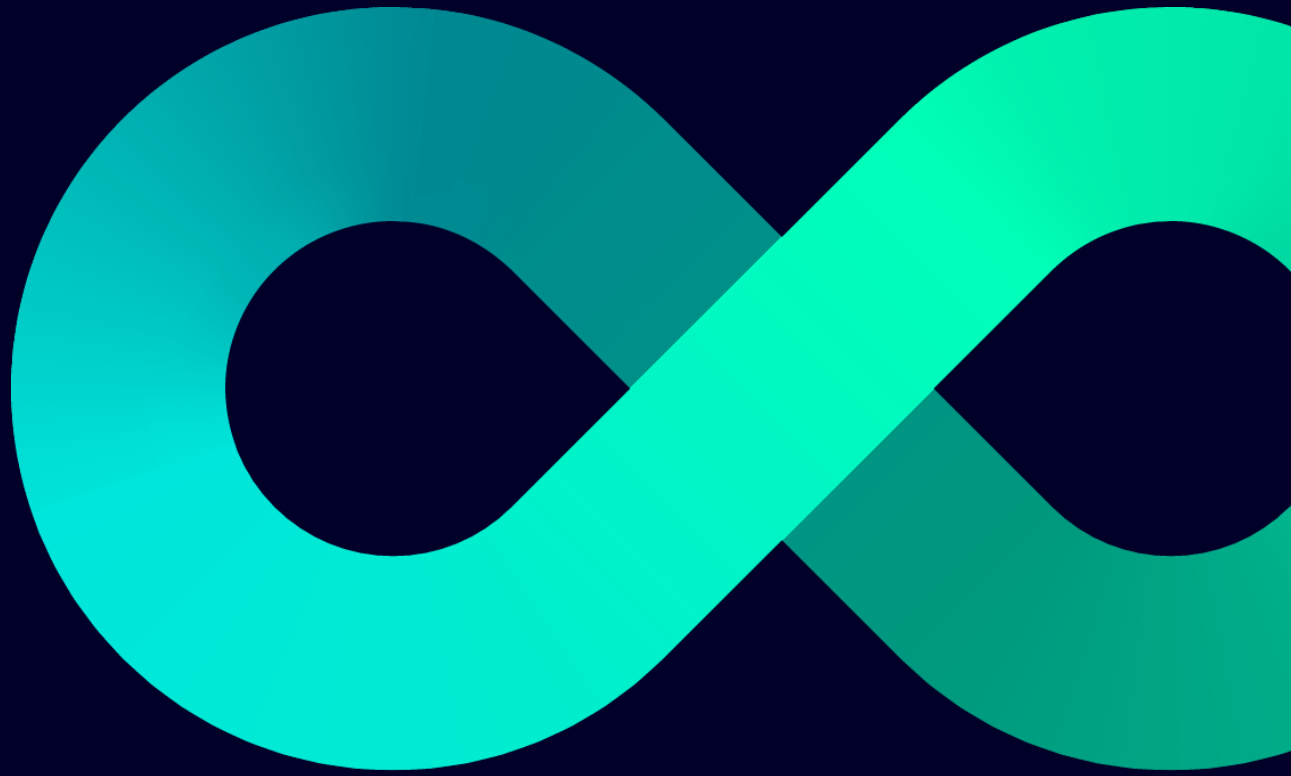
Ontologies in Industry

The Good, the Bad, and the Ugly ?



SIEMENS

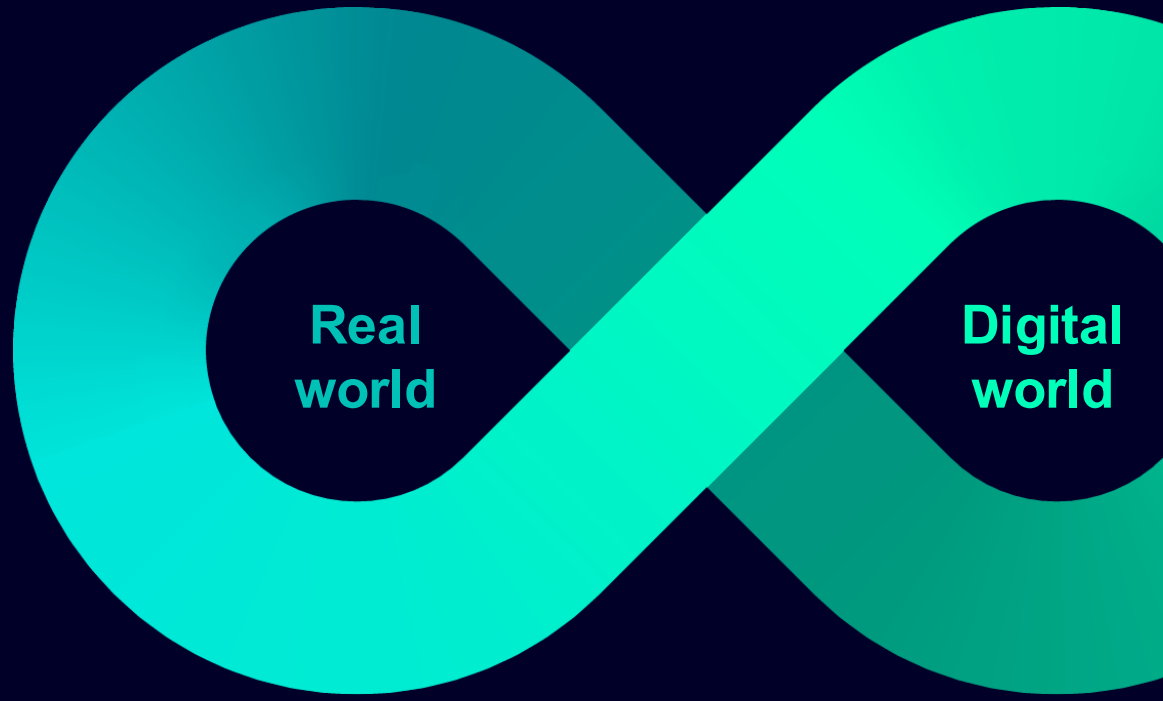
Your presenter

- Studied Computer Science at LMU in Munich (focus on Database Systems & “Knowledge Discovery in Databases”)
- PhD at TU Hamburg-Harburg and Universität zu Lübeck (Abductive reasoning over DL KBs)
- Principal Key Expert for Knowledge Graph & Semantics at Siemens Foundational Technologies
- Working on topics around knowledge representation, ontologies, knowledge graphs, and their intersection with (narrow and generative) AI

SIEMENS

By combining the real and the digital worlds, Siemens empowers customers to accelerate their digital and sustainability transformation

- Glass Production
- Pharma-ceutical Industry
- Campus
- Tire Industry
- Mining Industry
- Cement
- Transpor-tation and Logistics
- Panel Building
- Wind Energy
- Pulp and Paper
- Life Science
- Healthcare
- Oil and Gas Industry
- Automotive Manu-facturing
- Airports
- Electronics Industry
- Semi-conductors
- Data Centers
- Machinery and Plant Production
- Food and Beverage
- Water and Wastewater Industry
- Chemical Industry
- Municipalities and DSOs
- Cranes
- Intralogistics
- Aerospace
- Battery Manu-facturing



SIEMENS

Digital transformation has the potential to drive progress and growth and reduce resource consumption in all countries

Industry

Up to **50% material savings** can be realized using digital twins and innovative production technologies such as additive manufacturing.

Infrastructure

Buildings are currently responsible for **39% of global energy related carbon emissions**. Data analytics and automated building management can unlock large saving potentials.

Mobility

Up to **30% higher network capacity** can be achieved through automatic train operation and by optimizing train flows and rail operations.

SIEMENS

AI is a key enabling technology for all of Siemens research

Strong investments into Research & Development
drive our innovation power and success

€6.2bn R&D invest ~8% of revenue

5,400 new inventions

45,000 patents granted

47% of active patent families contributing to SDGs

16 research & innovation ecosystems worldwide
universities, research institutes, start-ups

Siemens Company Core Technologies
Innovation fields with high relevance for key sustainability challenges

- Data Analytics & AI
- Connectivity & Edge
- Simulation & Digital Twin

Siemens' AI facts & figures

- **Siemens AI Patent Position**
  #11 Worldwide
  #1 Europe
- 1,400+ AI Experts
- Research & Innovation Hubs in Europe, US, Asia

SIEMENS

CCT Data Analytics and Artificial Intelligence (DAI)

- Focus: **Research and predevelopment on Industrial Artificial Intelligence**
- >230 employees across 14 research groups in 7 countries
- Core research areas
  - **Generative AI**: LLM, time series foundation models, agentic AI, …
  - **Machine Learning**: reinforcement learning, transformers, Gaussian processes, physics aware machine learning, …
  - **Data Analytics**: prediction, anomaly detection, classification, information visualization, …
  - **Reasoning and Semantics**: Ontologies, Knowledge Graphs, AI memories, Graph Neural Networks, …
  - **Optimization and Control**: Discrete Optimization, Stochastic Optimization, Convex Optimization, Quantum Optimization, …

SIEMENS

The Good

Success stories using semantic technologies at Siemens

The Bad

Where we are still struggling

The Ugly ?

Now that GenAI is here – who still needs semantics?

The Good

Success stories using semantic technologies at Siemens

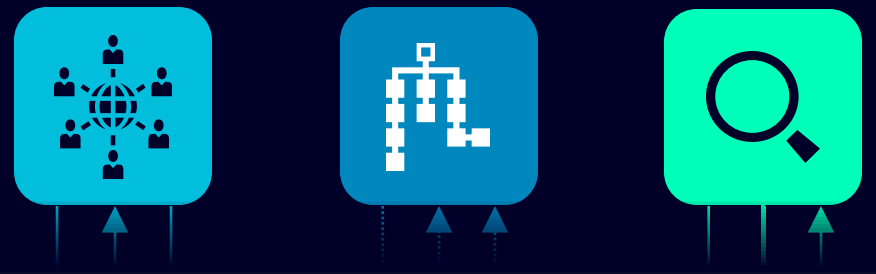
The Bad

Where we are still struggling

The Ugly ?

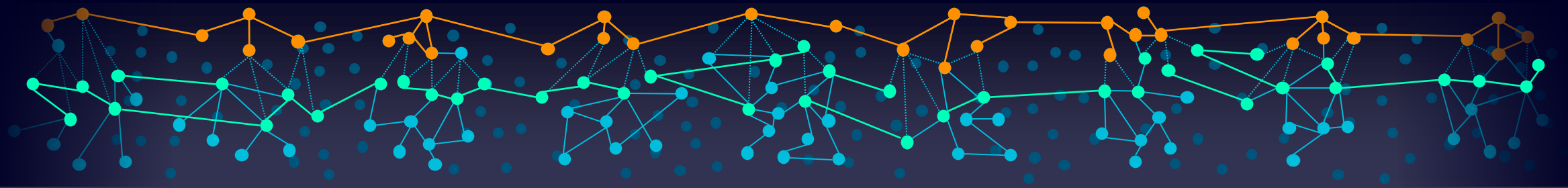
Now that GenAI is here – who still needs semantics?

Semantic abstraction layers support data unification and integration across independent systems and ensure Semantic Interoperability



Integrated and standardized data access

Curated Semantic Knowledge Base



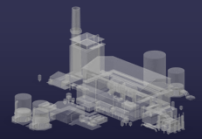
Tables

Relational DB

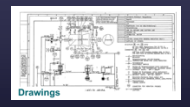
Historian

BOM

Product Specification



Plant Design



Drawings

Service Reports

CAD / CAM

- Terminology and data model
- Instance data / concrete objects

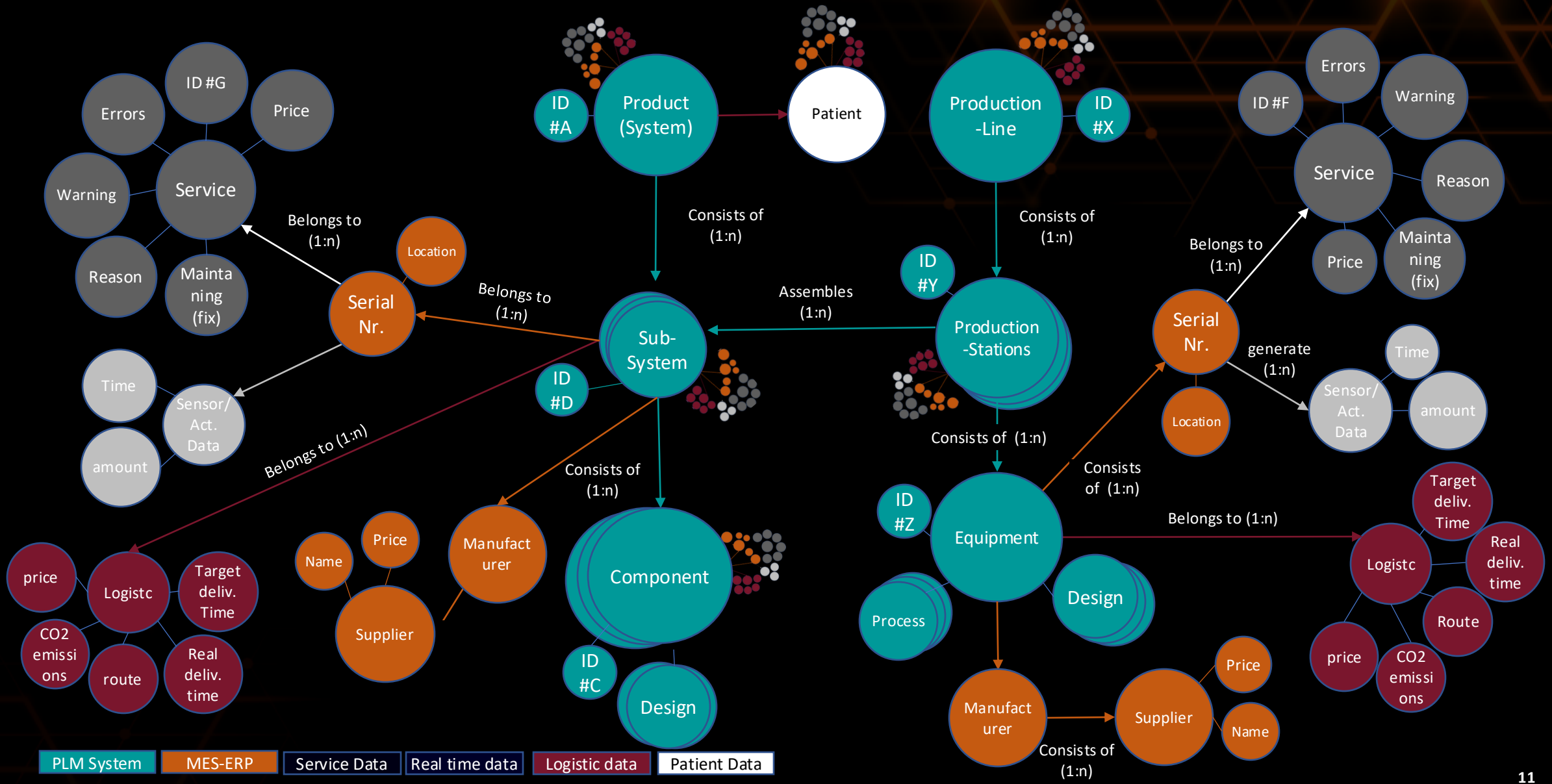
SIEMENS

Semantic Data Layer @ Siemens Healthineers

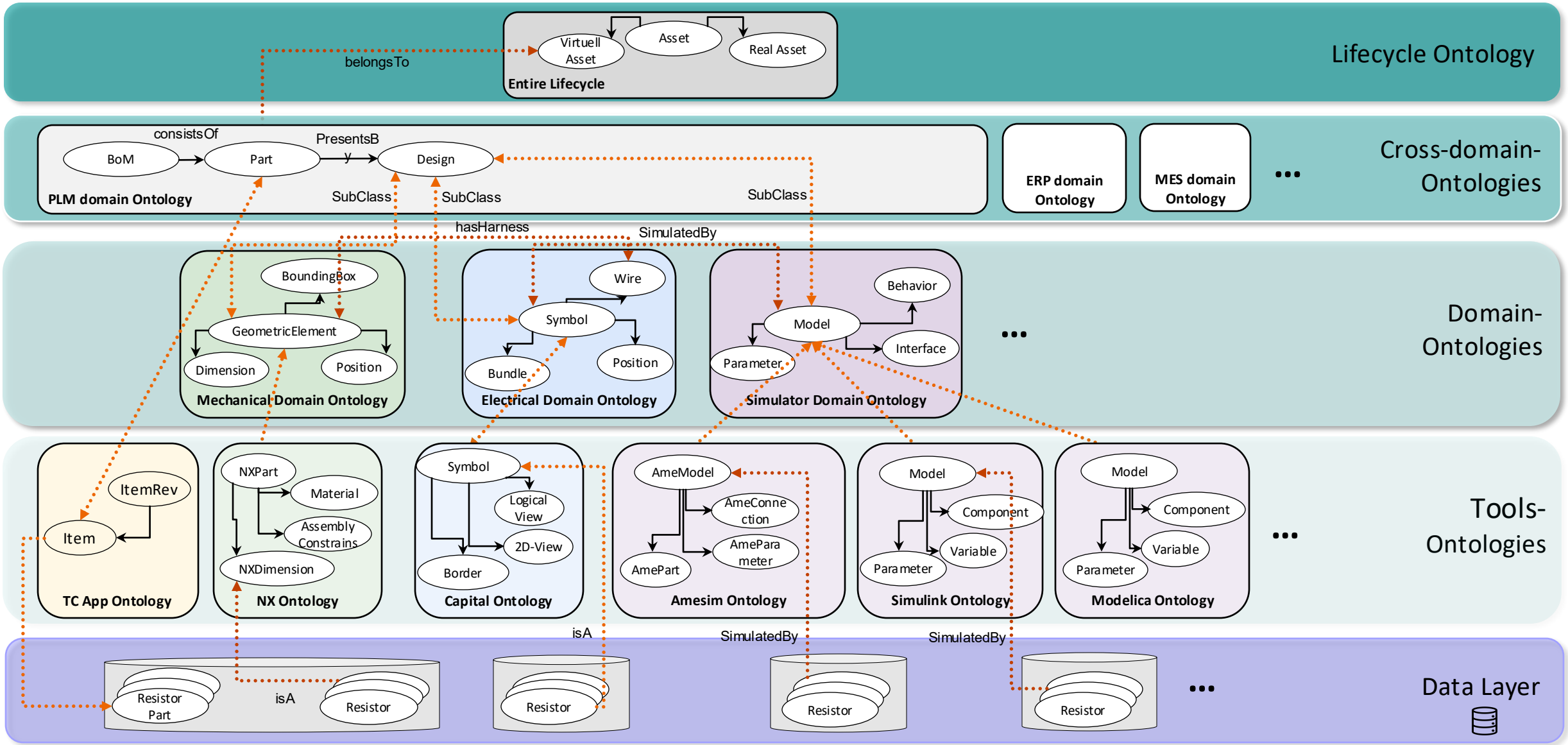
Work by
Dr.-Ing. Behrang Ashtari, Siemens Healthineers
& team

SIEMENS

Semantic Layer: Healthineers Enterprise Ontology



TE PLE Semantic Data Layer – A multi-layered Enterprise Ontology



Digital Twin Graph @ Siemens Mobility

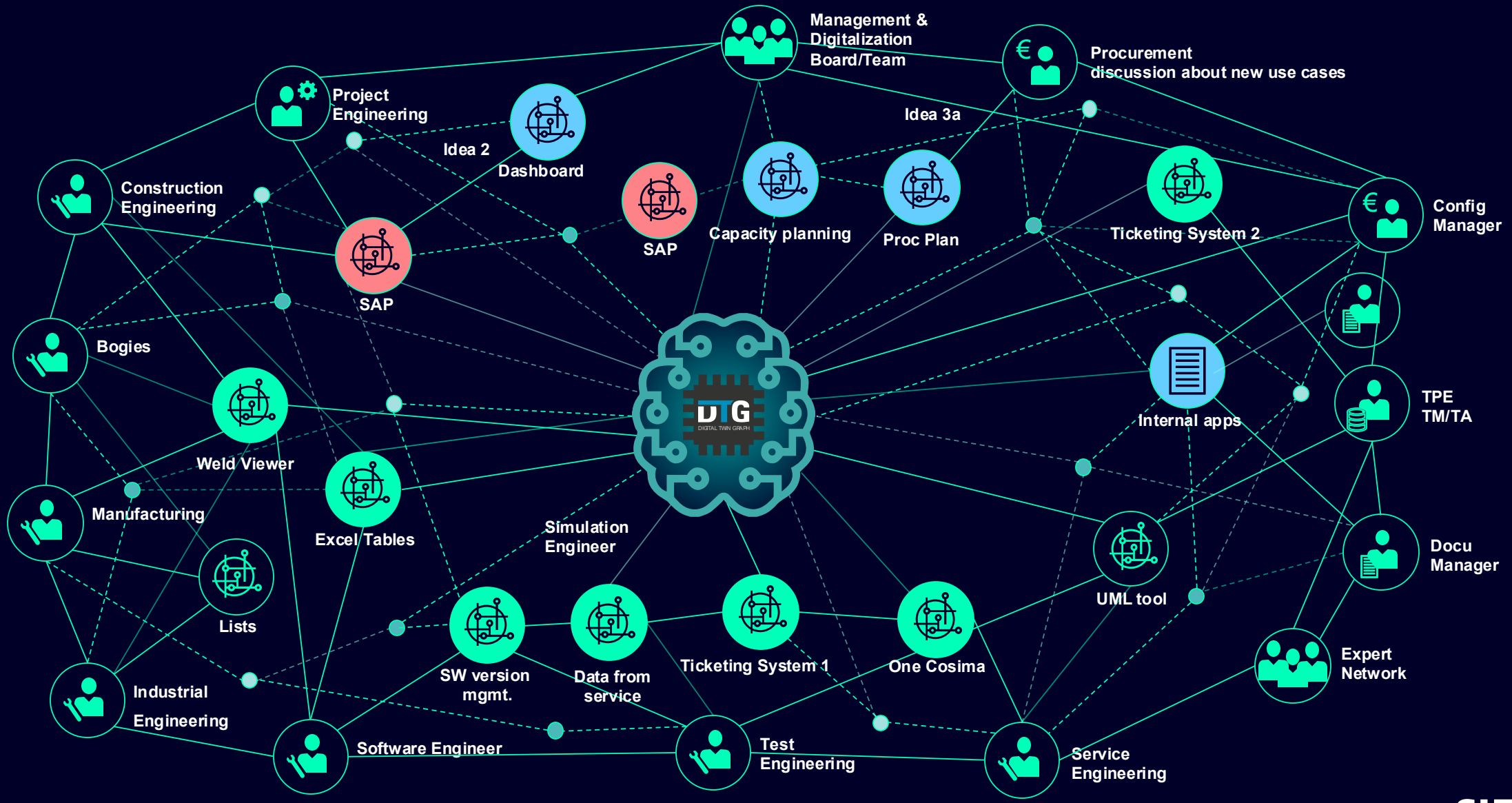
Work by

Juan-Manuel Lorenzi, Foundational Technologies

& team

SIEMENS

The SMO Digital Twin Graph connects information across silos & PLM phases



SIEMENS

Intelligent recommender for graph-based simulation selection

Teamcenter Simulation

Verification Requests

VR

VR

Simulation Models

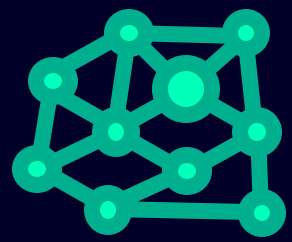
SIM Model

SIM Model

SIM Model

Automated (structured and unstructured) Data Extraction

Recommender Engine



Knowledge Graph DB

query

response

Simulation Engineer

VR

BOM

REQ

REQ

SIM Model A

SIM Model B

SIM Model C

SIM Model D

SIEMENS

Product configuration management

Work by

Neeti Ravi, Electrification & Automation

& team

SIEMENS

KG use case 1 | Value Proposition Concept

Project/ Tool name: KG use case 1

Owner(s): SI EA

Project vision:

- Establish a **single source of truth** as the strategic foundation for **SI EA product and configuration** data
- Leverage this centralized data **to drive improved collaboration, innovation, and future-readiness** across the organization

Project objectives:

- Deliver **a cloud-based and scalable data management application** to enter, update and maintain consistent and reusable data, seamlessly integrating the currently fragmented data sources
- Empower the SI EA business with a **digital**, **future-ready, tool-independent approach** to data management and utilization

Target group

Users working with **product and configuration** data, including:

- Product Lifecycle Mgrs (PLM)
- Variant Configuration Mgrs. (Operations)
- R&D
- Engineering
- Costing & Pricing

Pain Points

- **Fragmented data sources** and silos
- **Unreliable, not machine-readable** data
- Inefficient **collaboration** and **knowledge** sharing
- Challenges in **leveraging data strategically**

New Functionalities

- Unified, **cloud-based** data repository
- **Integrated** data from multiple sources
- Advanced **data quality management.**
- Features for teams' **collaboration**
- Predictive analytics and **AI-powered** insights

Expected Value

- **Better decisions** based on better data quality
- **Faster innovation** and collaboration
- **Better accountability & traceability** of data changes
- **Increased agility** and future-readiness

Current status

- **The first release is available** for PLM and replaces excel files to maintain one **Medium Voltage Switchgear product** data. Advancing development and pilot testing of future capabilities.

Future Goals

Enhanced capabilities and expand into more data use cases and products.

40+ products with **500+** technical features**, 50+** electrical components**, 250+** accessories**, Millions** of interlockings,

SIEMENS

Ontological Modelling of Materials

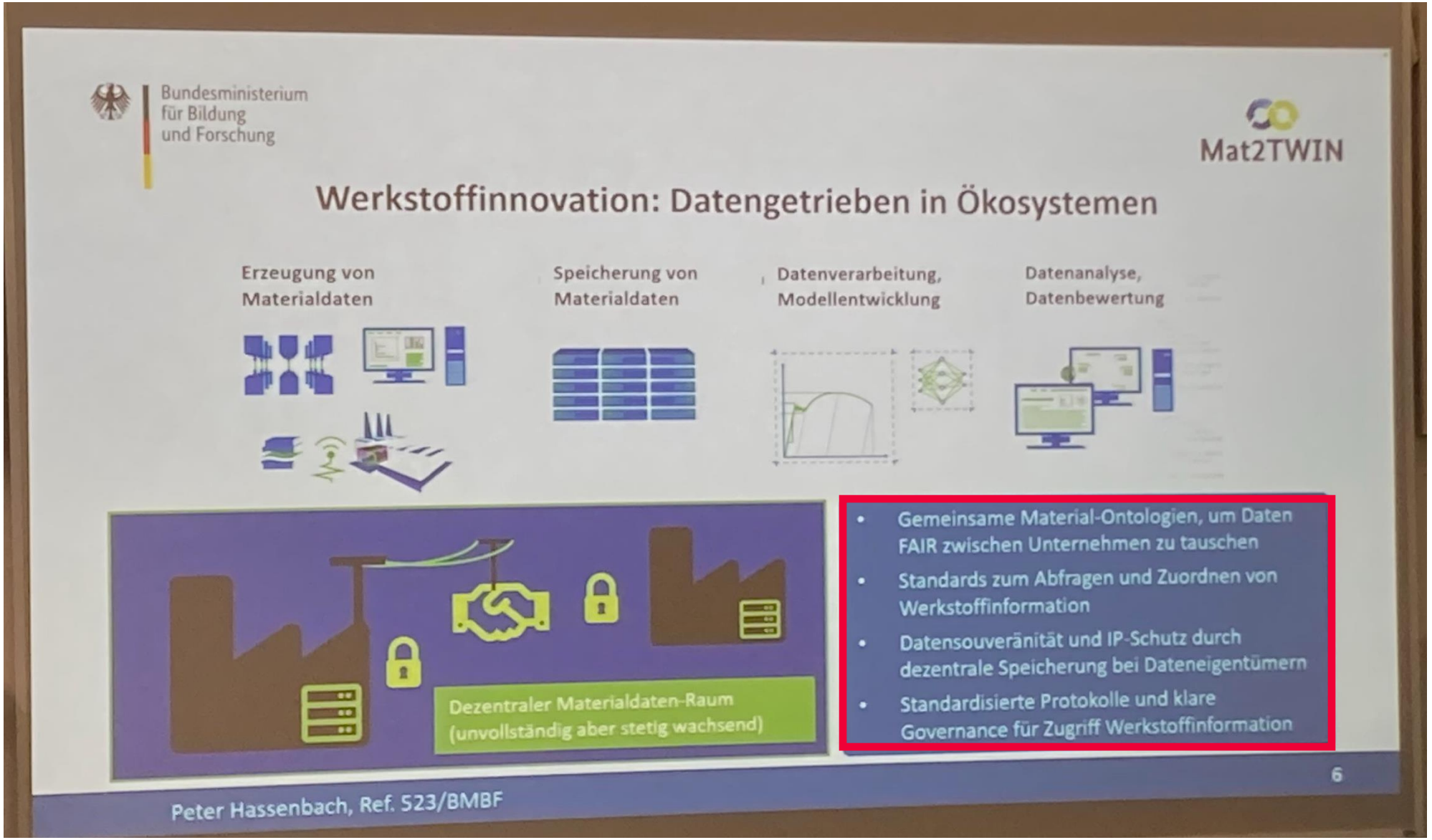
Work by

Patrick Schneider, Foundational Technologies

& team

SIEMENS

Keynote BMBF Materialforschungskonferenz 2025



SIEMENS

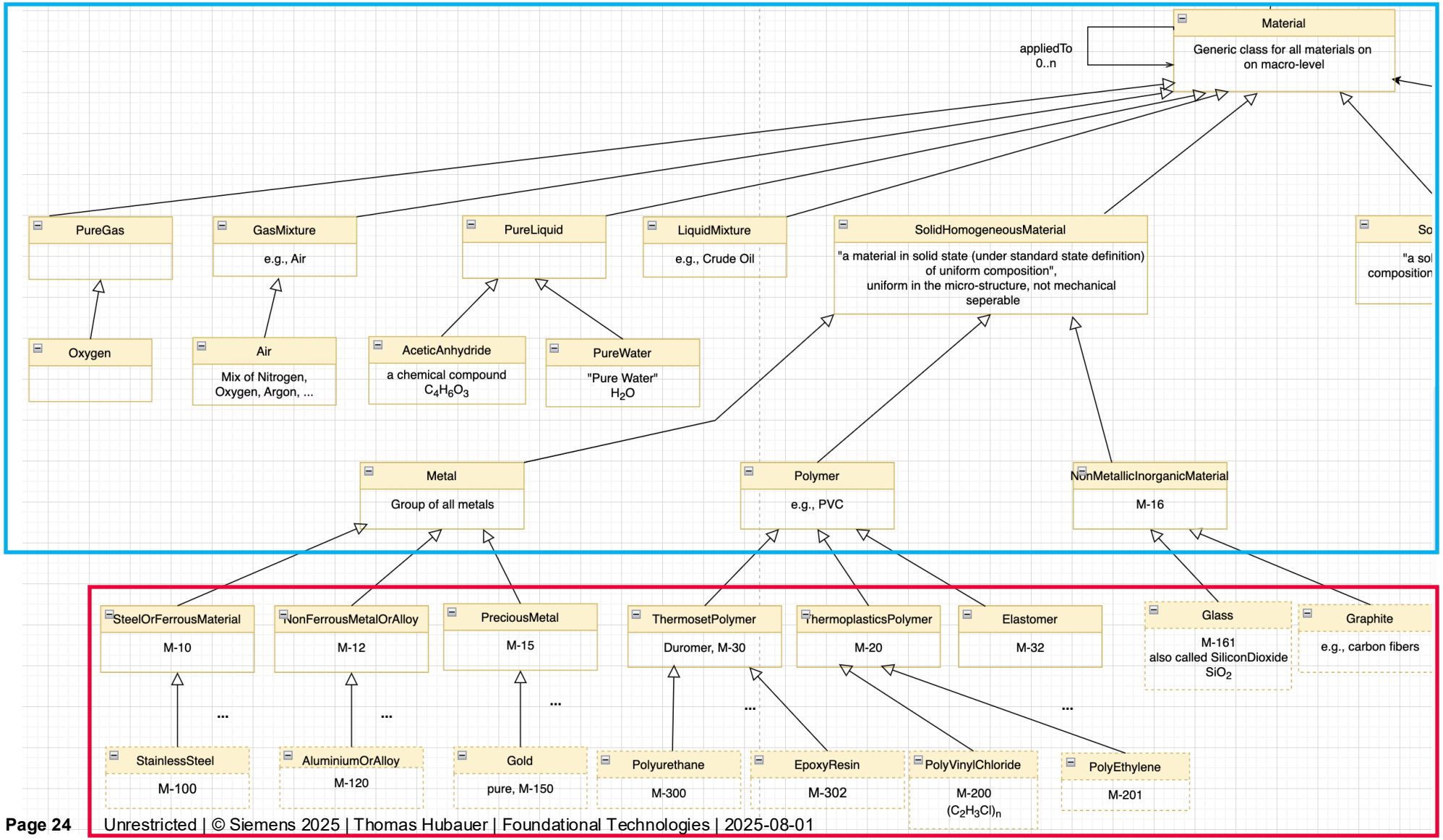
OntOMat - Project Overview

- *Funded under the "**Plattform MaterialDigital**" initiative by* Frauenhofer IVM, Max-Planck-Institut, KIT, etc.
- "The platform should become the **infrastructure for exchange and linking of data, ontologies, SW solutions** for the **material domain**" (in D)
- Overview on https://www.materialdigital.de
- Two funding calls, third one soon to come
- **OntOMat is**
  - Sustainable **ontology-based development**
  - for **fiber-reinforced materials** and
  - their **manufacturing processes**
  - and **simulation processes**
- **Partners**:
  - Siemens Technology
  - DLR – Institute of Lightweight Systems
  - BIAS – Institute of Applied Beam Technology
  - Fraunhofer Institute for Material Mechanics
  - Nexpirit GmbH

SIEMENS

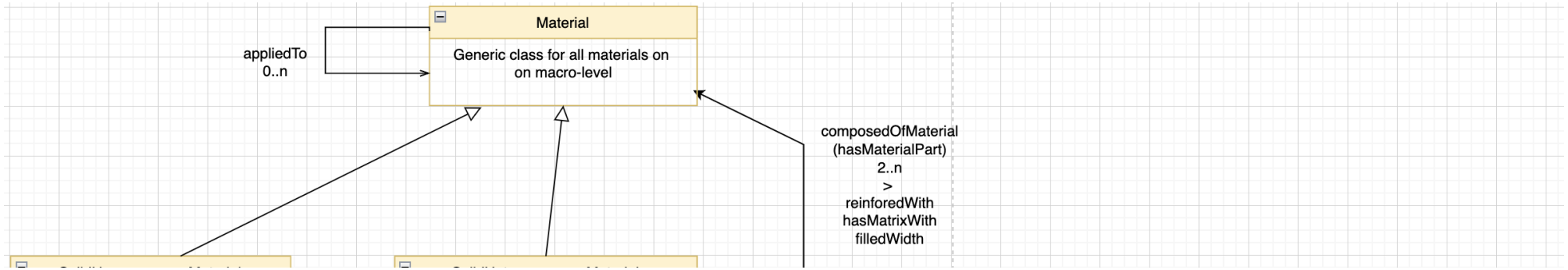
Ontology – Material Classification Ontology

Top-level is from IDO, then own classes, and bottom classed from IEC 62474:2018



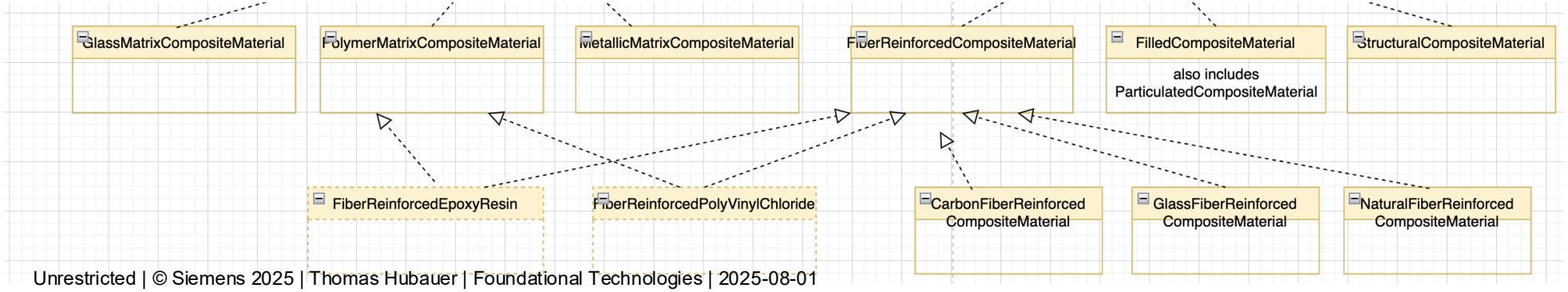
SIEMENS

Ontology – Material Classification Ontology (cont.)



Classification of composite materials via reasoning (by equality axioms):

```
PolymerMatrixCompositeMaterial  ≡ CompositeMaterial ∧ ∃ matrixWithTransitive.Polymer
....
FiberReinforcedCompositeMaterial ≡ CompositeMaterial ∧ ∃ reinforedWithTransitive.Material
....
FiberReinforcedPolyVinylChloride ≡ CompositeMaterial ∧ ∃ reinforedWithTransitive.Material ∧ ∃matrixWithTransitive.PolyVinylChloride
FiberReinforcedEpoxyResin ≡ CompositeMaterial ∧ ∃ reinforedWithTransitive.Material ∧ ∃ matrixWithTransitive.EpoxyResin
....
FilledReinforcedEpoxyResin ≡ CompositeMaterial ∧ ∃ filledWithTransitive.Material ∧ ∃ matrixWithTransitive.EpoxyResin
....
```



Processes: VDI/VDE Process Description is our Modeling Approach

VDI/VDE 3682 (formalised process description) is a generic approach to describe manufacturing process from design/construction perspective published in 2015

ICS 01.110, 25.040.40 | VDI/VDE-RICHTLINIEN | Mai 2015 / May 2015

VEREIN DEUTSCHER INGENIEURE
VERBAND DER ELEKTROTECHNIK ELEKTRONIK INFORMATIONSTECHNIK

Formalisierte Prozessbeschreibungen
Konzept und grafische Darstellung
Formalised process descriptions
Concept and graphic representation

VDI/VDE 3682
Blatt 1 / Part 1

Ausg. deutsch/englisch
Issue German/English

Die deutsche Version dieser Richtlinie ist verbindlich.

The German version of this standard shall be taken as authoritative. No guarantee can be given with respect to the English translation.

Inhalt Seite

Contents Page

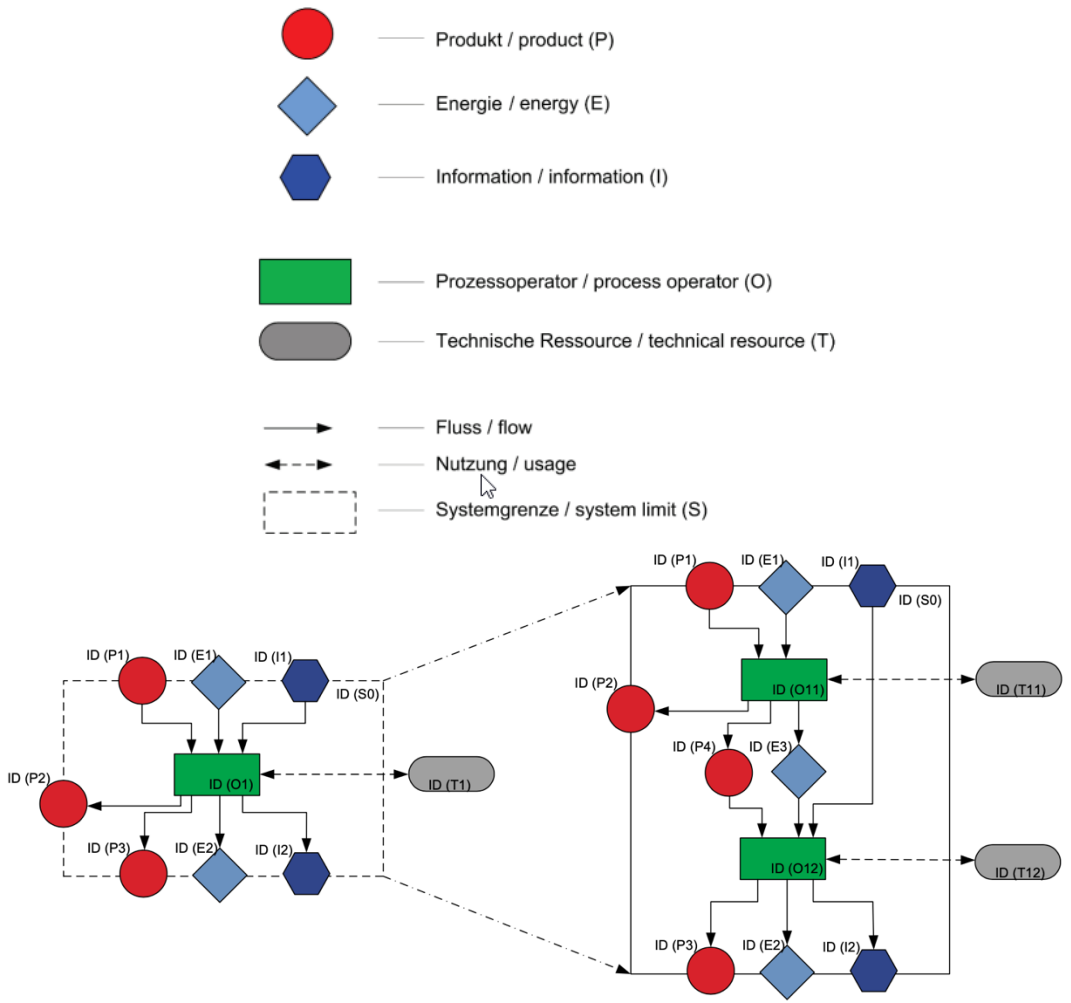
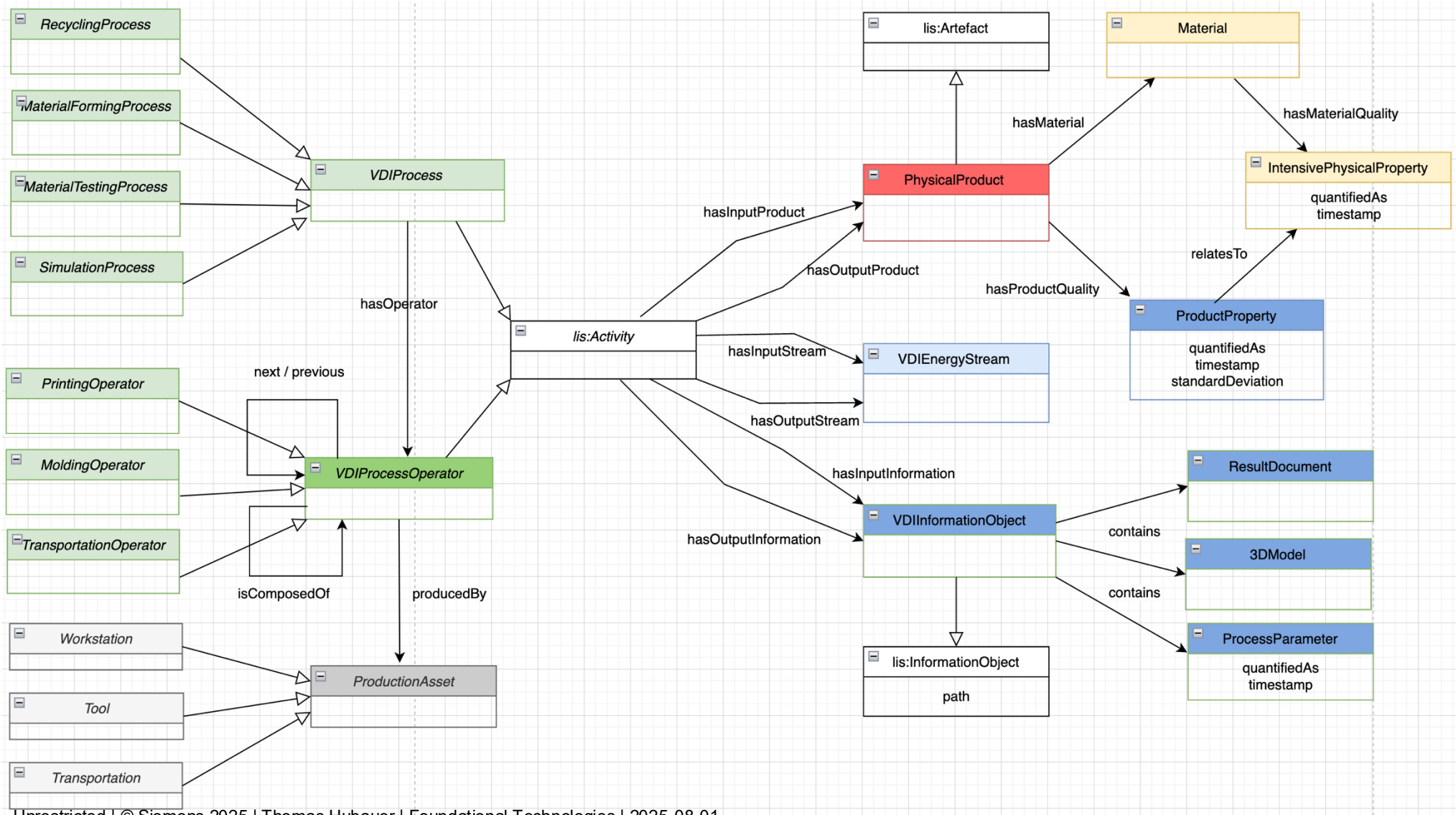


Bild 5. Dekompositionsschritt

Figure 5. Decomposition of a process

Ontology: The VDI/VDE 3682 Ontology

VDI/VDE 3682 model is captured OntOMat ontology (simplified version), but we also refined it a bit…



SIEMENS

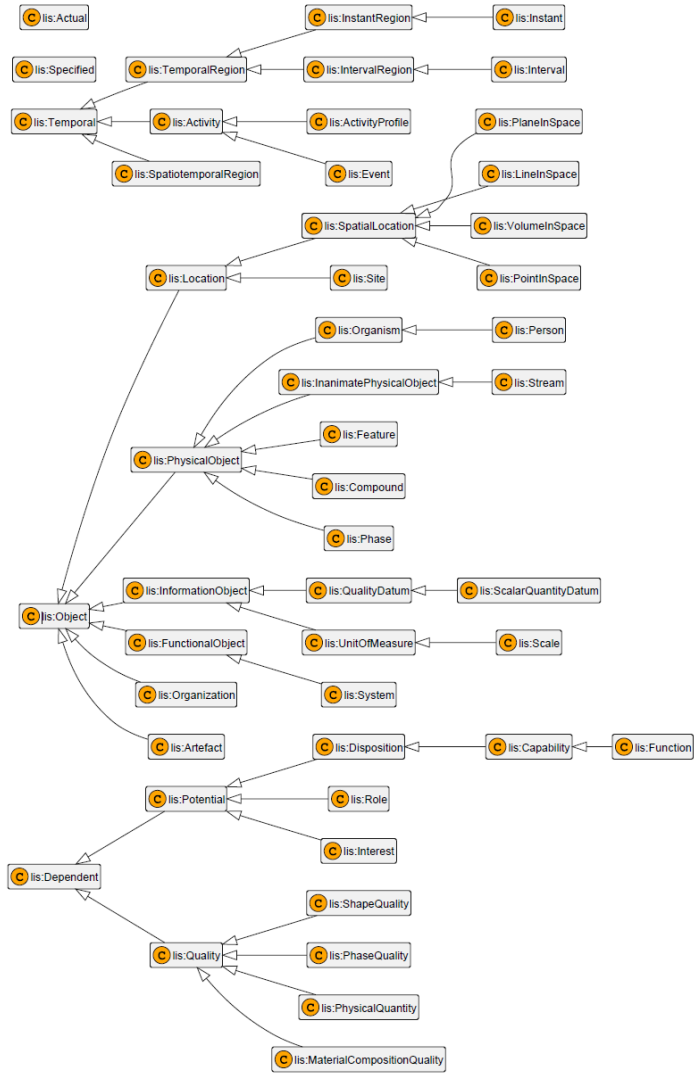
Standardization & the Siemens Ontology Library

Work by
Dr. Maja Milicic-Brandt, Foundational Technologies
& team

SIEMENS

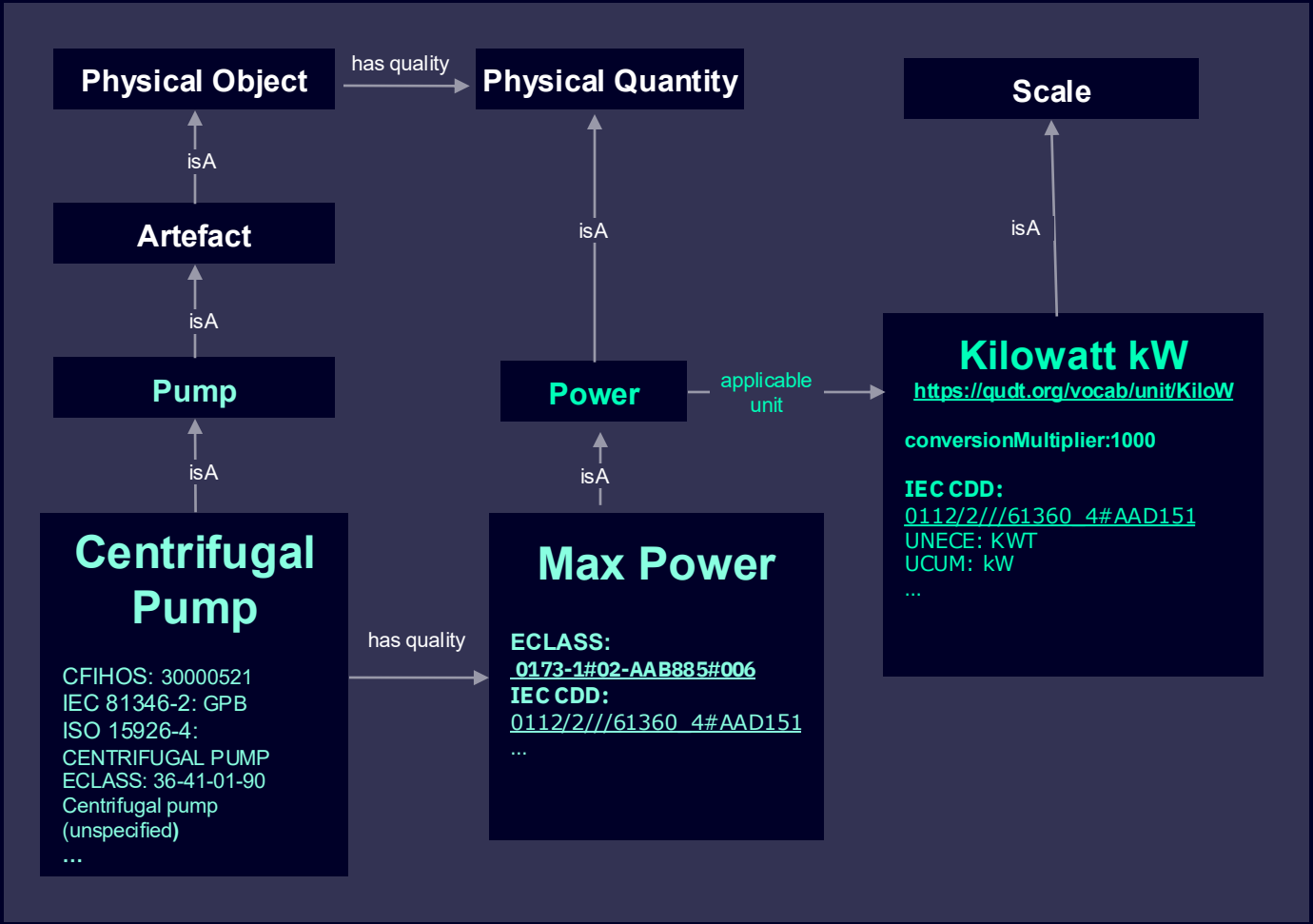
ISO 23726-3 IDO is an upper ontology for representing industrial data, information, requirements and standards

- A precise, abstract and simple vocabulary, including classes and relationships (properties) between these.
- The rules and restrictions (grammar) for an ontology-based ecosystem
- Derived from / inspired by
  - ISO 15926-2:2003
  - ISO/IEC 21838-2:2021 – Basic Formal Ontology (BFO)
- Formulated in the language of W3C OWL 2
  - Precise modelling
  - Automated reasoning
- Developed in Norwegian Energy (O&G) industry and applied in several others



IDO class hierachy (CD version)

Standardized Ontologies define Modeling Patterns for Reference Data Libraries and provide Foundation for Interoperability and Re-Use



Industrial Data Ontology – IDO
is an industry-domain-agnostic ontology that defines top-level classes, relationships and modeling patterns for **industry reference data libraries**.

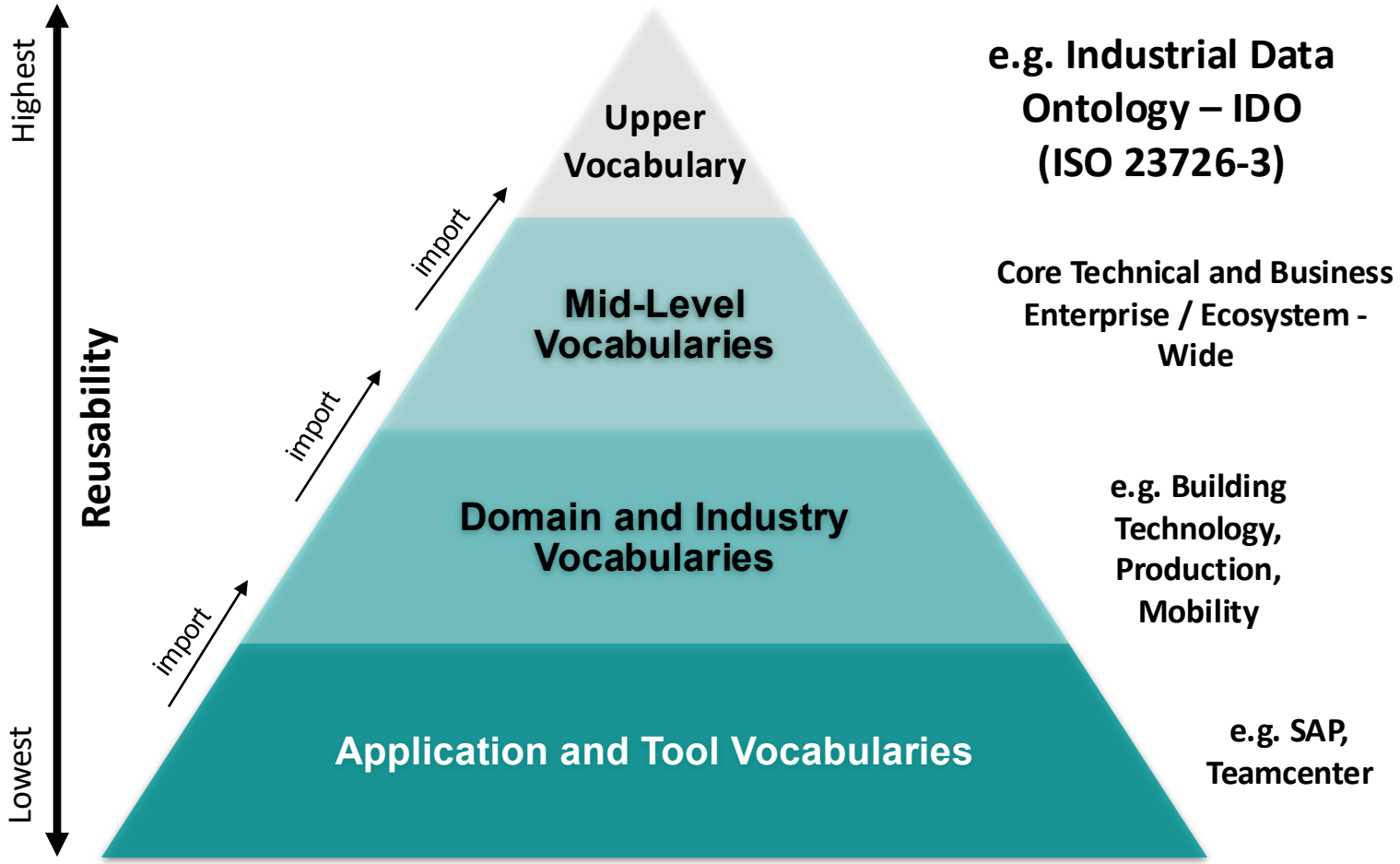
IDO is being standardized as a part of the new standard ISO 23736 – Ontology-Based Interoperability under ISO/ TC 184/ SC 4.

Final Remarks

- Standards mapping is laborious but leads to a better data quality!
- NLP tools and LLMs can help!
- We need people with the right skills and an ecosystem-wide cooperation!

SIEMENS

Ontologies ensure Interoperability of Enterprise Vocabularies by Importing and Re-using Generic Concepts and Modelling Patterns; FAIR principles

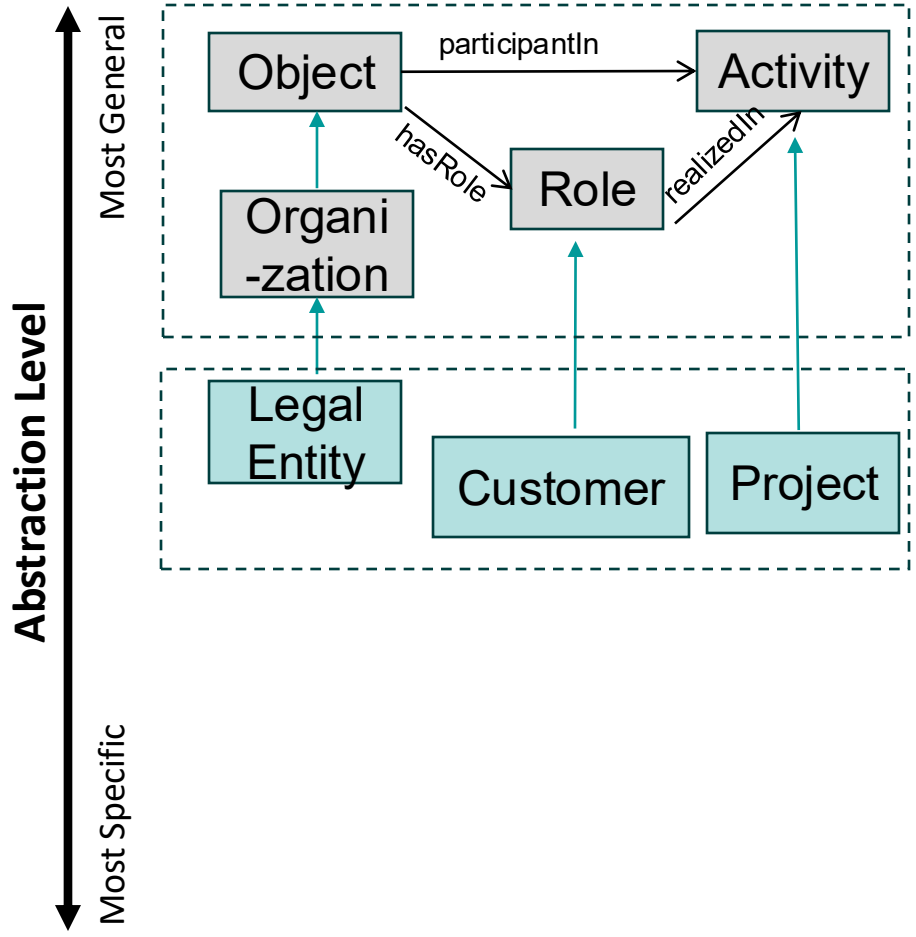


e.g. Industrial Data Ontology – IDO (ISO 23726-3)

Core Technical and Business Enterprise / Ecosystem - Wide

e.g. Building Technology, Production, Mobility

e.g. SAP, Teamcenter



SIEMENS

The Siemens Ontology Library
Lowering the entry barrier to semantic modeling

Siemens Ontology Library

Industry standard | Building | Rail | Siemens Core | Energy | Production

Siemens-wide **shared resource** (via GitLab, Intranet, community building)

Strong **recommendation:**
- Ontology Library as **starting point for your modelling project**
- **Publish** your data model **as an (OWL) ontology**

Guidelines

Templates

Automated publishing process (CI/CD)

SIEMENS

The Good

Success stories using semantic technologies at Siemens

The Bad

Where we are still struggling

The Ugly ?

Now that GenAI is here – who still needs semantics?

The Good

Success stories using semantic technologies at Siemens

The Bad

Where we are still struggling

The Ugly ?

Now that GenAI is here – who still needs semantics?

The Siemens Ontology Library
… why we struggled

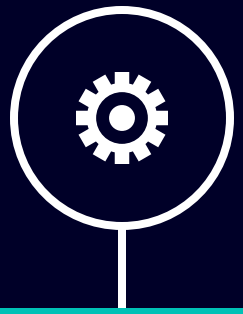
Creation of shared ontologies still rather limited …

- Curation of ontologies considered a **“detour”**
- **Lack of intuitive tooling** for Domain Experts
- **Modelling** by Knowledge Engineers **does not scale (enough)**
- **Lack of** people with **double skill sets** (domain & semantics)

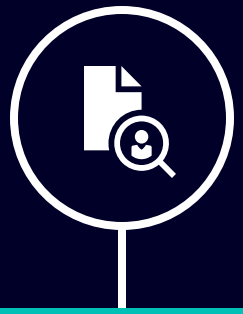
Active usage of ontologies in code still rather rare …

- **Microservices and DDD** preferred paradigm among SW Architects
- Swagger, JSON Schema, LinkML etc the **home turf of SW Developers**
- **Independent services** and teams the main priority
- **Cognitive burden** of understanding an ontology

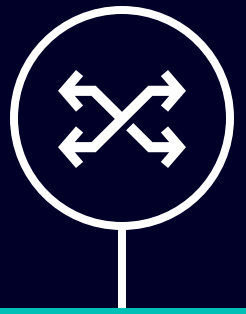
Islands of semantics in standalone-services



Extensive need for mappings

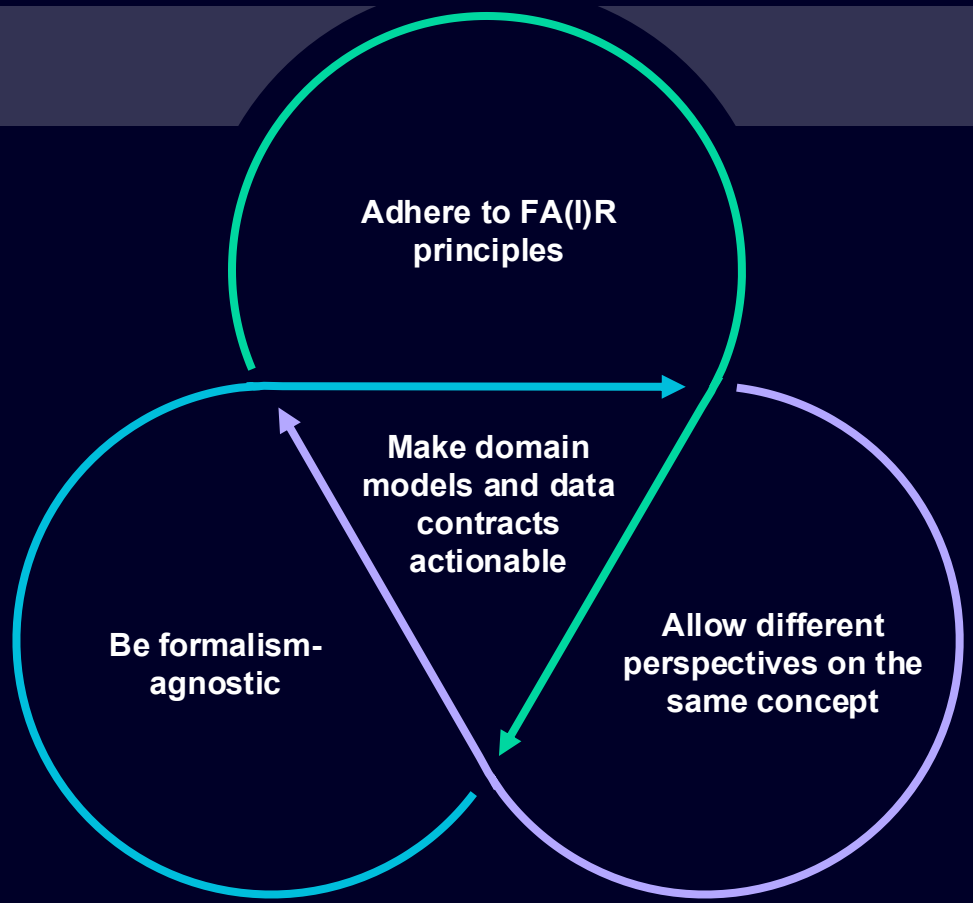


Disconnect between ontologies and vocabularies used in code



SIEMENS

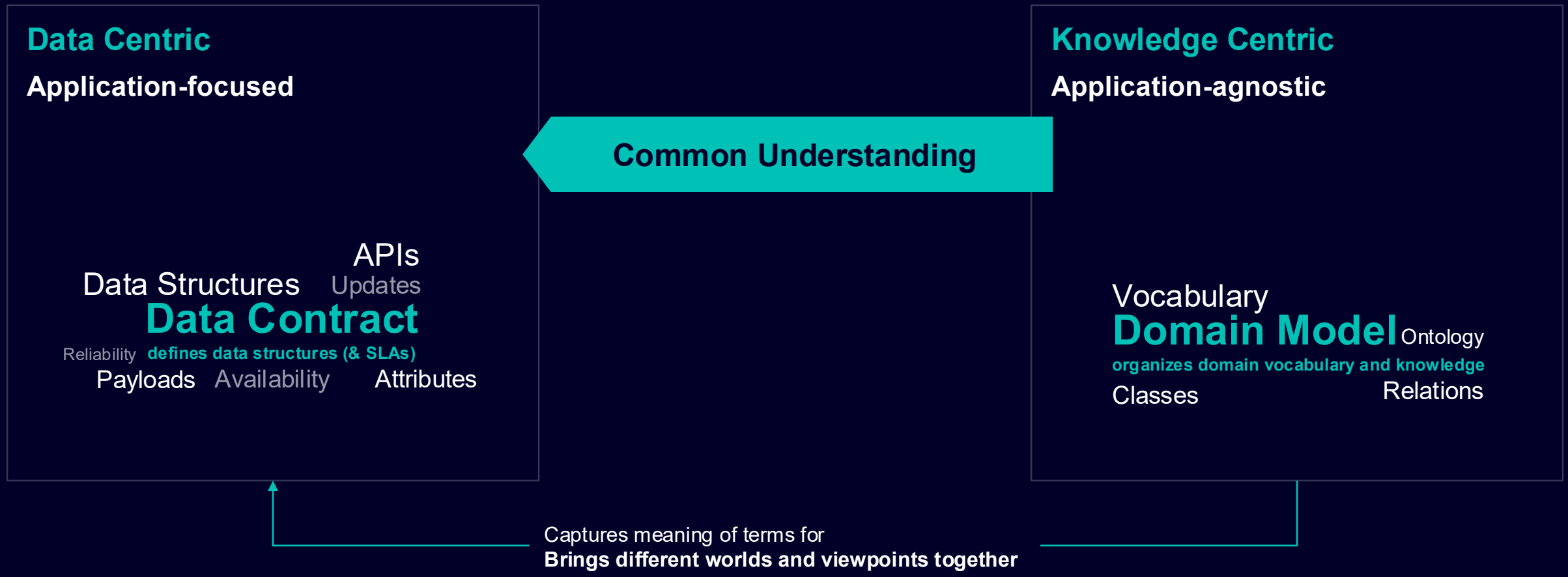
Towards ONE Siemens Polyglot Model Library
We have set ourselves the following tasks



- **Learning 1:** Accept that domain models come “in all shapes and sizes”
- **Learning 2:** Accept that truth is both global and local
- **Learning 3:** Transparency first – harmonization later
- **Learning 4:** Understanding (a domain model) is a haptic process

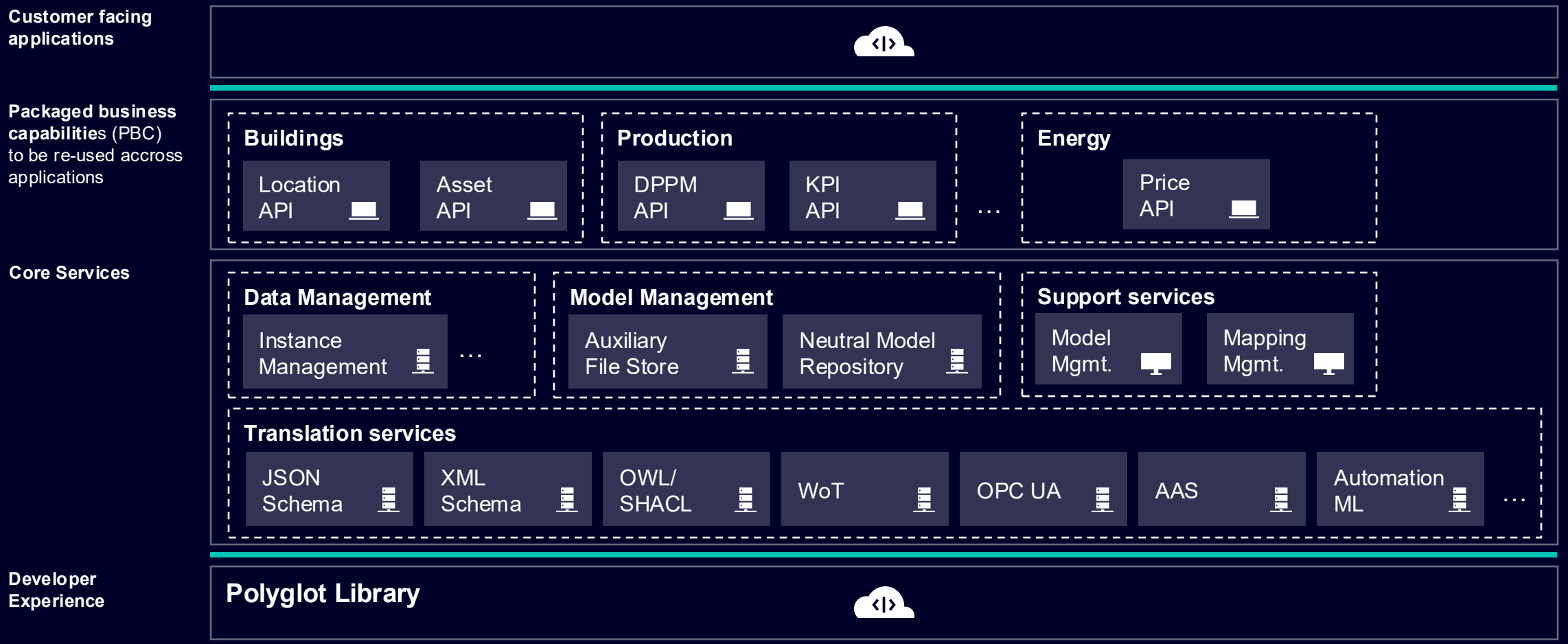
SIEMENS

Towards ONE Siemens Polyglot Model Library
Bringing together Data Contracts and Domain Models



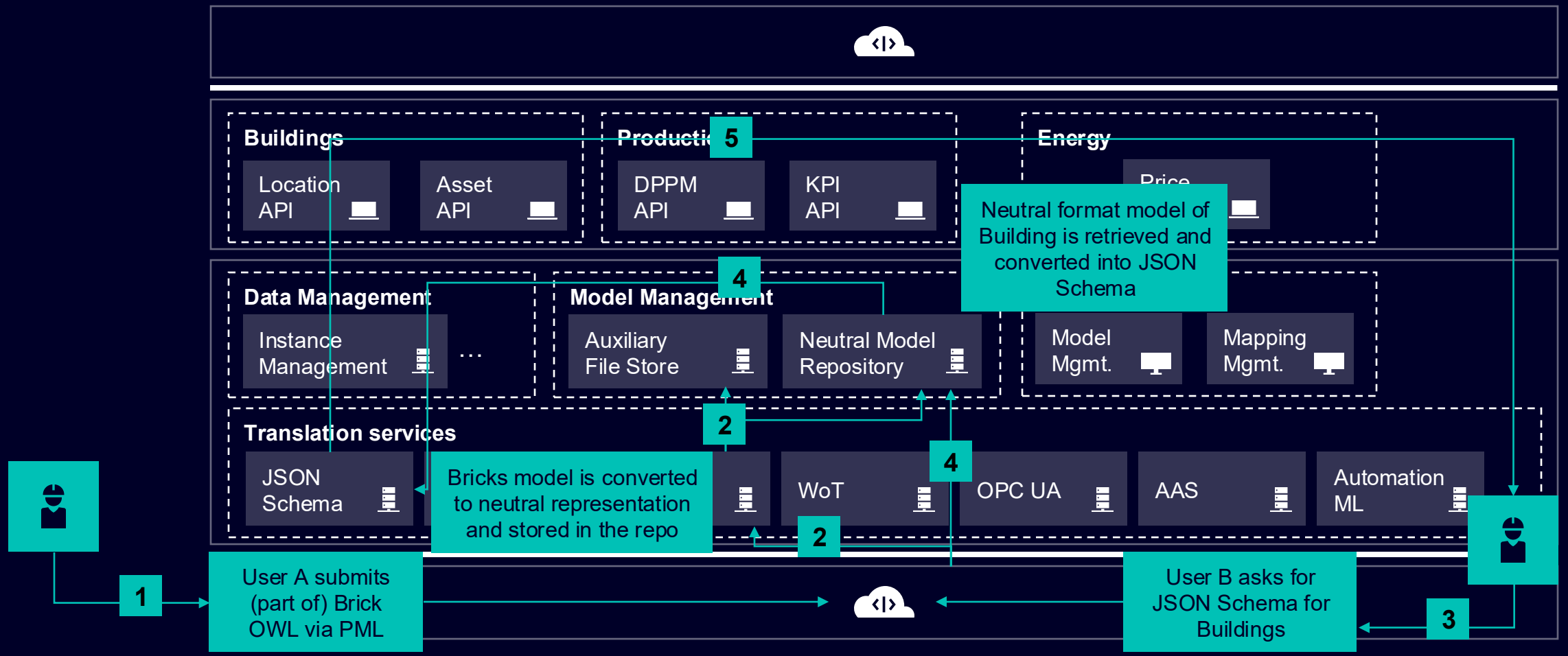
SIEMENS

Towards ONE Siemens Polyglot Model Library
Technical Sketch



SIEMENS

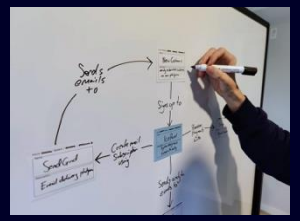
Towards ONE Siemens Polyglot Model Library
Technical Sketch



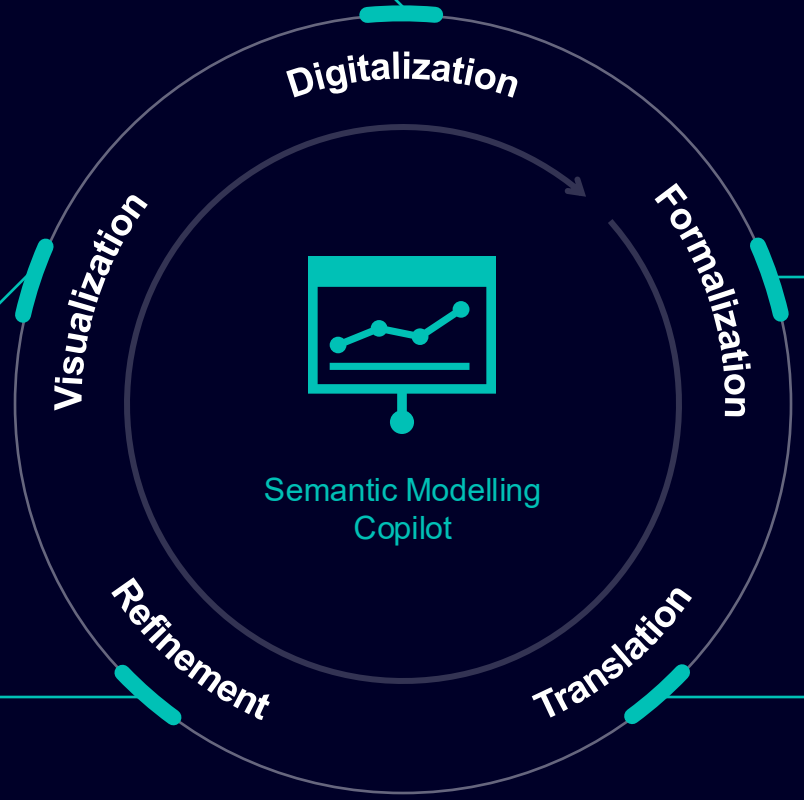
SIEMENS

Semantic Modelling Copilot
Accelerating the modelling journey for non-ontologists

Drawing-2-Diagram
Generate draw.io file from whiteboard drawing



Schema-2-Visualization
Generate visualization (e.g., UML) from schema specification



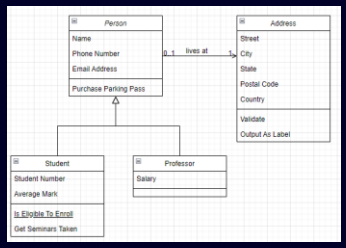
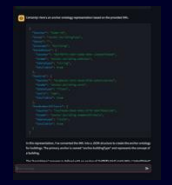
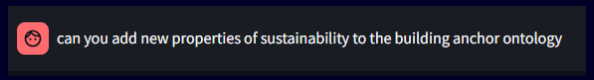


Diagram-2-Schema
Generate schema from diagram considering core schemas



Schema-2-Schema
Data-2-Data
Generate standardized schema transformations and data mappings

Language-2-Schema
Change schema based on natural language instructions or document input



SIEMENS

The Good

Success stories using semantic technologies at Siemens

The Bad

Where we are still struggling

The Ugly ?

Now that GenAI is here – who still needs semantics?

The Good

Success stories using semantic technologies at Siemens

The Bad

Where we are still struggling

The Ugly ?

Now that GenAI is here – who still needs semantics?

nature

Explore content | About the journal | Publish with us | Subscribe

nature > news > article

NEWS | 24 July 2025

DeepMind and OpenAI models solve maths problems at level of top students

For the first time, large language models performed on a par with gold medallists in the International Mathematical Olympiad.

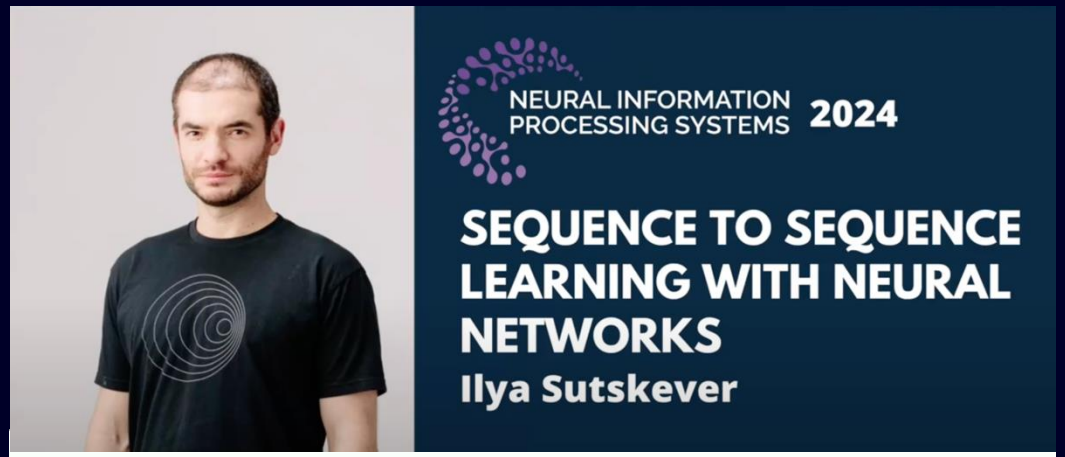
By Davide Castelvecchi

Models from OpenAI and DeepMind achieved gold-medal scores in the International Mathematical Olympiad. Credit: MoiraM/Alamy

Google DeepMind announced on 21 July that its software had cracked a set of maths problems at the level of the world's top secondary-school students, achieving a gold-medal score on

SIEMENS

By 2028 the Internet is running out of training data



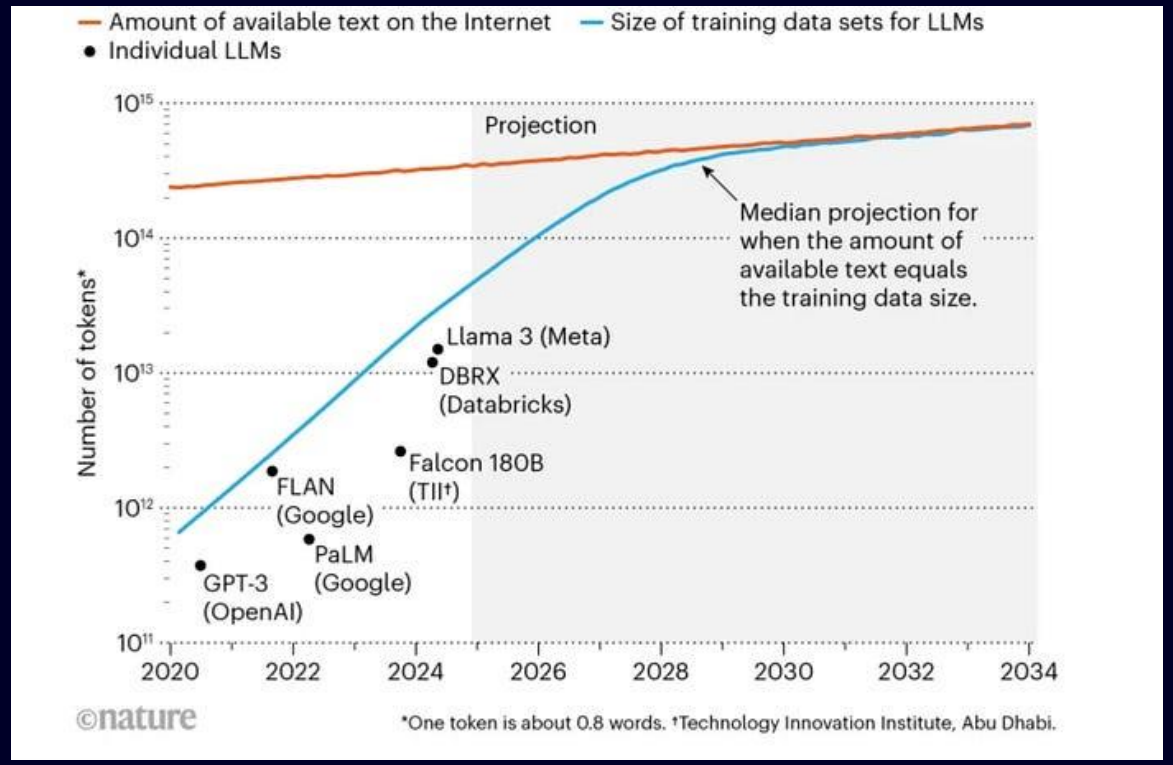
Pre-training as we know it will end

Compute is growing:

- Better hardware
- Better algorithms
- Larger clusters

Data is not growing:

- We have but one internet
- **The fossil fuel of AI**

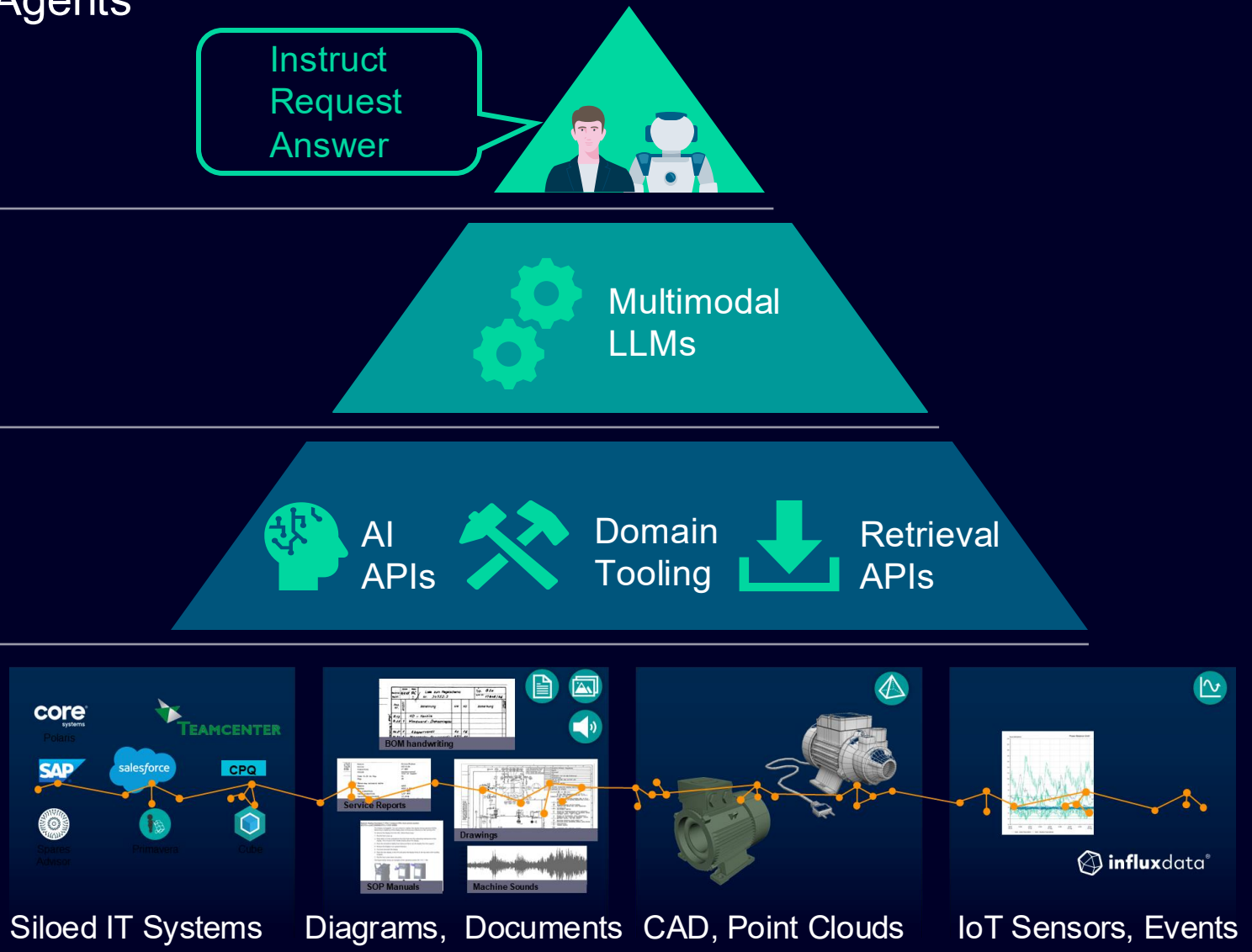


More Compute + More Data = Better AI ?

SIEMENS

Industrial GenAI systems will be more than a single Foundation Model!

Ecosystem of Multimodal Agents



Industrial Grade AI

- Explainability
- Transparency
- Continuous evaluation
- Guardrails
- Safe & secure Infrastructure
- Data safety & security

SIEMENS

Existing Commercial Pretrained Models

are now Multi Modal!

Text

Image

Video

Audio

What these Multi Modal Models can now do

Vision
- Image classification
- Object detection
- Image-to-Image

Audio
- Audio classification
- Speech recognition
- Audio generation

Code
- Code generation
- Code translation
- Tabular regression

Table
- Tabular classification
- Tabular regression

Language
- Conversations
- Translation
- Knowledge extraction
- Summarization

SIEMENS

Existing Commercial Pretrained Models

are now Multi Modal!

- **Text**
- **Image**
- **Video**
- **Audio**

Modalities

Industrial Foundation Model

Training AI on the “language” of Engineering and Manufacturing

- **System design**
- **Mechanical design**
- **Electrical design**
- **Simulation**
- **Manufacturing**
- **BOM**

SIEMENS

Our options to integrate industrial domain knowledge into generative models

Prompting: Learning via few in-domain samples

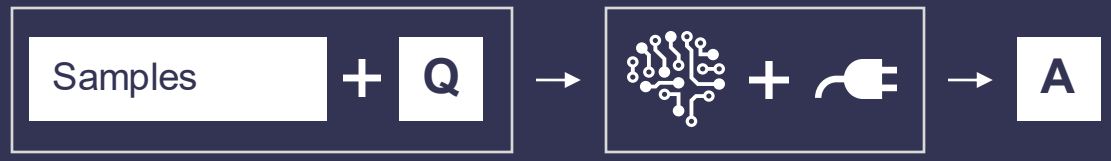
Option 1a

Prompting with information retrieval:
Retrieve and add relevant content to the prompt

Option 1b

Information access via plug-ins:
LLM calls a plug-in with access to own content

Option 2

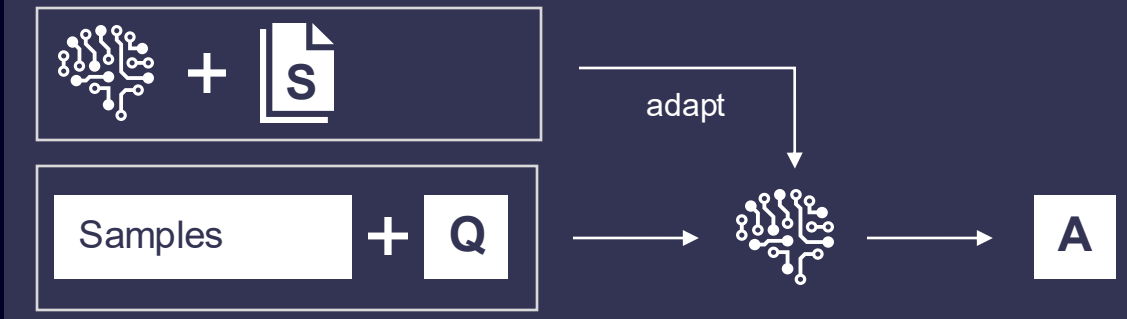


Supervised fine-tuning: LLM as basis for training an in-domain prediction model with labelled data

Option 3

Re-training & Training "from scratch": Train with a large unlabeled corpus to enable better domain representations

Option 4



Cost & Complexity

Take 3rd-party models "as is" (Opt. 1a&b) and add to them (Opt. 2)

Modify models (Opt. 3) or build new ones (Opt. 4)

SIEMENS

Example Industrial Engineering
Deploying Siemens Industrial Copilots throughout the machine lifecycle

Code

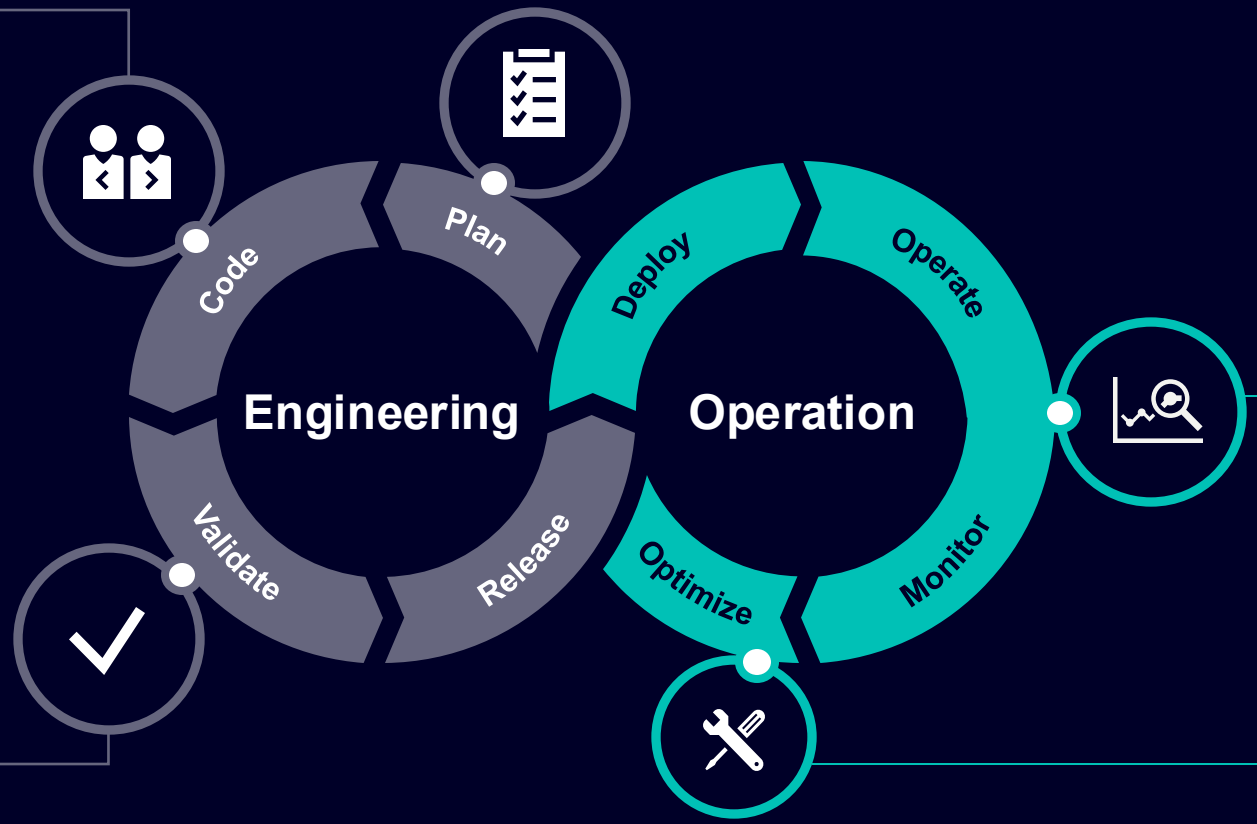
Generate HW-Config,
HMI screen & code, PLC code

Documentation

Support engineers
with automation information

Validation

Generate unit tests
of function blocks



Operate

Finding and fixing errors
based on documentation

Validation

Generate unit tests
of function blocks

SIEMENS

Siemens Product Announcements on GenAI in 2024

Pressemitteilung 22. Apr 2024 Digital Industries Nürnberg

Siemens Xcelerator: Siemens treibt Skalierung generativer KI mit Siemens Industrial Copilot voran

- Siemens macht Automatisieren einfach mit dem ersten generativen KI-gestützten Produkt für Engineering im industriellen Umfeld
- Siemens Industrial Copilot beschleunigt Generierung von komplexem Automatisierungscode, verkürzt Entwicklungszeiten und steigert Produktivität
- Anbindung an TIA Portal ermöglicht Kunden Generierung von SCL-Code, HMI-Visualisierung und Suche von Dokumenten in natürlicher Sprache
- Ab Sommer 2024 auf dem Siemens Xcelerator Marketplace verfügbar

mendix

Get Ahead of the AI Hype Cycle

Mendix helps harness the power of AI from idea to experiment to deployment.

Start for free

The GBS AI Assistant's microservices

Free Prompt

Entity Extraction

GenAI Assistant

Summarize Documents

Translator

Document Search

SIEMENS

Products & Services Industries Company

Pressemitteilung 05. Februar 2024 Digital Industries Nürnberg

Generative künstliche Intelligenz hebt Predictive Maintenance von Siemens auf die nächste Stufe

- Durch die Erweiterung bewährter maschineller Lernverfahren um generative KI entsteht eine robuste, umfassende Lösung für die vorausschauende Wartung.
- Über eine dialogorientierte Benutzeroberfläche können Anwender auf einfache Weise proaktive Maßnahmen ergreifen und so Zeit und Ressourcen sparen.
- Die neue generative KI-Funktionalität von Senseye Predictive Maintenance ermöglicht eine vorausschauende Wartung mit interaktivem Austausch zwischen Mensch und Maschine.

Siemens Industrial Copilot: Enorme Vorteile im Engineering

Von der Theorie zum Produkt: Erstes generative KI-gestütztes Produkt für industrielles Engineering

Auf der Hannover Messe 2023 haben Siemens und Microsoft gemeinsam ihre Vision für einen generativen KI-gestützten Assistenten vorgestellt: Der Siemens Industrial Copilot beinhaltet die Automatisierungs- und Prozesssimulationstechnologie von Siemens' digitaler Businessplattform Siemens Xcelerator. Die Sprachmodelle von Microsoft Azure OpenAI Service erweitern den Siemens Industrial Copilot, um beispielsweise die Erstellung und Optimierung von Software-Code für die Fabrikautomatisierung zu ermöglichen. Auf der Smart Production Solutions (SPS) Messe im Herbst 2023 präsentierte Siemens gemeinsam mit Schaeffler AG erstmals eine Produktionsmaschine, die mit dem Siemens Industrial Copilot erweitert wurde. Siemens geht auf der Hannover Messe 2024 den nächsten Schritt: das erste generative KI-gestützte Produkt für Engineering im großen Maßstab.

Siemens and Microsoft deepen partnership

- Introduction of **Siemens Industrial Copilot**, a generative AI powered assistant
- Enhanced human-machine collaboration & boost in productivity
- Automotive supplier Schaeffler AG as early adopter
- Collaboration **to build additional copilots across industries**
- Teamcenter app for Microsoft Teams to drive PLM innovation

Integration of AWS Bedrock with Mendix

Siemens and Amazon Web Services (AWS) are strengthening their partnership to make **generative AI easily accessible to application developers** across the Siemens Xcelerator ecosystem by integrating the AWS **Bedrock** Platform in **Mendix**.

Mendix customers can develop and scale their software applications much easier using multiple options of high-performance AI base models.

SIEMENS

Siemens beschleunigt Wasserstoffhochlauf per generativer Künstlicher Intelligenz

- Neue KI-Tools helfen bei Design, Engineering und Automatisierung von Wasserstoffanlagen
- Verfügbar zum Download auf dem Siemens Xcelerator-Marktplatz ab Ende 2024
- Achema-Messe: Wasserstoff als ein Schwerpunkt der Kunden-Showcases auf dem Siemens-Stand

Die Verfügbarkeit von grünem Wasserstoff ist entscheidend, um Nachhaltigkeitsziele im Industriesektor zu erreichen. Um den Wasserstoffausbau zu beschleunigen, unterstützt das Technologieunternehmen Siemens künftig die Wasserstoffindustrie mit Software-Tools auf Basis von generativer künstlicher Intelligenz. Vor allem in der Wasserstoffherstellung sollen die neuen Lösungen dazu beitragen, Design, Engineering und Automatisierung von Wasserstoffproduktionsanlagen deutlich zu vereinfachen und dadurch schneller Wasserstoff produzieren zu können.

Podcasts > Engineer Innovation Podcast

PODCASTS

How ChatGPT Is Redefining the Future of Engineering Simulation with Kai Liu

November 29, 2023 • 2 MIN READ

Share Print

SIEMENS Digital Industries Software

Software & Products Solutions & Services Industry Solutions Training & Support

Blogs Products Industries Podcasts Thought Leadership Corporate Community

All Thought Leadership > Thought Leadership

THOUGHT LEADERSHIP

How generative AI enhances the PLM process

April 28, 2023 • 3 MIN READ

Share Print

… and much more to come in FY25!

SIEMENS

Contact

Dr. Thomas Hubauer

Foundational Technology
Principal Key Expert
Knowledge Graph & Semantics

thomas.hubauer@siemens.com

SIEMENS