

# DEXPI and the Arrowhead fPVN Knowledge Graph based Digital Twin

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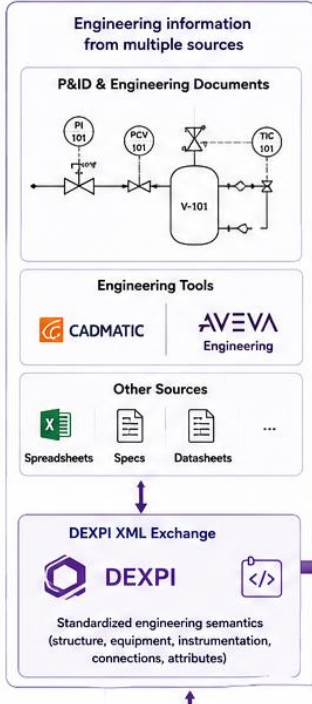
TBHK 2026-05-28

The Arrowhead fPVN project is supported by the Chips Joint Undertaking and its members, including the top-up funding by Finland, Denmark, Sweden, Spain, Italy, Rumania, Portugal, Hungary, and France

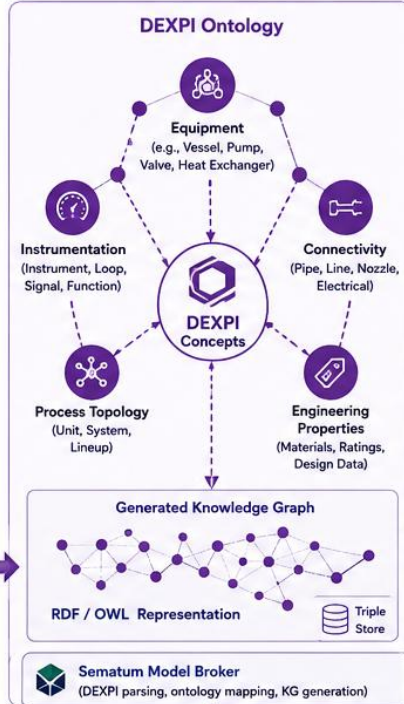


## DEXPI as the engineering semantic foundation for the Process Plant Digital Twin

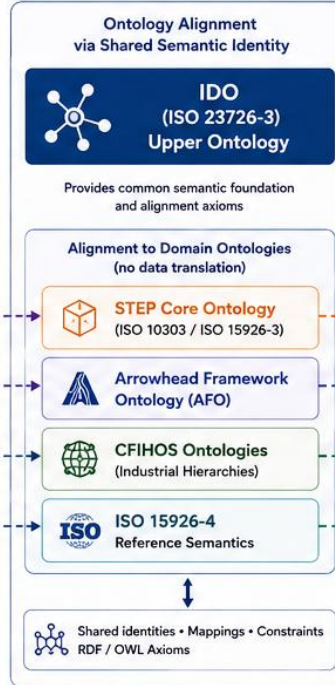
### 1 ENGINEERING DOMAIN Create & Capture



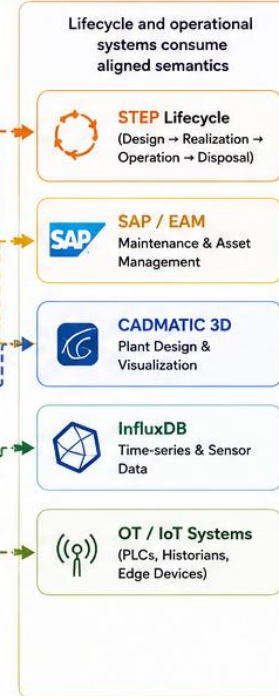
### 2 DEXPI SEMANTIC LAYER Engineering Knowledge



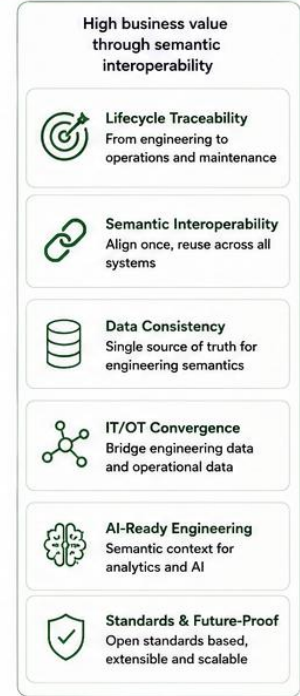
### 3 SEMANTIC ALIGNMENT LAYER Align – Don't Translate



### 4 LIFECYCLE & OPERATIONS Consume & Enrich



### 5 BUSINESS VALUE Outcomes



### 6 KNOWLEDGE GRAPH FOUNDATION



### ★ KEY MESSAGE

DEXPI engineering semantics are aligned – not translated – into interoperable lifecycle and operational Knowledge Graphs, enabling scalable Digital Twins and AI-driven applications.

### HOW IT WORKS



### STANDARDS & TECHNOLOGIES



# Model Broker Solution

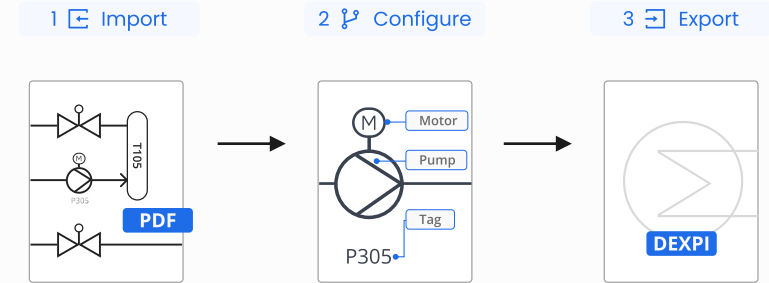
**Model Broker for Diagrams** is a software solution to automatically extract data from technical drawings

- **P&IDs**, control logic or electrical diagrams with vector graphics

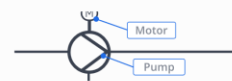
It converts the extracted information into structured data that follows industrial standards:

- P&IDs can be converted into **DEXPI** (XML), **Knowledge graphs** or CSV ( MS Excel) files
  - DEXPI 1.X, DEXPI 2.0 (Plant, Process and custom profiles are supported)
  - **Knowledge graphs generated from DEXPI 2.0 XML**
  - Materials Take-Off, Tag-to-Tag, Equipment lists

## Piping and Instrumentation Diagrams



## Software features



### Symbol recognition

- Symbols in drawings are recognized by configuring patterns based on the graphical primitives



### Text recognition

- Text can be mapped as attributes of the recognized symbols



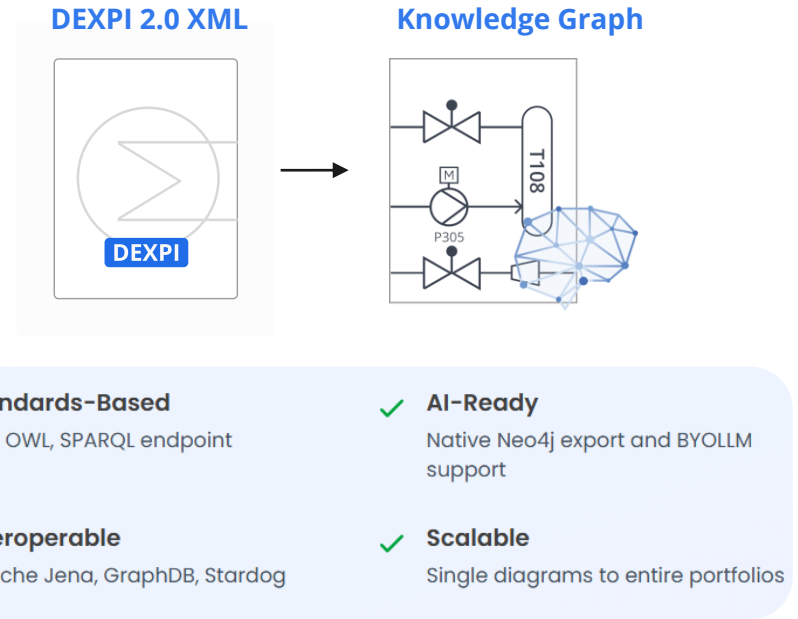
### Connectivity

- Connectivity between different diagram components is automatically created

# Transform static P&IDs into AI-ready knowledge graphs

Model Broker toolset transforms DEXPI 2.0 XML into semantic RDF knowledge graphs. This enables valuable semantic integration between your P&ID data and other process, automation and production information, unlocking:

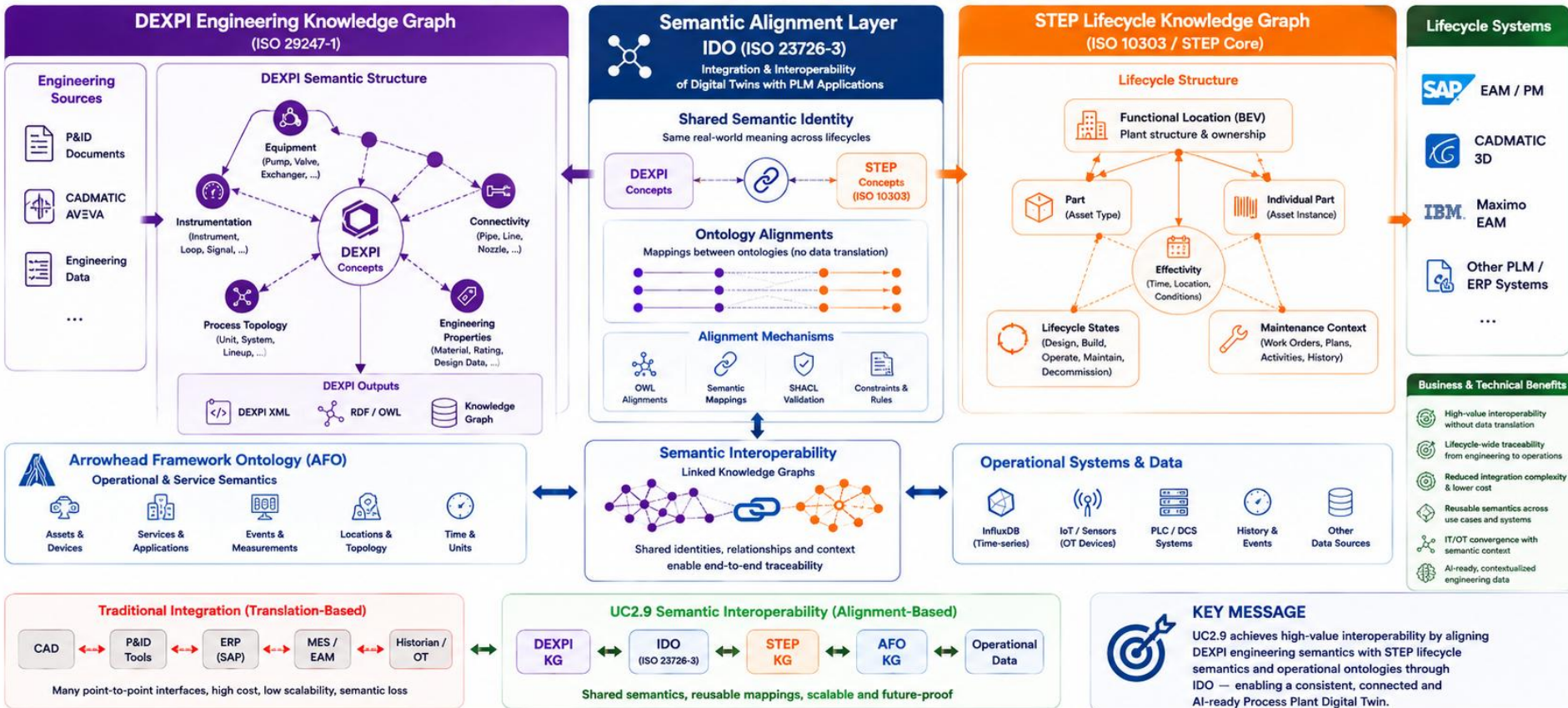
- AI-driven process copilots and next-generation engineering intelligence
- Context-aware decision support systems with high semantic fidelity
- Automation of tasks such as HAZOP analyses, quality assurance and anomaly detection
- Native integration of your P&ID data with Neo4j, Jena, and other commercial graph platforms



# DEXPI + STEP Semantic Alignment

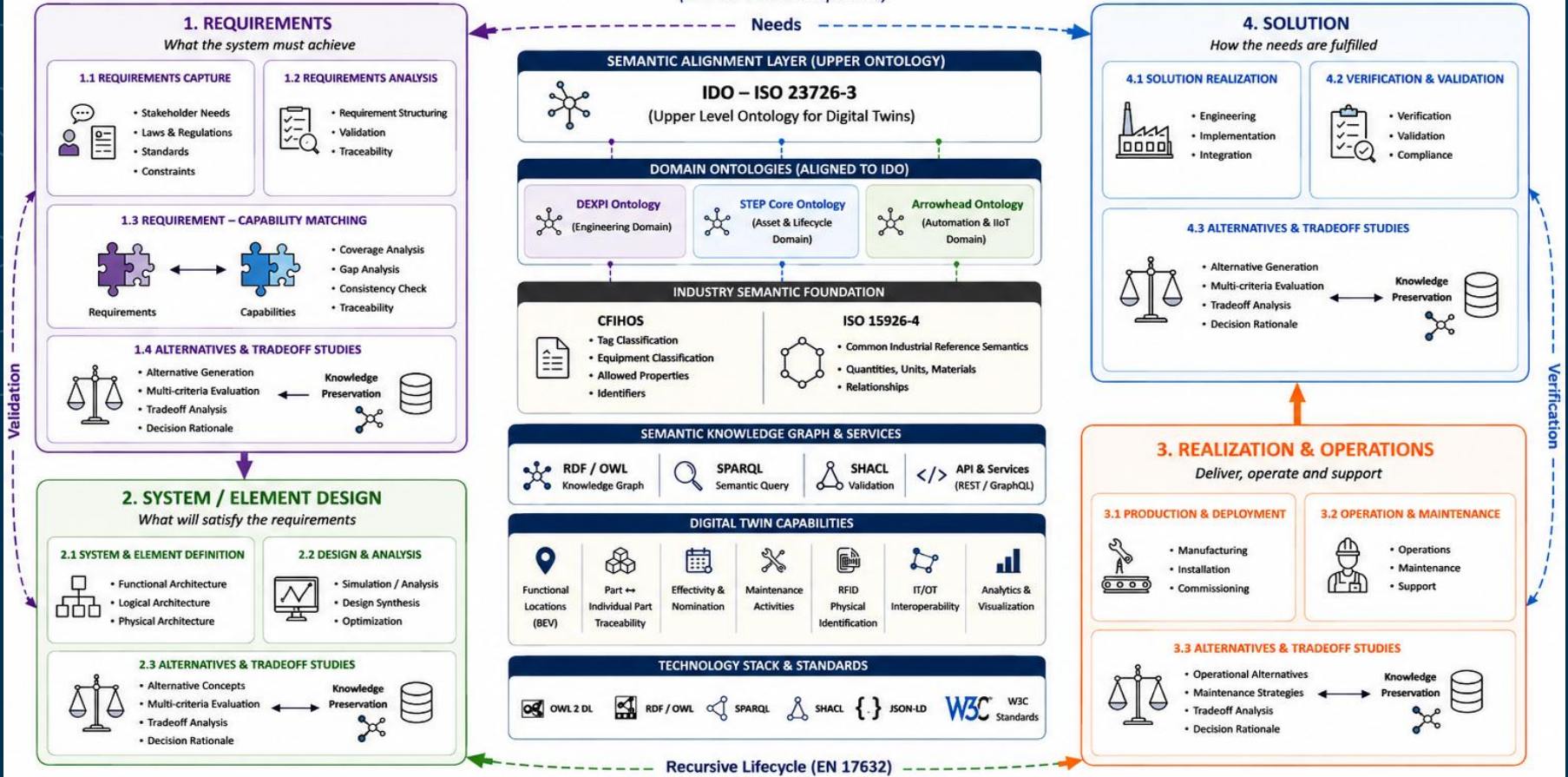
Engineering-to-Lifecycle Interoperability in UC2.9

Align Knowledge Graphs through Shared Semantics — Not Translation



# UC 2.9 – PROCESS PLANT DIGITAL TWIN ARCHITECTURE

IDO aligned, semantically interoperable architecture across the full systems engineering lifecycle  
(EN 17632 compliant)



**CROSS-DOMAIN INTEROPERABILITY**

Engineering Lifecycle Maintenance Automation/IIoT Operations

**KEY OUTCOMES**

- ✓ Interoperable Digital Twins across the lifecycle
- ✓ Semantic consistency and data re-use
- ✓ Improved asset traceability and maintenance
- ✓ IT/OT integration and data convergence
- ✓ Knowledge preservation across decisions
- ✓ Foundation for effective engineering AI applications

**DATA SOURCES / INTEGRATION**

PLM / PDM ERP / EAM / CMMS Historians / MES IIoT / Sensors Documents / Files

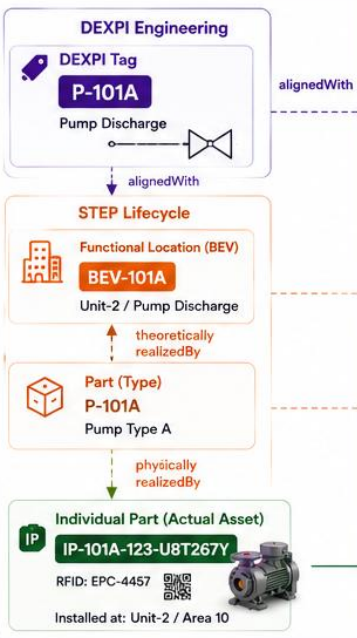
**LEGEND**

- Requirements Flow
- Design Flow
- Realization Flow
- Solution Flow
- Information Flow
- Traceability / Alignment
- Feedback / Recursion

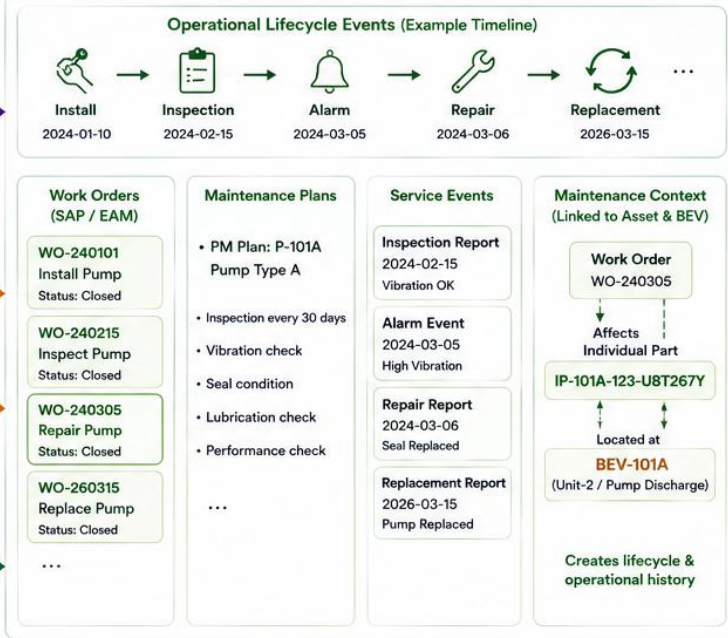
**NOTES**

- All data and models are semantically described and linked.
- SHACL constraints ensure data quality, consistency and interoperability.
- Knowledge is preserved across alternatives, decisions and baselines.

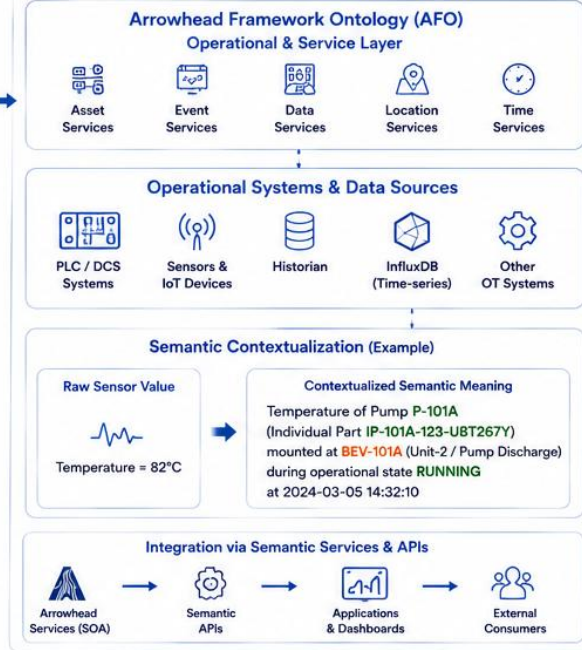
### 1 Engineering & Lifecycle Context



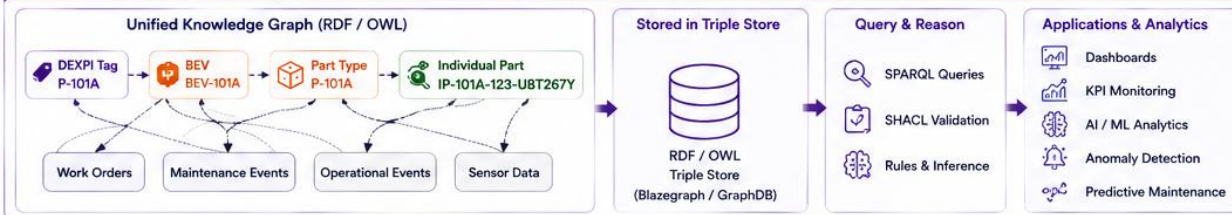
### 2 Maintenance Activities (Operational Lifecycle)



### 3 Operational Integration & Context



### 4 Semantic Operational Digital Twin (Knowledge Graph Foundation)



### Business Value

- ✓ End-to-end lifecycle & operational traceability
- ✓ Faster root-cause analysis & troubleshooting
- ✓ Proactive & predictive maintenance
- ✓ Reduced downtime & maintenance cost
- ✓ Operational awareness with full context
- ✓ AI-ready, contextualized operational data

# 7 Semantic Interoperability Instead of Translation

Why Ontology Alignment + Knowledge Graphs Scale

★ UC2.9 enables high-value interoperability by aligning engineering and lifecycle semantics – not by translating information. Shared meaning, reusable mappings, and knowledge graphs create a future-proof foundation for Digital Twins.

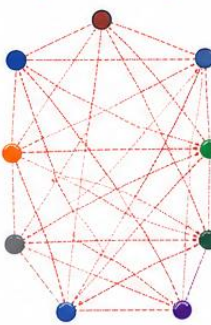
## ✗ Traditional Integration: Translation-Based

Point-to-Point Interfaces • Data Translation • High Complexity

Typical Landscape

- Engineering (CAD / P&ID)
- ERP / EAM (SAP, Maximo)
- MES / CMMS
- Historian / PI
- PLC / DCS
- Other OT Systems

Many Point-to-Point Integrations



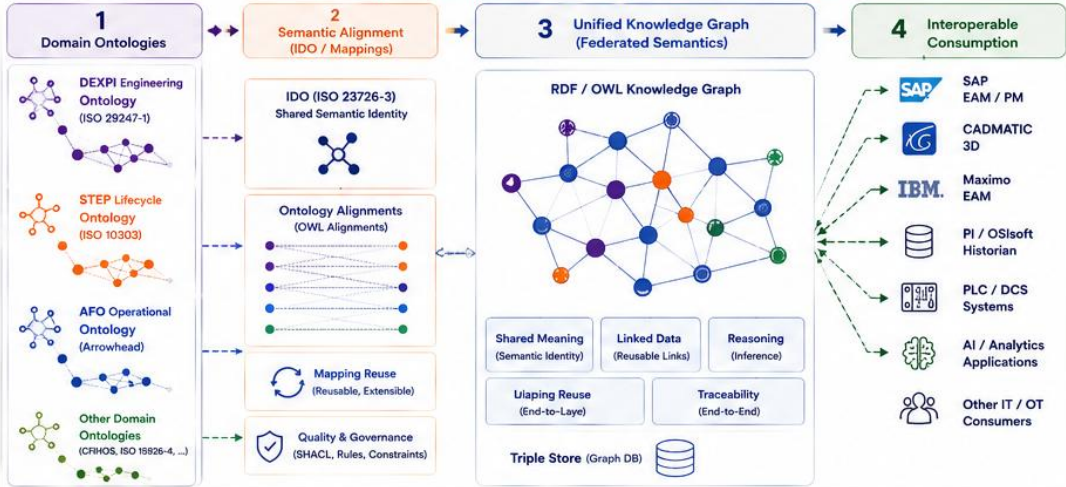
Issues & Limitations

- N<sup>2</sup> Integrations (Complexity explodes)
- High cost to build and maintain
- Brittle integrations Error prone
- Semantic loss during translation
- Difficult to scale and reuse
- Hard to adapt to new systems
- Not AI-ready (Siloed data)

☹️ **Result:** High integration cost, low agility, semantic loss, poor scalability, weak operational awareness.

## ✓ UC2.9 Approach: Semantic Interoperability (Alignment-Based)

Ontology Alignment • Knowledge Graphs • Shared Semantics • Scalable

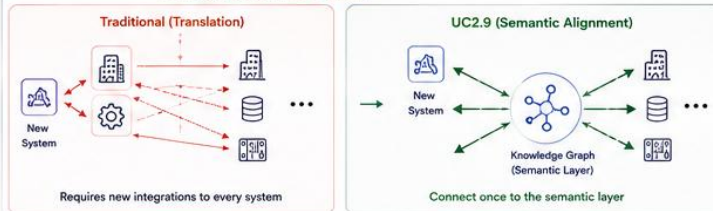


😊 **Result:** Low integration cost, high scalability, reusable semantics, AI-ready, strong operational awareness.

### Why Semantic Interoperability Wins

- ✓ Meaning is preserved, not translated
- ✓ N integrations instead of N<sup>2</sup>
- ✓ Reusable mappings across systems
- ✓ Easy to add new systems
- ✓ Strong governance and data quality
- ✓ AI-ready contextualized knowledge

### Example: Add a New System



### Enabling W3C Standards

- RDF: Data model for knowledge representation
- OWL: Ontologies and class relationships
- SPARQL: Query and retrieve knowledge
- SHACL: Validation of shapes and constraints
- RDFS / OWL Reasoning: Inference & consistency
- Linked Data Principles: Global interoperability

### Business Impact

- ✓ Faster integration & lower cost
- ✓ Lifecycle continuity & traceability
- ✓ IT / OT convergence
- ✓ Better decision making
- ✓ Predictive & prescriptive maintenance
- ✓ Foundation for AI & Autonomous Ops

Key Standards & Technologies



# PROCESS PLANT DIGITAL TWIN – BIDIRECTIONAL NAVIGATION

Connecting 3D Plant Context with Semantic Knowledge Graph

**3D TO GRAPH**  
Select in 3D to explore semantic context

**GRAPH TO 3D**  
Select in Graph to locate in 3D plant environment

**3D PLANT VIEW**

**P-100A**  
Centrifugal Pump  
Status: In Service  
Location: Area 10  
[View in Graph](#)

**3D OVERVIEW MAP**

**SELECTED ASSET SUMMARY**

**P-100A**  
Centrifugal Pump

Tag (DEXPI) P-100A  
Functional Location FL-1001  
System Pumping System  
Area Area 10  
Status ● In Service  
Lifecycle State (STEP) Installed  
Manufacturer PumpTech  
Model CP-X100  
Serial No. 10001A  
Installed On 2018-11-21  
Effectivity 2018-11-21 - Present

**QUICK ACTIONS**

- Show Neighbors (3D)
- Show in Graph
- View Engineering Data
- View Lifecycle History
- Create Work Request
- Open in SAP PM

**KNOWLEDGE GRAPH VIEW**

All Equipment Systems Functions Locations Documents

**GRAPH LEGEND**

- Functional Location
- Equipment
- Product / Asset
- Maintenance
- Work / Document
- Lifecycle
- Capability / Req.

**RELATIONSHIPS**

- realizes
- partOf
- parallelTo
- classifiedAs
- hasActivity
- generates
- hasState
- fulfills
- replacedBy
- linkedTo
- derivedFrom

**NEIGHBORING ASSETS (3D)**

XV-101 Control Valve	3.2 m	
P-100B Centrifugal Pump	5.6 m	
PI-101 Pressure Indicator	8.7 m	

Show all in 3D

**LIFECYCLE HISTORY (STEP)**

2015-03-15 Manufactured	2018-11-21 Installed	2021-06-10 Maintenance (Overhaul)	2024-02-18 Maintenance (Seal Replacement)
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Effectivity: 2018-11-21 - Present (In Service)

**ENGINEERING CONTEXT (DEXPI)**

P&ID	P-101
Functional Spec	FS-1001
Equipment Spec	ES-1001
3D Model	P-100A.smc
Instrumentation	PI-101, TI-101

Open in Engineering System

**REQUIREMENTS & CAPABILITIES**

- Requirement (CFIHOS) REQ-7001  
Maintain Flow Rate > 100 m³/h
- Capability CAP-8001  
120 m³/h @ 50m Head

Show all relationships

**RELATED DOCUMENTS**

- Datasheet\_P-100A.pdf
- Maintenance\_Manual.pdf
- Alignment\_Procedure.pdf
- Work\_Instructions.pdf
- Inspection\_Report\_2024.pdf

Show all documents



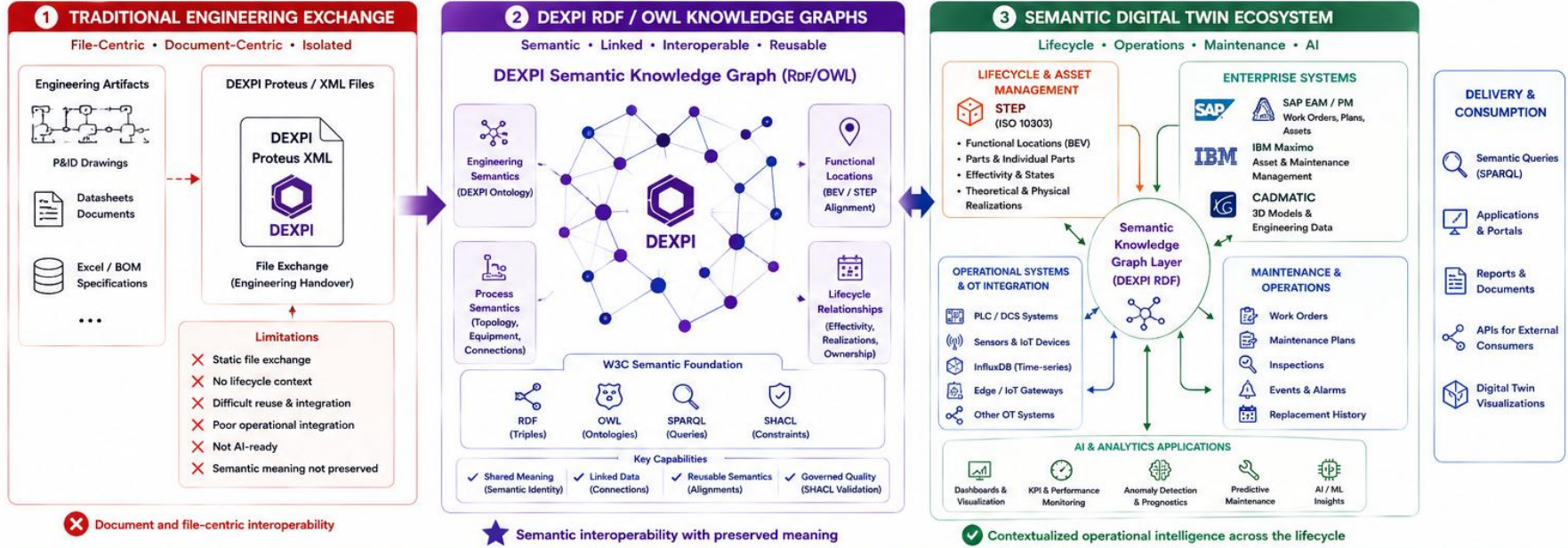
CONTEXTUAL UNDERSTANDING. SMARTER DECISIONS.

Seamlessly navigate between 3D plant context and semantic knowledge to explore relationships, analyze impact, and make better engineering and operational decisions.



From Engineering Files to Interoperable Knowledge Graphs and AI-Ready Digital Twins

“ The key innovation is *not only DEXPI file exchange* — but transforming *DEXPI engineering semantics* into interoperable *RDF/OWL Knowledge Graphs* aligned with *lifecycle and operational ontologies*.



## WHY DEXPI RDF / OWL IS THE DIFFERENTIATOR



## ENABLED BY OPEN STANDARDS & ONTOLOGIES



## BUSINESS & STRATEGIC IMPACT

- Reduced integration complexity & cost
- Faster engineering & operational alignment
- Complete lifecycle traceability
- Improved asset reliability & availability
- Data-driven & predictive operations
- Stronger foundation for AI & autonomy
- Scalable, interoperable, future-ready

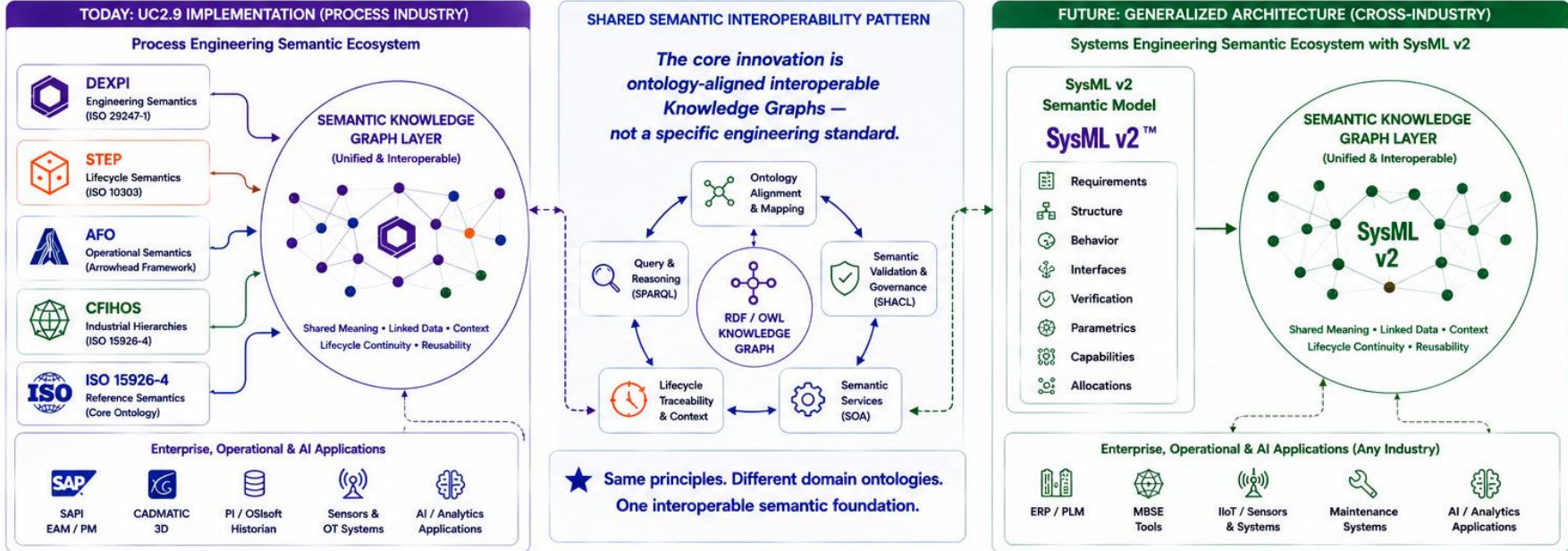


UC2.9 demonstrates how DEXPI RDF, STEP lifecycle semantics, and interoperable Knowledge Graphs create a scalable foundation for future semantic Digital Twins and engineering AI applications.





The UC2.9 semantic interoperability architecture is not limited to DEXPI or process plants. DEXPI is one domain ontology for process industry — SysML v2 can play the same role for any complex engineered system.



COMPARISON	Aspect	DEXPI (Process Industry)	SysML v2 (Cross-Industry Systems Engineering)
	Scope	Process plants and facilities	Any complex engineered system
	Primary Focus	P&ID, equipment, process, instrumentation	Requirements, behavior, structure, systems, interfaces
	Semantic Domain	Process engineering semantics	Systems engineering semantics
	Lifecycle Coverage	Plant lifecycle (design → operations → maintenance)	System lifecycle (concept → in-service → disposal)
	Industry	Process industry (oil & gas, chemicals, power, etc.)	Aerospace, automotive, defense, rail, energy, manufacturing, etc.
	Example Standards	DEXPI, STEP, AF0, CFIHOS, ISO 15926-4	SysML v2, STEP, AF0, ISO 15926-4 (as applicable)

### WHY THIS MATTERS

- ✓ Architecture is ontology-driven, not application-driven
- ✓ Scales across domains and industries
- ✓ Promotes reuse, interoperability, and innovation
- ✓ Preserves engineering intent across the lifecycle
- ✓ Enables AI-ready, contextualized engineering
- ✓ Reduces vendor lock-in and data silos

**DEXPI RDF demonstrates the pattern. SysML v2 could generalize the semantic Digital Twin architecture across industries.**