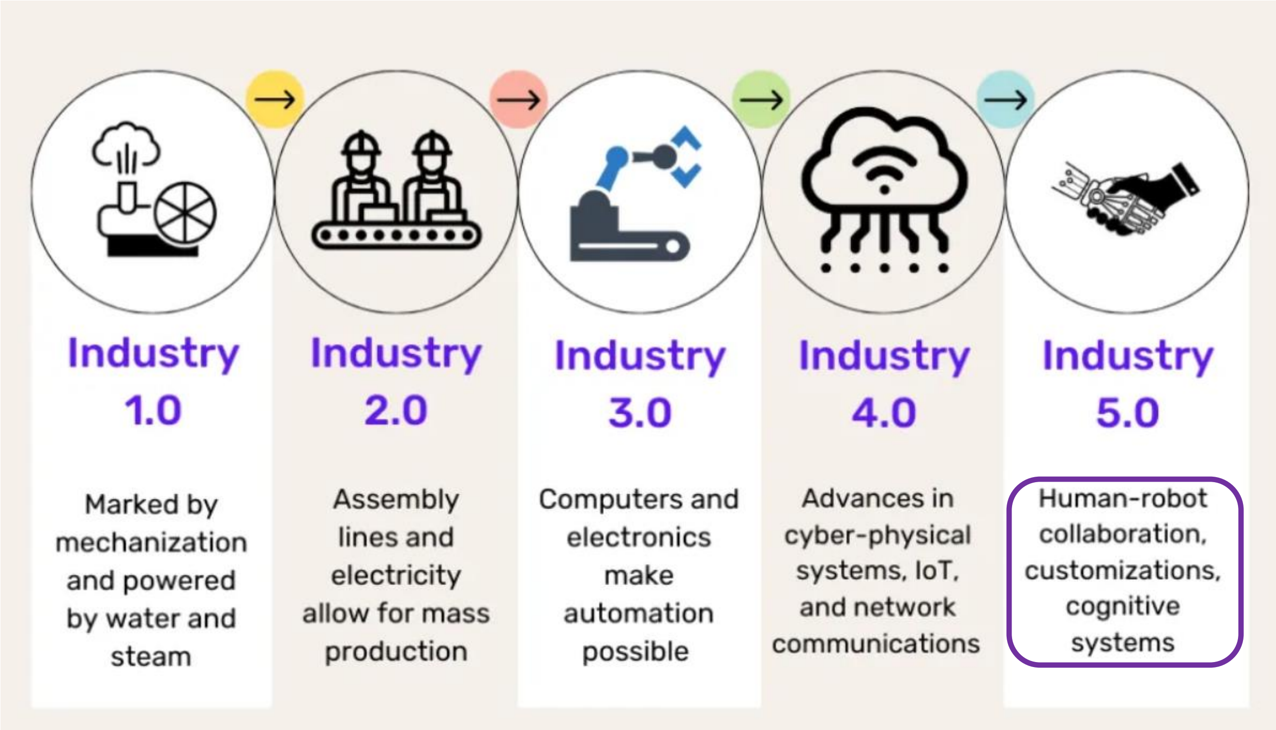
interoperability of cyber-physical system of systems,

5G / 6G mobile networks, and AI/ML applications in Industry5.0

Pal Varga – pvarga@tmit.bme.hu

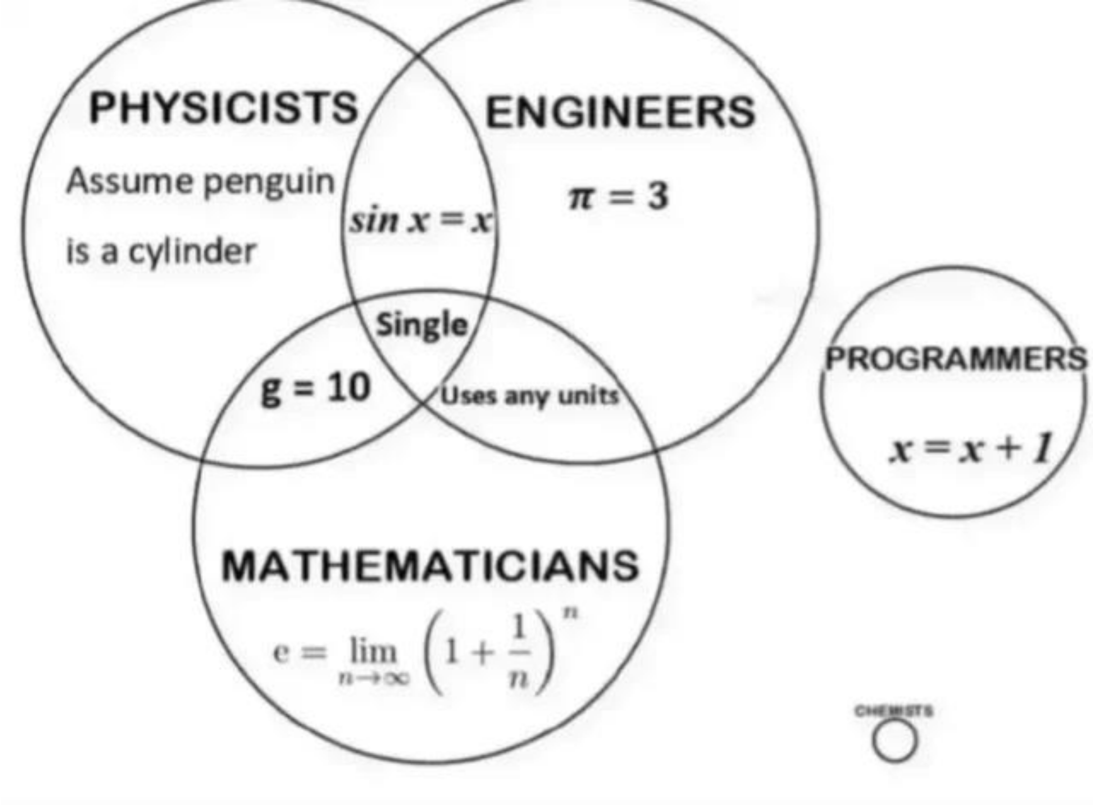
BME TMIT

Towards Industry5.0



Source: Google images

Oh, Engineers



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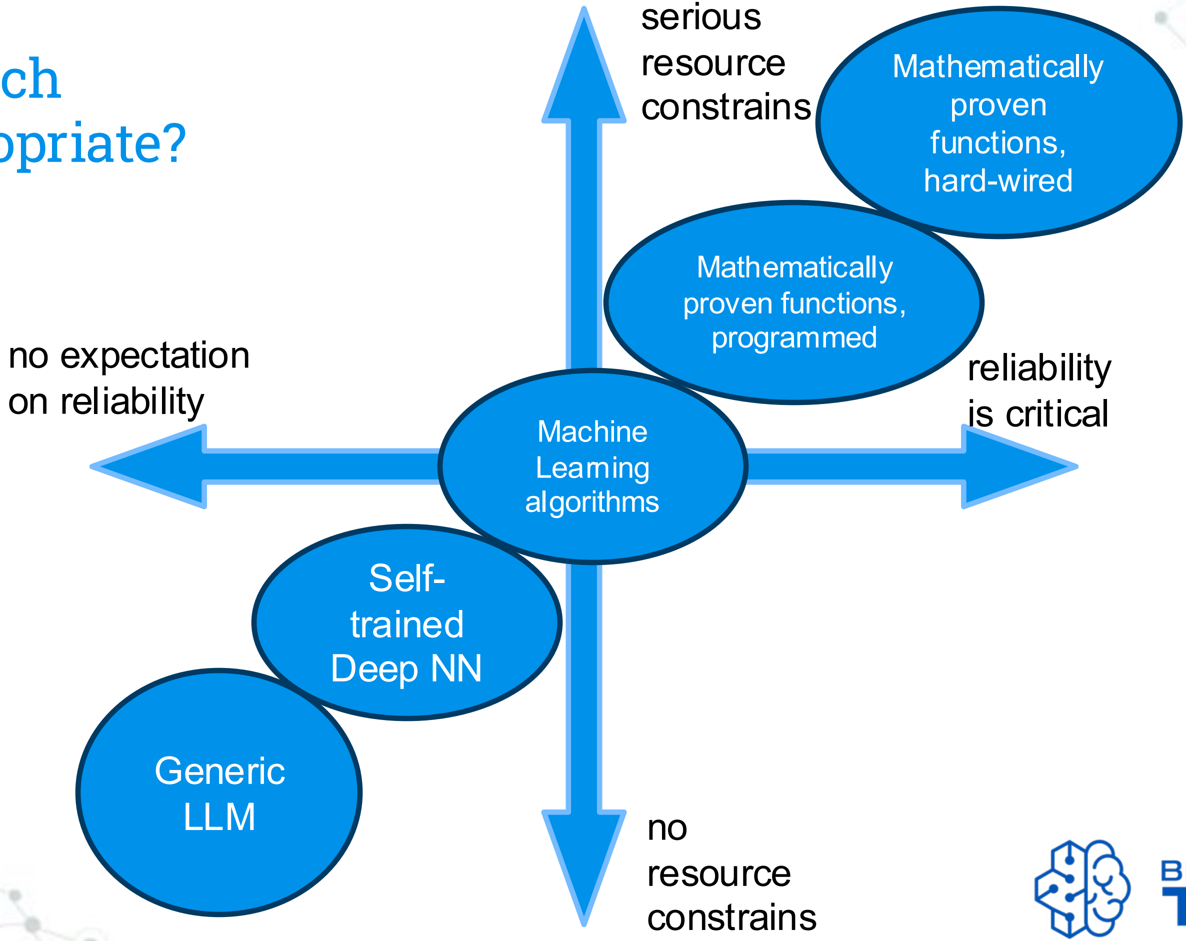
Engineers:

What approach may be appropriate?



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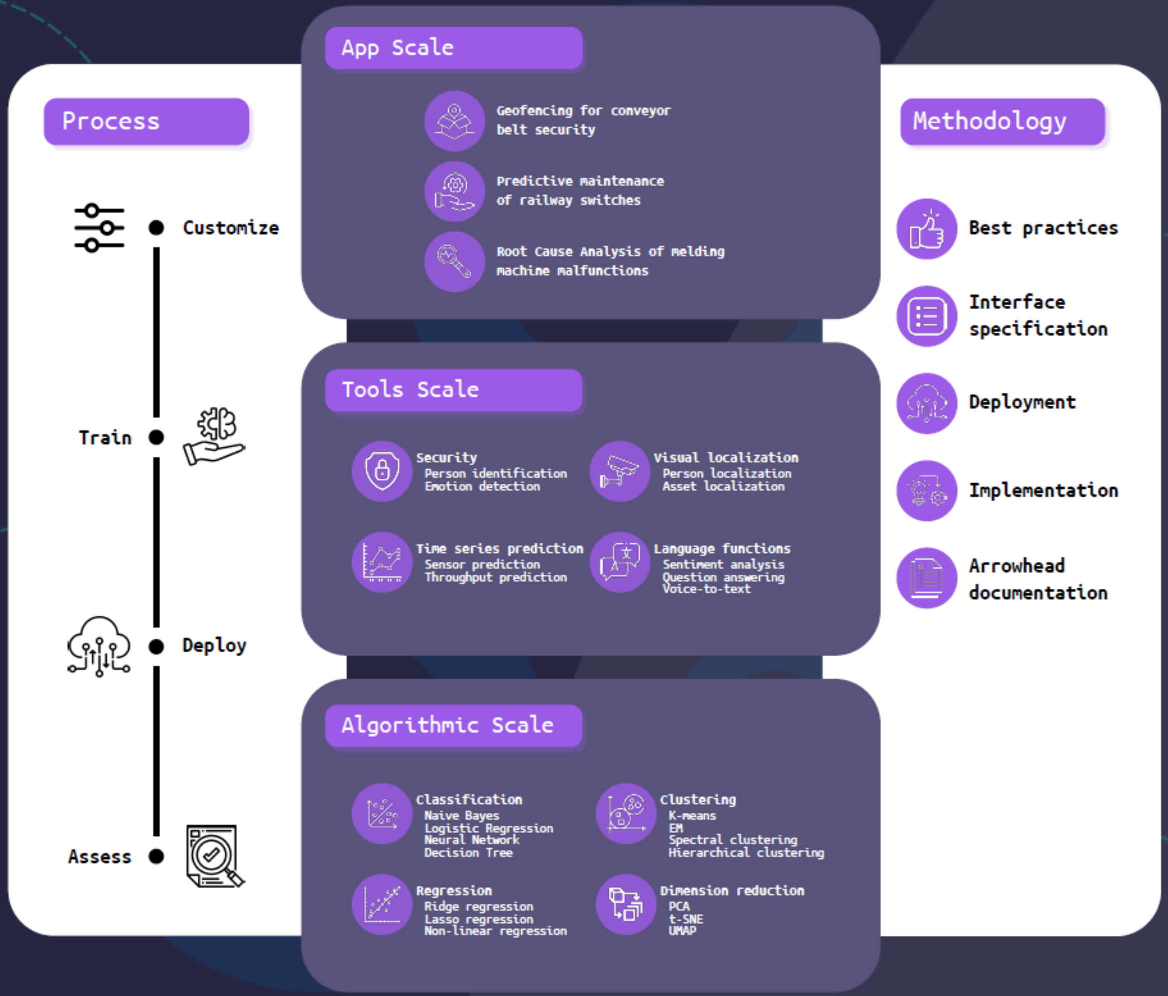
AIMS 5.0 AI Toolbox Concept



Hollósi, G., Ficzere, D., Frankó, A., Bancsics, M., AlMahasneh, R., Lukovszki, C., & Varga, P. (2024, May). AIMS5. 0 AI Toolbox: Enabling Efficient Knowledge Sharing for Industrial AI. In *NOMS 2024-2024 IEEE Network Operations and Management Symposium* (pp. 1-6). IEEE.

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Design, Develop, Deploy with Digital Twins by Default

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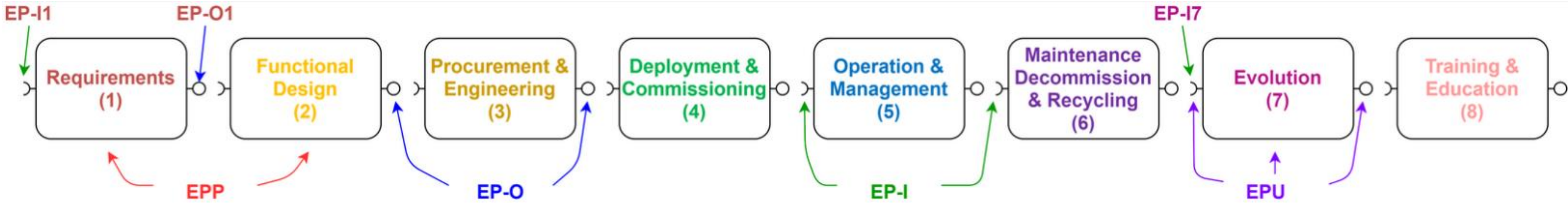
Any industrial CPSoS lifecycle is better when executed with a **Digital Twin–first** approach.



G. Urgese, P. Azzoni, J. van Deventer, J. Delsing, A. Macii, and E. Macii, "A SOA-based engineering process model for the life cycle management of system-of-systems in industry 4.0," Appl. Sci., vol. 12, no. 15, p. 7730, Aug. 2022.

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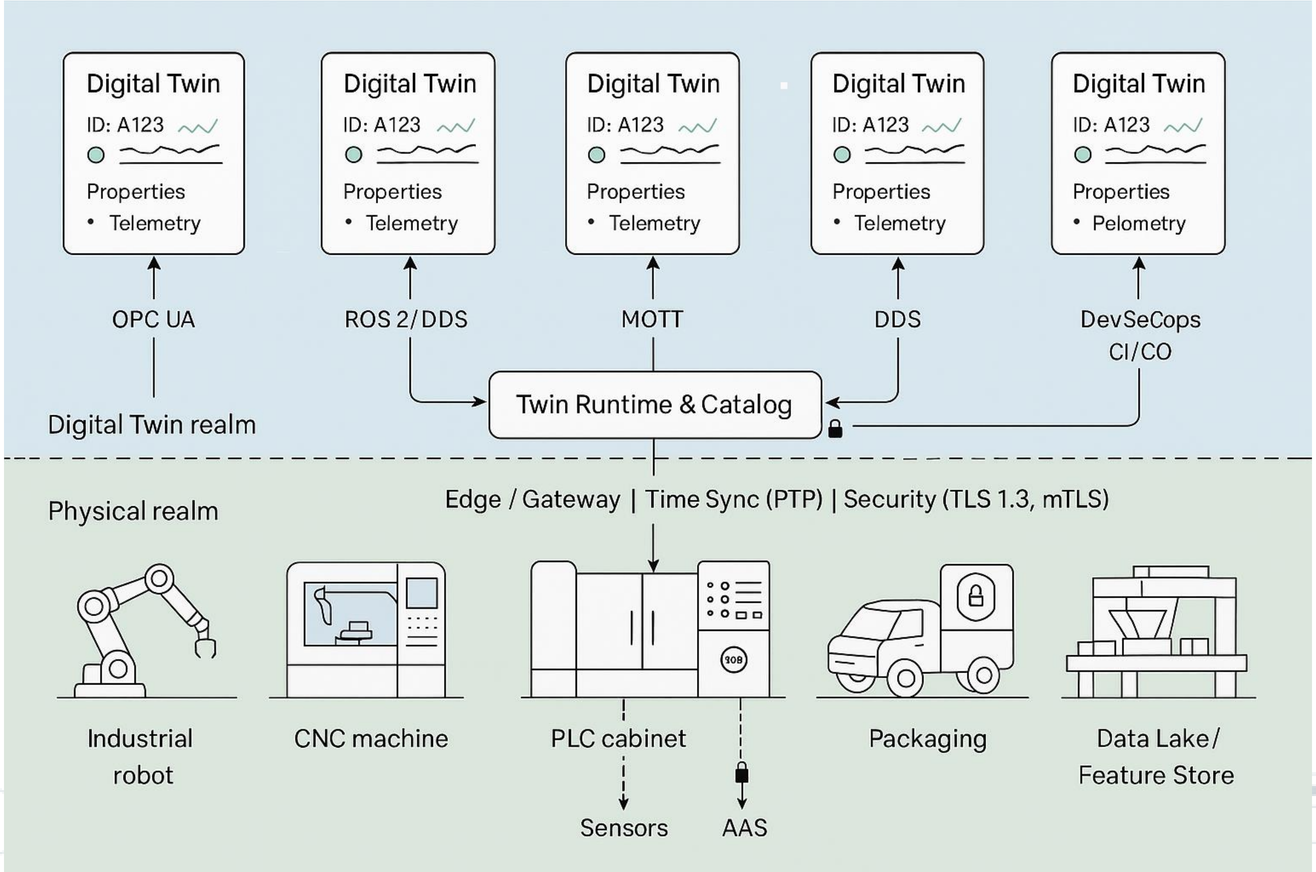
Execute the life-cycle elements on the DT-level first!



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What DT-by-Default changes (vs. traditional)

- **Closed-loop engineering**
  - Live telemetry → model updates → prescriptive actions → verified outcomes
- **Shift-left validation**
  - Virtual commissioning & HW-in-the-Loop **reduce** floor time, rework, and ramp-up risk
- **SoS composability**
  - AAS/semantics let you assemble twins of assets, lines, and supply chains
- **Governed performance**
  - Contracts + SLOs for latency, jitter, loss; evidence for audits (safety, GDPR/AI-Act)
- **Human-centric**
  - Copilots, explainability, and safe handover for operators (Industry 5.0)

DevOps and MLOPs extended for Digital Twins

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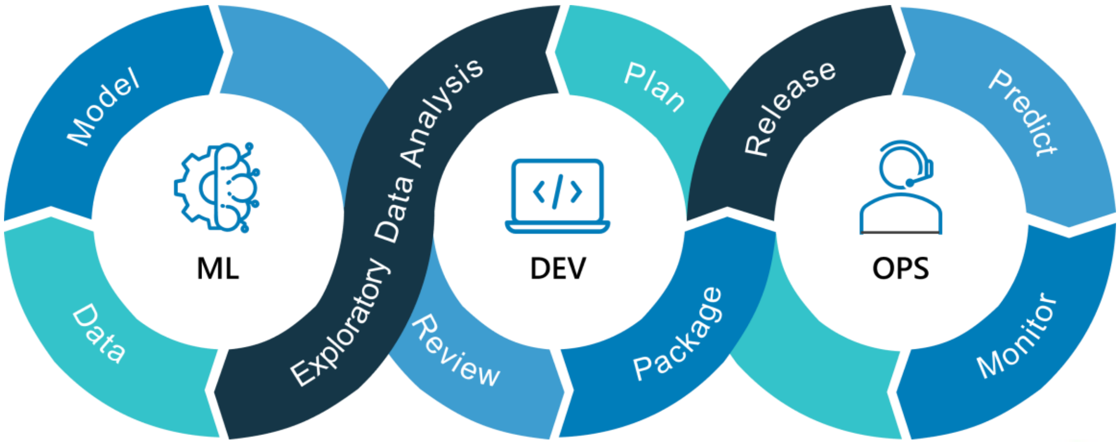
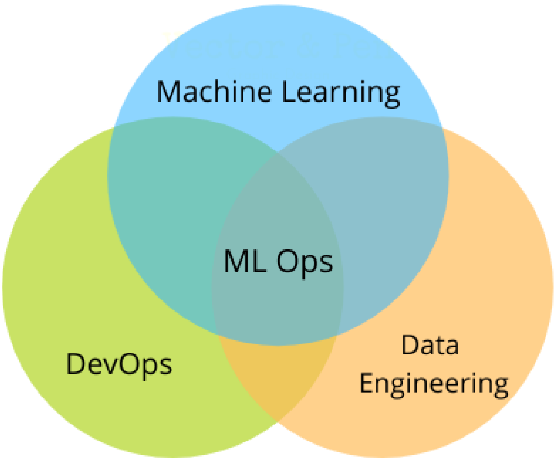
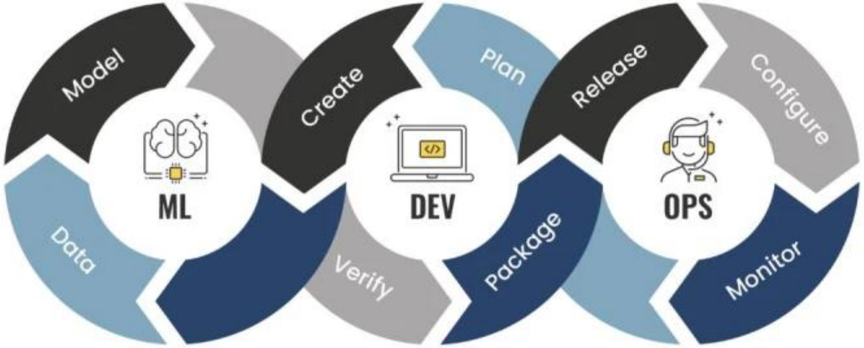
MLOps – Deploying ML models in Cloud infrastructures with Hyperautomation



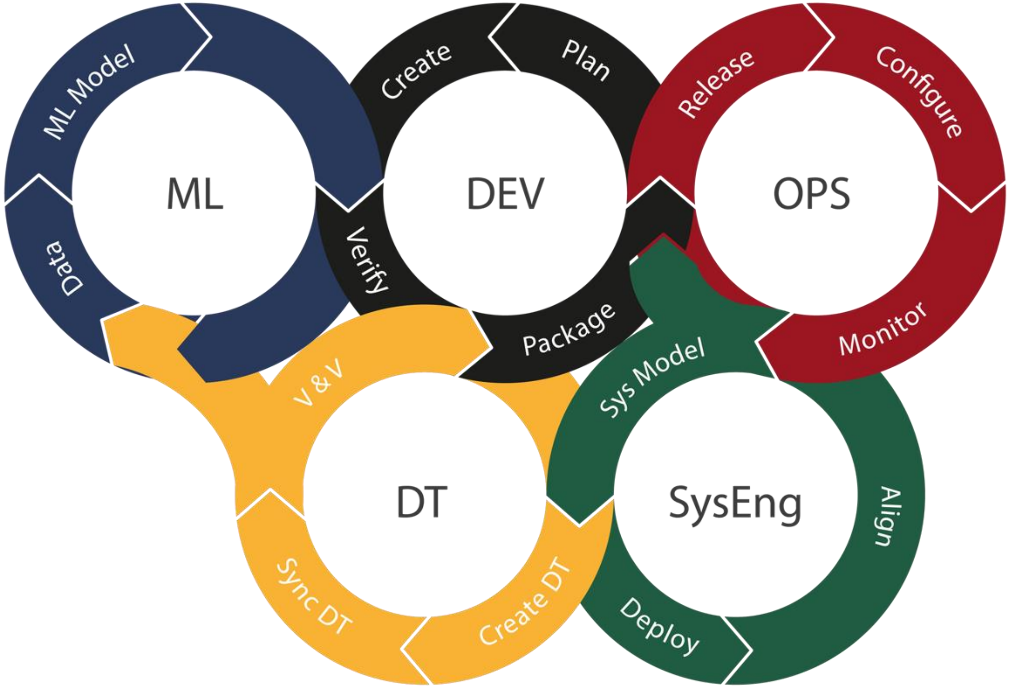
https://sourceforge.net/software/mlops/





https://canonical.com/blog/what-is-mlops

CPS OPS: Extending MLOps to Cyber-Physical Systems



Cs. Hegedűs, P. Varga –
Tailoring MLOps Techniques for Industry 5.0 Needs
IEEE CNSM, Niagara Falls, Canada, 2023

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Intent-based management of Cyber-physical System of Systems

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Main goals and Key components of Intent-based CPS

🎯 **High-level Objectives:** Translates human-defined business and operational goals into technical configurations.

🧠 **AI-Driven Automation**: Uses machine learning to optimize system performance.

🔄 **Continuous Adaptation**: Dynamically adjusts operations based on real-time data.

🎙️ **Intent Specification:** Clear definition of goals & operational needs.

⚙️ **Automated Orchestration:** Automatic translation of intents into configurations.

⚙️ **Automated Execution:** Capabilities and calling tools.

🔎 **Real-Time Monitoring:** Continuous evaluation and adjustments to meet defined intents.

🕵️ **Multi-agent behavior**

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🌟 Why Intent-based CPSoS management matters

📈 **Growing Complexity:**
CPSoS “networks” are evolving with cloud, edge, and asset interoperability.

🛠 **Error Reduction:**
Decreases manual configuration errors significantly.

💡 **Business Alignment:**
Directly matches infrastructure and asset behavior with business goals.

⏱ **Operational Efficiency:**
Accelerates CPSoS changes and reduces response times.

Intent-Based Workflow

Intent Specification:

Users define business goals in simple language.

Automatic Translation:

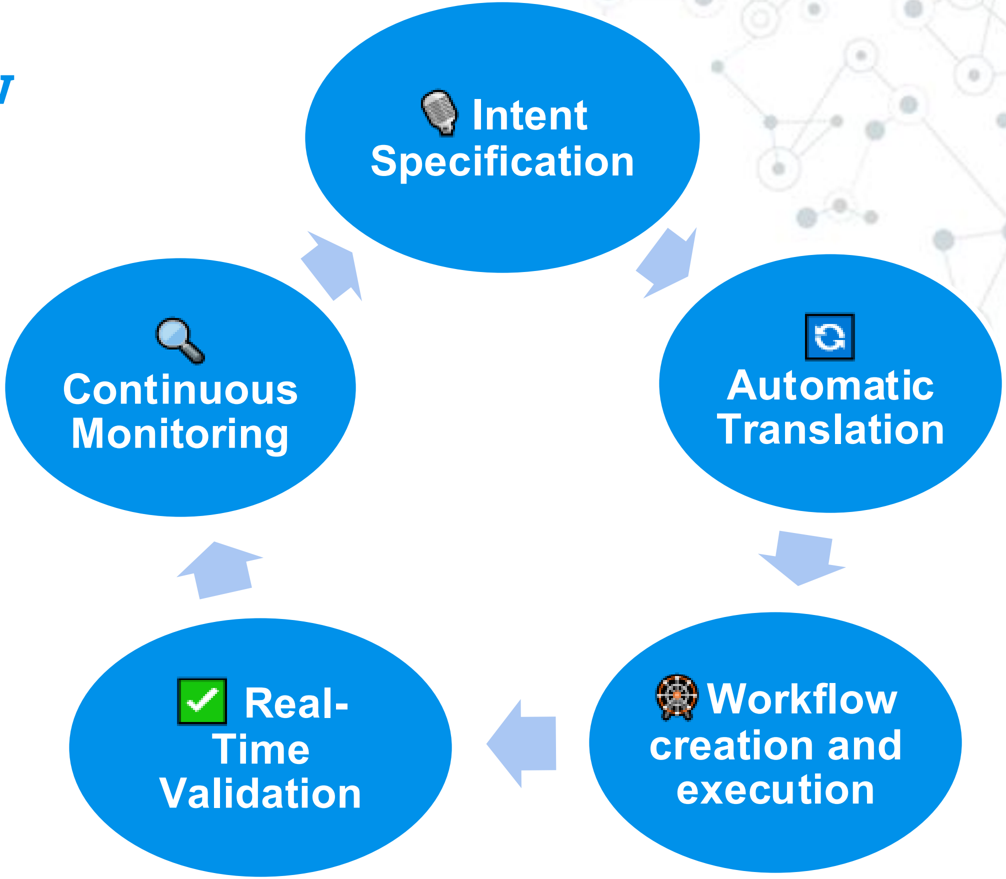
AI translates intents into detailed commands and configurations.

Real-Time Validation:

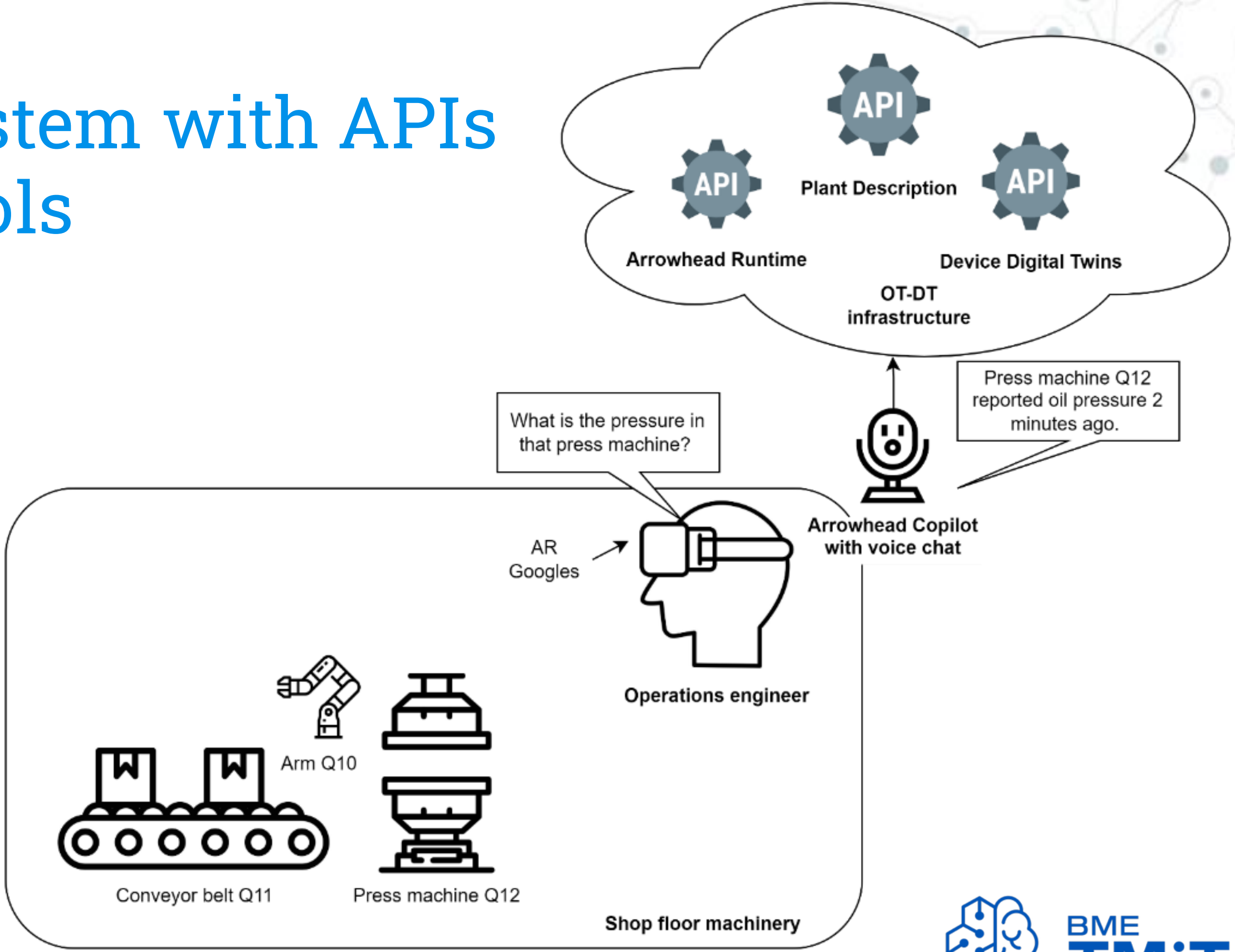
“DT” or CPS continuously validate behavior against defined intent.

Continuous Monitoring:

AI-driven systems adjust configurations dynamically for optimal performance.



Co-pilot system with APIs towards tools



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Use-cases for Industry5.0

🏭 Use Case: Smart Manufacturing

🤖 **Automated Production:** Self-optimizing assembly lines adapting to intent-driven objectives.
📉 **Downtime Reduction:** Proactive maintenance driven by intent-based predictive analytics.
🚧 **Flexible Operations:** Seamless integration and modification of manufacturing workflows.

🚗 Use Case: Autonomous Vehicles

🌄 **Dynamic Route Management:** Optimal route planning based on real-time data and intent.
🚦 **Traffic Safety:** Intent-driven safety - adjusting vehicle behavior.
🔋 **Energy Efficiency:** Real-time optimization of energy usage.

🔐 Security and Reliability in CPS

🛡️ **Proactive Threat Detection:** Identification & mitigation based on security intents.
⚠️ **Fault Management:** AI-driven systems automatically adjusting to minimize disruptions.
🗄️ **Data Integrity:** Ensuring data reliability and compliance.

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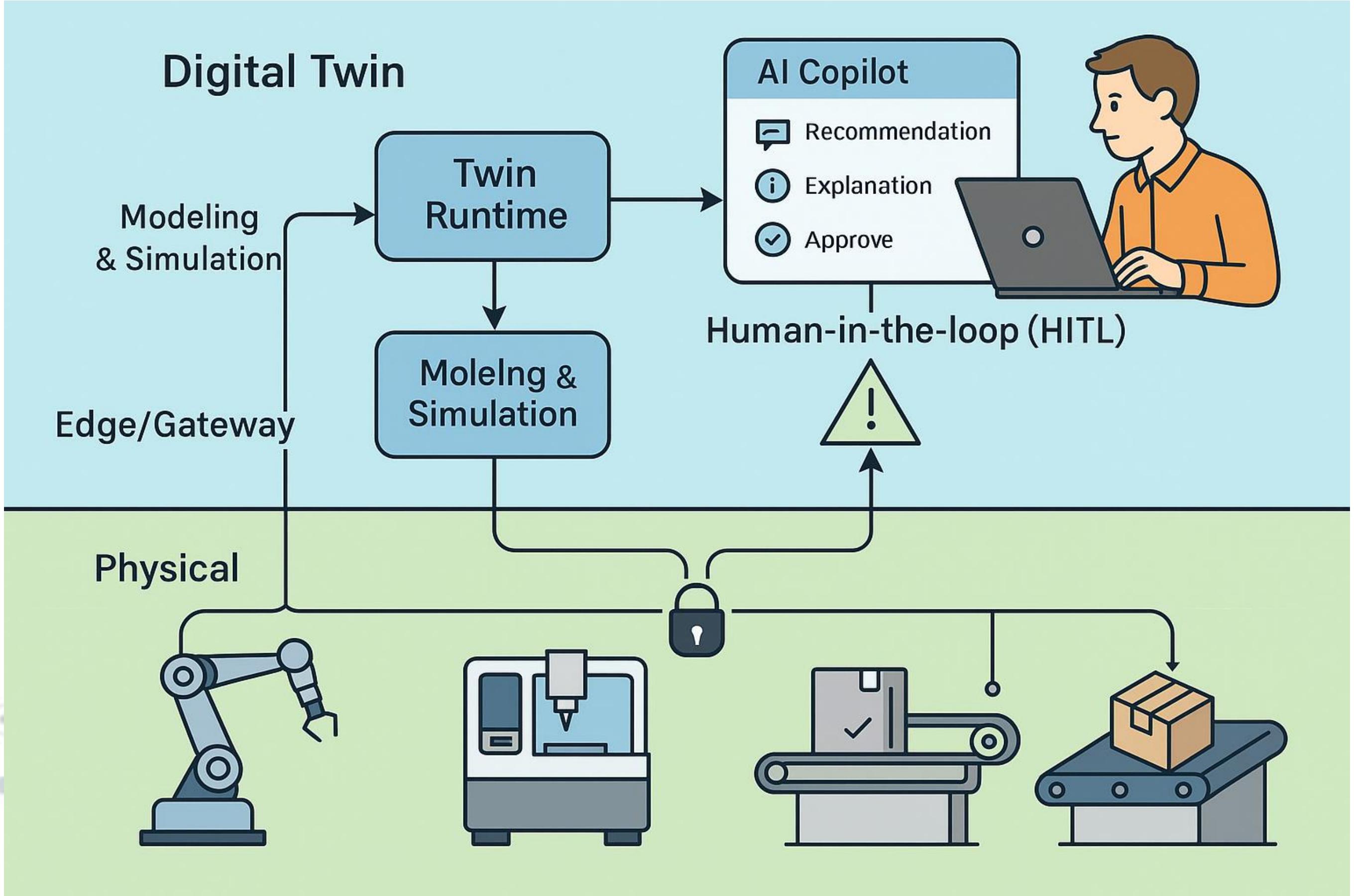
Use Copilot with Digital Twins



Your AI Copilot,
Your Digital Twin.

Now it’s Your Turn.

BME TMiT

Gracias por tu atención ☺

Pal Varga – pvarga@tmit.bme.hu

BME TMiT

TNO ESI

Powered by industry
and academia

ENGINEERING THE FUTURE: ADDRESSING SYSTEM COMPLEXITY IN HIGH-TECH EQUIPMENT

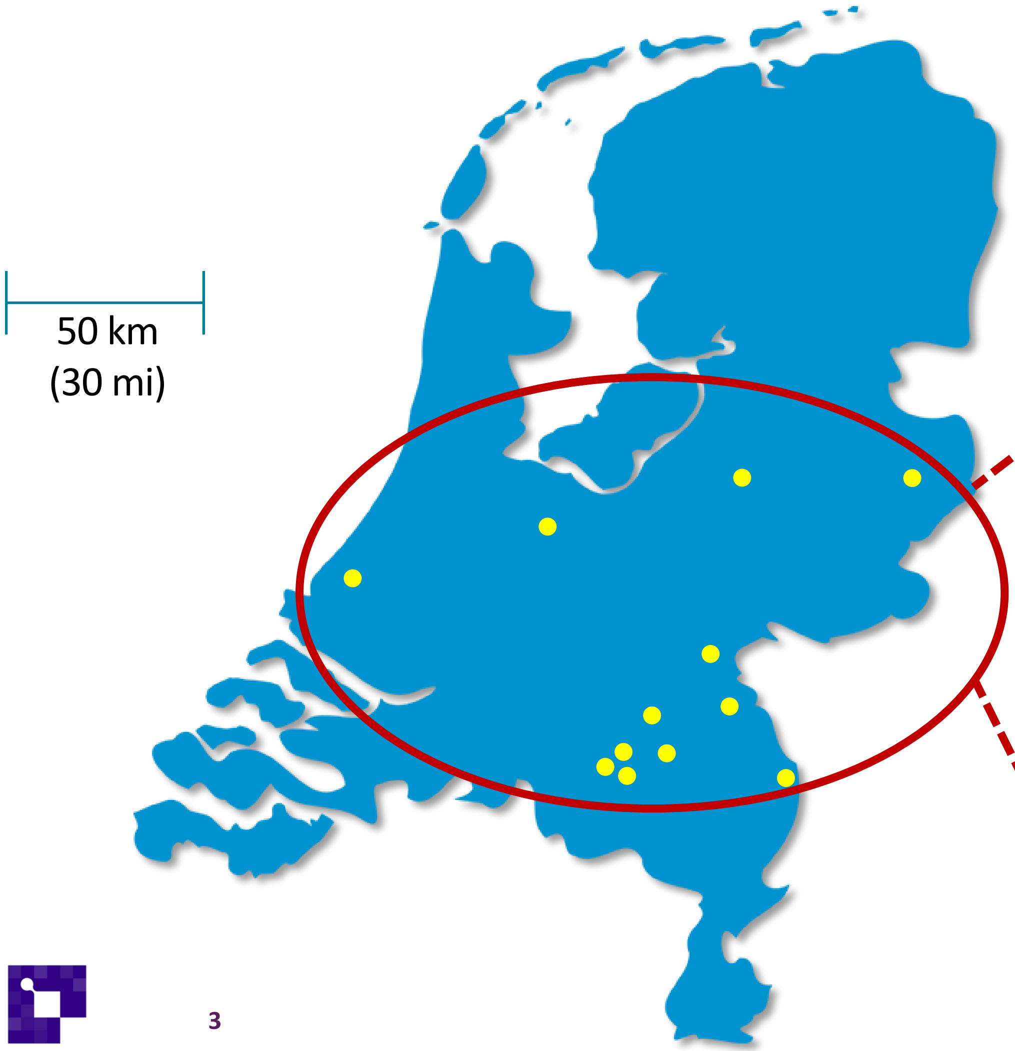
Prof. dr. Benny Akesson | INSIDE Connect 2025

INSIDE
Industry Association

Powered by industry, academia and TNO

TNO ESI

THE DUTCH HIGH-TECH EQUIPMENT INDUSTRY



INSIDE
Industry Association

SYSTEM COMPLEXITY IS INCREASING!

Five technological and market trends drive increasing complexity in high-tech equipment:

1. **Additional functionality**
   - Number of interfaces and lines of code are **rapidly increasing**
2. **Mass customization**
   - Increased customization of systems at design time to the point where **each system is unique**
3. **Long life-times**
   - Systems operate for decades and need to **continuously evolve** after deployment
4. **Increasing autonomy**
   - Systems acting autonomously with **little or no human interaction**
5. **Systems of systems**
   - Interconnected systems of which **nobody is in complete control**

Leibbrandt, Wouter, et al.. "TNO-ESI–Systems Engineering Methodologies for Managing Complexity in the High-Tech Equipment Industry: Our Roadmap." INSIGHT 25.4 (2022)
Hendriks, T. and Azur, S. "Vision and Outlook for Systems Architecting and Systems Engineering in the High-tech Equipment Industry" TNO Report 2024 R10542, 2024

MANAGING COMPLEXITY

Managing complexity in high-tech equipment is critical to successful development and deployment

- For a company, failure to manage complexity can lead to **errors**, **delays**, and **cost overruns**

Consequences of increasing complexity are visible in daily industrial practice

- Increasing development and maintenance **costs**
- Increasingly hard to **guarantee functional correctness** and **balance system qualities**
- Increasing **scarcity of experienced engineers**

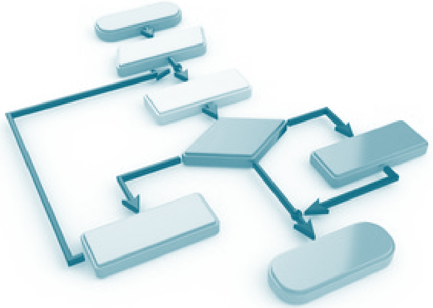
Hendriks, T. and Azur, S. "Vision and Outlook for Systems Architecting and Systems Engineering in the High-tech Equipment Industry" TNO Report 2024 R10542, 2024
B. Meier, M. Skelin, F. Beenker, and W. Leibbrandt, Eds., "HTSM Systems Engineering Roadmap." 2020
A. van der Werf, et al. "Made in NL: The value of the Dutch high-tech manufacturing industry," PricewaterhouseCoopers, 2024

METHODOLOGIES NEEDED

New methodologies and tools are required to **increase engineering productivity** and **address the shortage of experienced engineers** through

- **abstraction**, to hide unnecessary detail of increasingly complex systems
- **automation**, to increase engineering productivity
- **democratization** of engineering, to reduce dependency on experts

TNO-ESI is an organization that **orchestrates** the **innovation chain** for engineering methodologies in the Dutch high-tech eco-system and conducts **applied research to improve industrial practice**



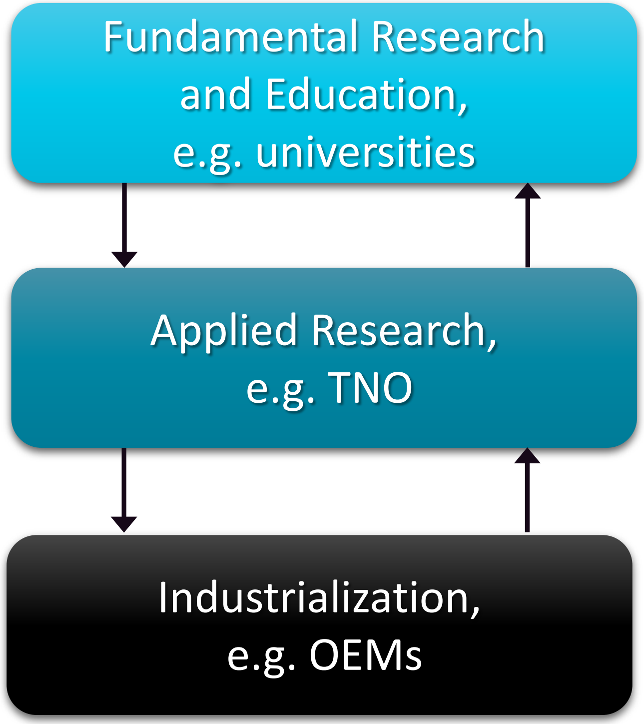
Hendriks, T. and Azur, S. "Vision and Outlook for Systems Architecting and Systems Engineering in the High-tech Equipment Industry" TNO Report 2024 R10542, 2024
B. Meier, M. Skelin, F. Beenker, and W. Leibbrandt, Eds., "HTSM Systems Engineering Roadmap." 2020

THE INNOVATION CHAIN

The path from ground-breaking research to industry impact often happens through an **innovation chain**

- **Universities:** Education and basic technology research
- **Applied Research Organizations:** Maturation and integration of research results and application/validation in industry context
- **Industry:** Industrialization of technology

It is important to **understand your role** in the innovation chain, and the roles of the other actors to work together effectively!



TNO-ESI AT A GLANCE

SYNOPSIS

- Foundation ESI started in 2002
- ESI acquired by TNO per January 2013
- ~60 staff members many with extensive industrial experience
- 8 Part-time professors

FOCUS

Managing complexity of high-tech systems

through

- model-based engineering
- formal methods and
- artificial intelligence

delivering

- methodologies validated in cutting-edge industrial practice

PARTNER BOARD

MODEL-BASED ENGINEERING

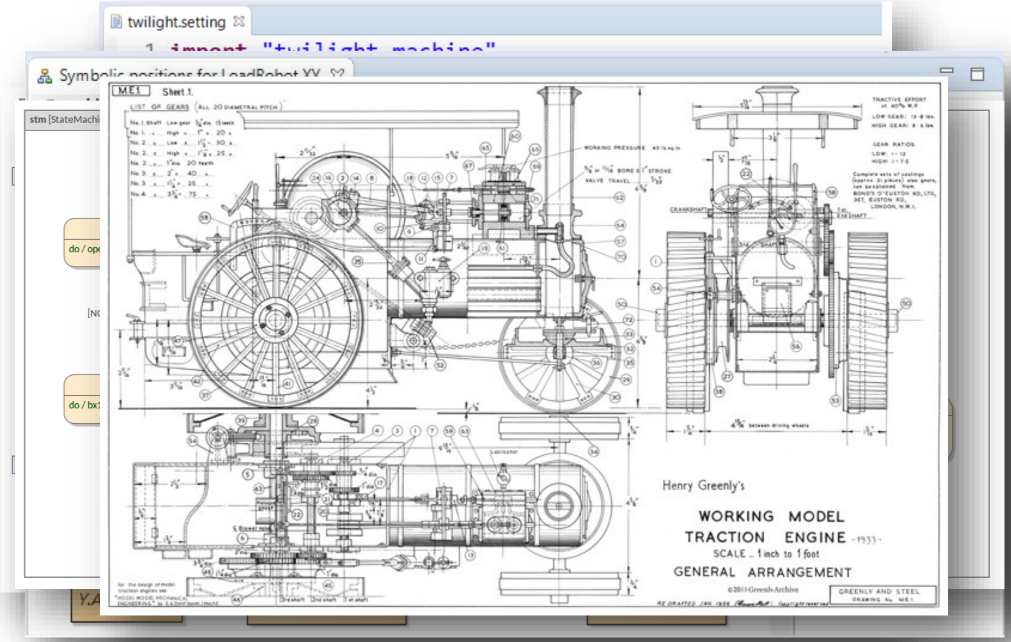
System complexity can be tackled through **model-based engineering** methodologies

Models expressed in some **formalism/language** are important artifacts during the life cycle of the system

- Provide **abstraction** from unnecessary details and serves as basis for **automation**

Models can be used as a **single source of truth** for:

- **Specification**
- **Communication** within and between disciplines
- **Analysis** of (non-)functional behavior
- **Synthesis** of design artifacts,
  e.g. documentation, code, and tests



Oortwijn, W., et al. "Vision and Outlook for System Evolution and Diversity" TNO Report 2024 R10716, 2025

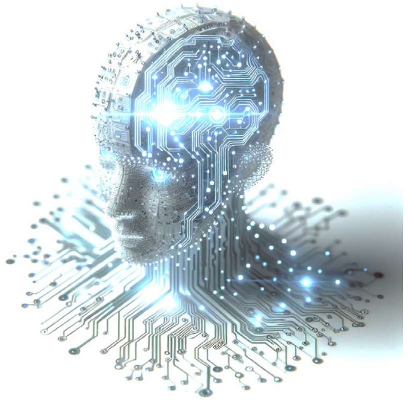
ARTIFICIAL INTELLIGENCE

Large Language Models (LLMs) have potential for increasing engineering productivity through **digital assistants**

- Quite mature technology for **knowledge consolidation, democratizing engineering** in large organizations
- Useful for semi-automatic **generation of documents and code**

Technology has potential to **facilitate transition** from document-based to model-based engineering through (semi-)automatically generation of other artifacts, considering organizational context, e.g.

- Structural or behavioral **MBSE models** to reduce modelling effort (scales to complex systems?)
- **Models for formal methods**, democratizing their use (sufficient available examples?)



Powered by industry and academia

RENAISSANCE: REDUCING EFFORT FOR MAINTAINING AND MODERNIZING LEGACY SOFTWARE

COSTLY DEBT OR VALUABLE HERITAGE?

The high-tech equipment industry develops **long-living software-intensive systems**

- The software inside these systems inevitably suffers from accumulated **technical debt**
- Large code bases using obsolete libraries, frameworks, or design patterns
- Hampers development of innovative new features for customers

Technical debt is **extremely costly**

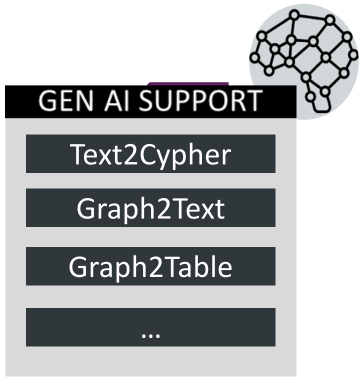
- Software technical debt is estimated to cost 1.52 trillion dollars in the US [1]
- Maintenance is estimated at 75% to 90% of software development life cycle cost [2, 3]
- Legacy software is, at the same time, an inevitable burden and a **valuable heritage**

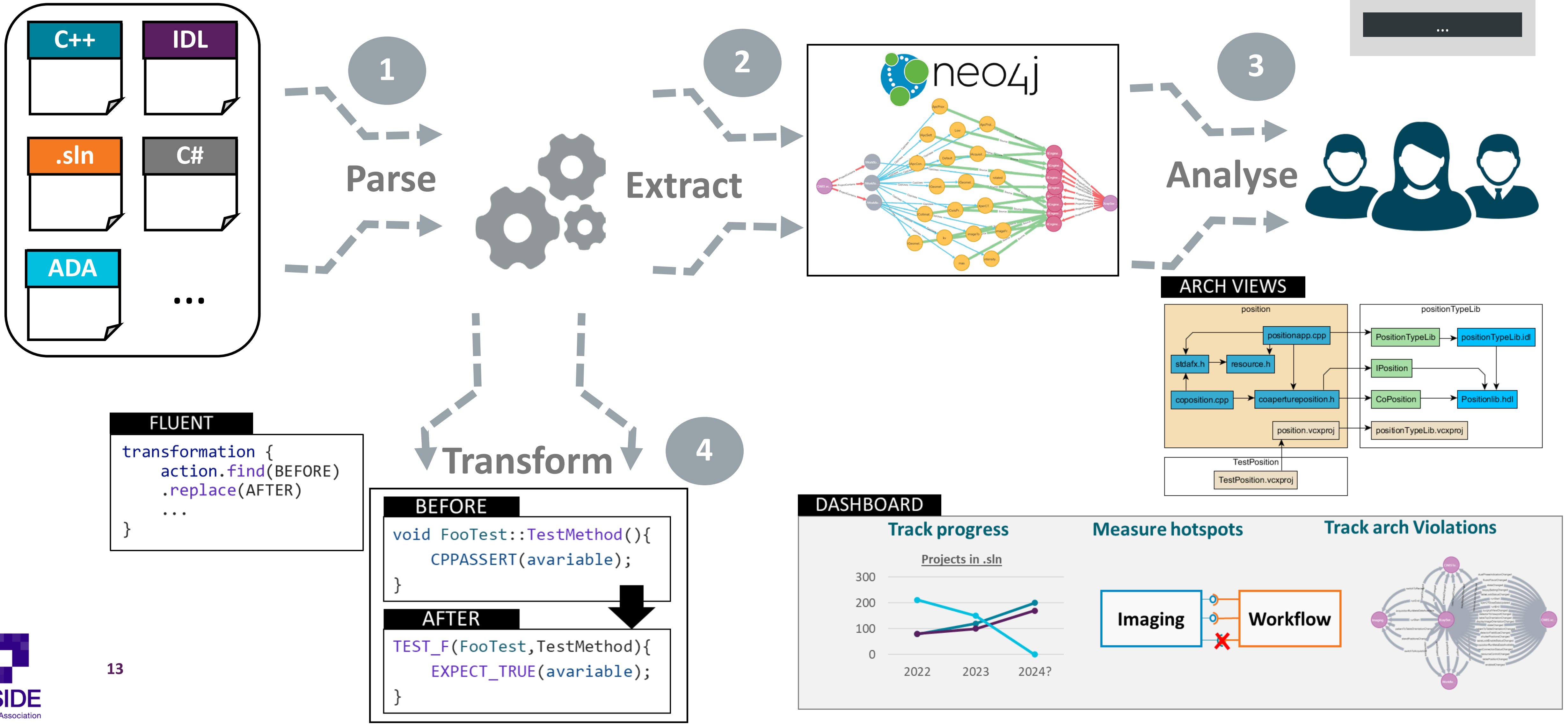
There is a broad need for **efficient and scalable solutions** to maintain and modernize legacy software

- Opportunities for **automation** using a model-based approach based on **static analysis** [4]

[1] Krasner, Herb. "The cost of poor software quality in the US: A 2022 report." Proc. Consortium Inf. Softw. Quality (CISQ). (2022)
[2] https://galorath.com/blog/software-maintenance-costs/
[3] https://web.archive.org/web/20120313070806/http:/users.jyu.fi/~koskinen/smcosts.htm
[4] Dams, Dennis, et al. "Model-based software restructuring: Lessons from cleaning up COM interfaces in industrial legacy code." Proc. SANER, 2018

RENAISSANCE: CODE ANALYSIS AND RESTRUCTURING





INDUSTRIAL IMPACT

Renaissance was developed and validated with several industry partners to assure **fitness for industrial practice**

A **training program** has been developed and followed by **50 engineers** from industry

Two **implementation partners** are applying Renaissance in their commercial offerings

Thermo Fisher Scientific – Electron Microscopy

- Reported that they “**managed to significantly reduce the time it takes us to build a new version of the software**”

Philips Healthcare – Image Guided Therapy Systems

- Reported that Renaissance empowers them to “**apply large scale analysis & refactoring that would otherwise be impossible**”.

ITEC/Nexperia

- Reported that they already **saved 300k$ and estimated to save another 900k$ using the approach while the investment was below 100k$**.

CONCLUSIONS

CONCLUSIONS

High-tech industry challenged to **increase engineering productivity** due to **growing system complexity**

New **methodologies** and **tools** required to increase engineering productivity and address scarcity of engineers

- Combining **model-based engineering**, **formal methods**, and **artificial intelligence**
- Technologies provide **abstraction**, **automation**, and **democratization** of engineering

An example methodology and tools from our ecosystem was demonstrated and its **impact** discussed

- **Rensaissance**: Reducing efforts for maintaining and modernizing legacy software

CALL TO ACTION

We want to continue talking to you about our open innovation eco-system, methodologies and tools, and competence development!

We are also happy to **collaborate** on research in areas including:

- Systems Architecting
- System Performance
- Intelligent Diagnostics
- Software Rejuvenation
- Verification of Systems and Software
- AI for systems engineering

Please join us at the ESI Symposium on October 7 in Eindhoven

BIOGRAPHY

Benny Akesson completed his doctoral studies at the Eindhoven University of Technology in the Netherlands in 2010. He is presently a Senior Research Fellow at TNO-ESI, leading applied research projects in collaboration between the public sector and industry. As the TNO-ESI Science Lead he also sets the scientific direction and orchestrates early knowledge development, including academic collaborations. Since 2019, he has been a Professor at the University of Amsterdam, where he holds the Chair of Design Methodologies for Cyber-physical Systems. His research interests include model-based engineering, real-time systems, and system performance engineering. Prof. Akesson has published over 80 peer-reviewed articles in conferences and journals and has been recognized with three Best/Outstanding Paper Awards and a CODES+ISSS Test-of-Time Award. A Senior Member of the IEEE, Prof. Akesson has contributed to approximately 40 program committees, also in chairing roles.

ABSTRACT

Engineering the Future: Addressing System Complexity in High-Tech Equipment

The Netherlands has a vibrant high-tech equipment industry in application domains including semiconductors, medical systems, and defense. Many companies in this industry are world-leading in their respective market segments and contribute significantly to the economy. However, this industry is challenged by a number of market and technology trends that result in increasing system complexity, driving up development and maintenance costs. To enable future systems to be developed cost-efficiently, new engineering methodologies are required to address the increasing complexity.

This presentation explores the trends contributing to the rising system complexity and present promising research directions to tackle this challenge. Addressing this will require a concerted effort from academia, applied research organizations, and industry, working together in an innovation chain.

ECLIPSE FOUNDATION

Why you should consider open source in your ecosystem

Boris Baldassari, PhD
Eclipse Foundation Europe

What is open source

There is only one definition of Free Software (since 1984)!

Freedom 0

To **run** the program, for any purpose

Freedom 1

To **study** how the program works, and change it to make it do what you wish

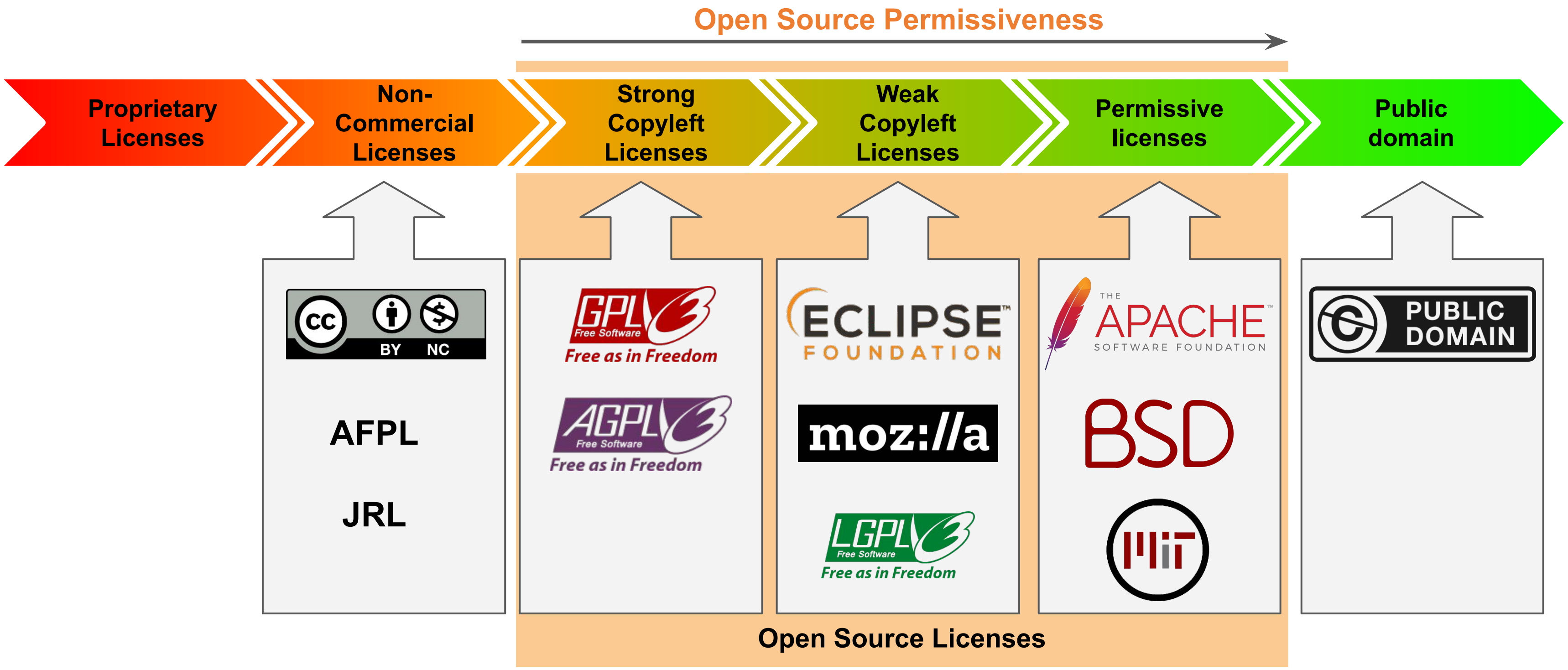
Freedom 2

To **redistribute** copies

Freedom 3

To distribute copies of your **modified** versions to others

The License Spectrum



It's all about the community

Open source is about a lot more than the source code.

The community around the project is the key:

- Answer questions, discuss use cases, provide support.
- Self-organise to plan roadmap, development, fixes, meetings..
- Bring diversity and provide innovative solutions.
- Disseminate & communicate about the project.

Ultimately, it's the community who makes a project a success.

Challenges to Open Source communities and projects

User Freedoms
Need to guarantee user freedom by going beyond licensing

Sustainability
Provide a sustainable environment, deal with ever-expanding expectations

Security
Supply chain security is in everyone's interest

Regulation
Government regulation of the technology industry is coming, and open source will be impacted

The role of Foundations

The Eclipse Foundation: A Guardian of the commons

No unwanted change in licencing

E.g. Terraform, Redis, Sentry, MongoDB..

We host the code and collaboration tools

No disruption of hosting or access

We hold the trademark

The name is bound to the project. Forever.

Enforce governance

Vendor Neutral, Open, Transparent. No bypass.

ECLIPSE FOUNDATION

Complementary professional services

- IP Management
- Specification Development
- IT Infrastructure
- External Contracting
- Marketing
- Community Management
- OSS Development Guidance
- Research projects dissemination

Strategic Focus Areas

Cloud Native Java

JAKARTA EE

MICROPROFILE
OPTIMIZING ENTERPRISE JAVA

OpenJ9

VERT.X

IoT & Edge

IoT Cloud Platform

Edge Computing

Industrial IoT

Automotive

openMobility

openMDM
Measured Data Management

openPASS

openADx

openGENESIS

Tools

eclipse

Capella

Eclipse Che

THEIA

Eclipse Foundation

IP Management & Licensing

Governance & Process

Community Development

Infrastructure

Some Eclipse members

Open source in the industry

81%

% companies consuming open source in products or services

44%

% firms contributing to upstream open source projects

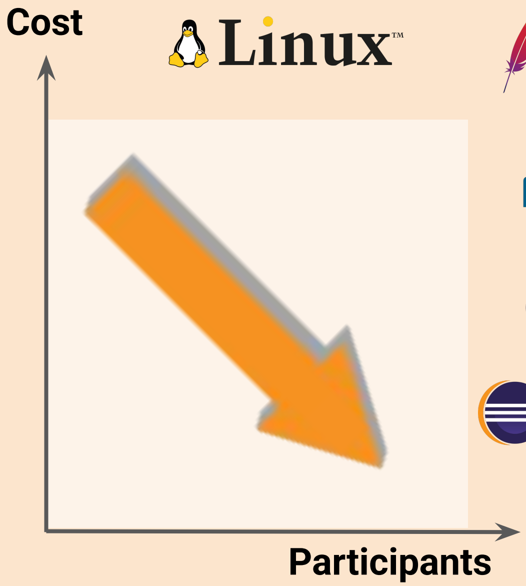
80-90%

Open source makes up 80-90% of applications

Sources: TODO Group, Forrester

The shifting impact of Open Source

Before: Commoditization strategy



Examples:

Linux

APACHE HTTP SERVER PROJECT

MySQL

php

eclipse

Now: how Innovation happens

Examples:

APACHE hadoop

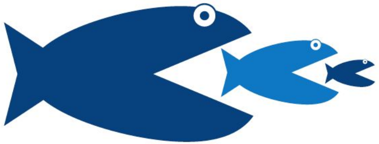
PyTorch

TensorFlow

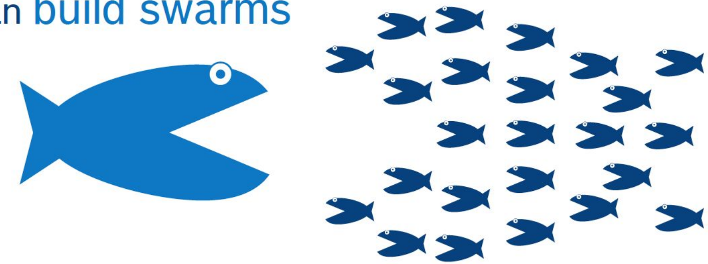
kubernetes

Playing the Platform Game
… and Win

Big fish eat small fishes



… but small fishes
can build swarms



18 Bosch Software Innovations GmbH | INST/CSS/BSV-OS | 27.04.2017

BOSCH

Stefan Ferber
CEO

BOSCH

"No company can realize the IoT on its own…
*Within the **Eclipse** **Community**, through the contribution of many IoT developers, tools and standards are created on an open platform that many companies can benefit from for their IoT applications."*

https://www.slideshare.net/appstacle/open-source-as-a-business-opportunity

ECLIPSE FOUNDATION

Open Source is Innovation at an Industrial Scale

Requirements & Use Cases

Competition

Commercial Adopters focus resources on rapidly building differentiating features

Value Line

Collaboration

Technology Producers jointly define roadmap and build core capabilities

Governance

The Eclipse Foundation provides an open, vendor-neutral environment to enable collaboration

Product-Ready Technologies

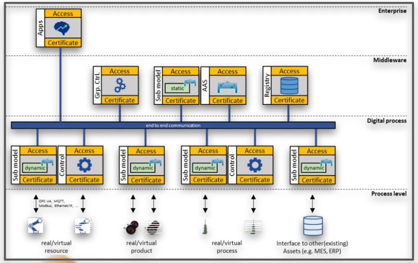
20€+ billion

of shared investment to date

eclipse iot

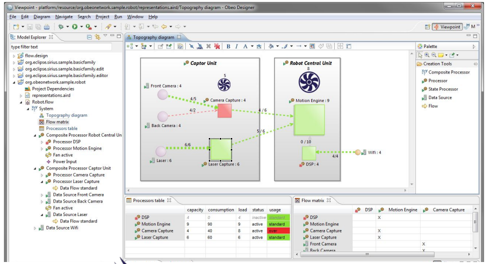
From research to well-established products

Industry 4.0 Operating System



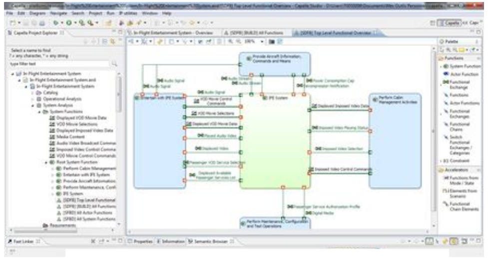
BaSyx

Customizable Graphical Modeling

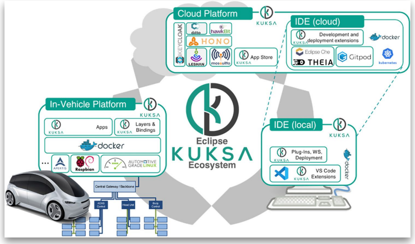


Sirius

MBSE for System Architecture

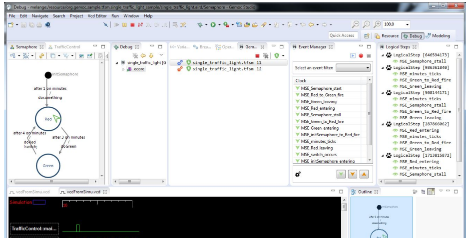


Capella



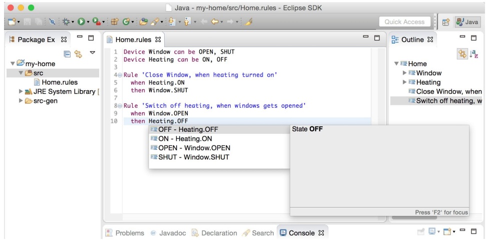
Supply Chain for SW Defined Vehicles

KUKSA



Modeling Languages

Gemoc Studio



Languages Engineering

Xtext

Take away...

Open Source is a journey, not a destination

https://c.pxhere.com/photos/47/76/cloud_mountain_highway_tree_street-140256.jpg!d

By JacLou DL, CC0 Creative Commons,
https://pixabay.com/photo-2645966/

ECLIPSE FOUNDATION

It’s all about the community.

(Be a Good Open Source Citizen)

Tim Berners-Lee
Inventor of
the WWW
(March 1989)

Vint Cerf
Co-inventor of
the Internet and TCP/IP
(December 1974)

Free Technologies are Game Changers

Thank you!

Open Discussion

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Closing Remarks

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Closing Remarks

- Engineering productivity can be improved with many different ways
  - Model-Based methodology → Higher abstraction level to tackle the complexity
  - Standardization of models and semantics to enable seamless model exchange and integration
  - Digital twinning → Enables shift-left system-level verification and closed-loop engineering
  - AI assisted design → Assistance, semi-automatic code and document generation, optimization
  - Ecosystem and open source → Finding balance between free and commercial
- A holistic approach provides the best results
  - Adopting a new design culture is necessary
- Europe is far behind other regions in productivity and facing resource problems
  - Need to develop new collaboration structures: B2B consortiums, company networks, etc.
  - Membership-based access to open source to keep our investment in Europe
  - Europe must develop a strong tools industry with a solid academic and community backbone

Ingredients of Successful Innovation