

# Enhancing Trustworthiness and Formalization in the Construction Industry with Modeling Languages and Ontologies

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# Build Trust Vision



- **Multinational** organization (1963)
- **Concrete** Mixing&Batching plants
- Heavy civil construction

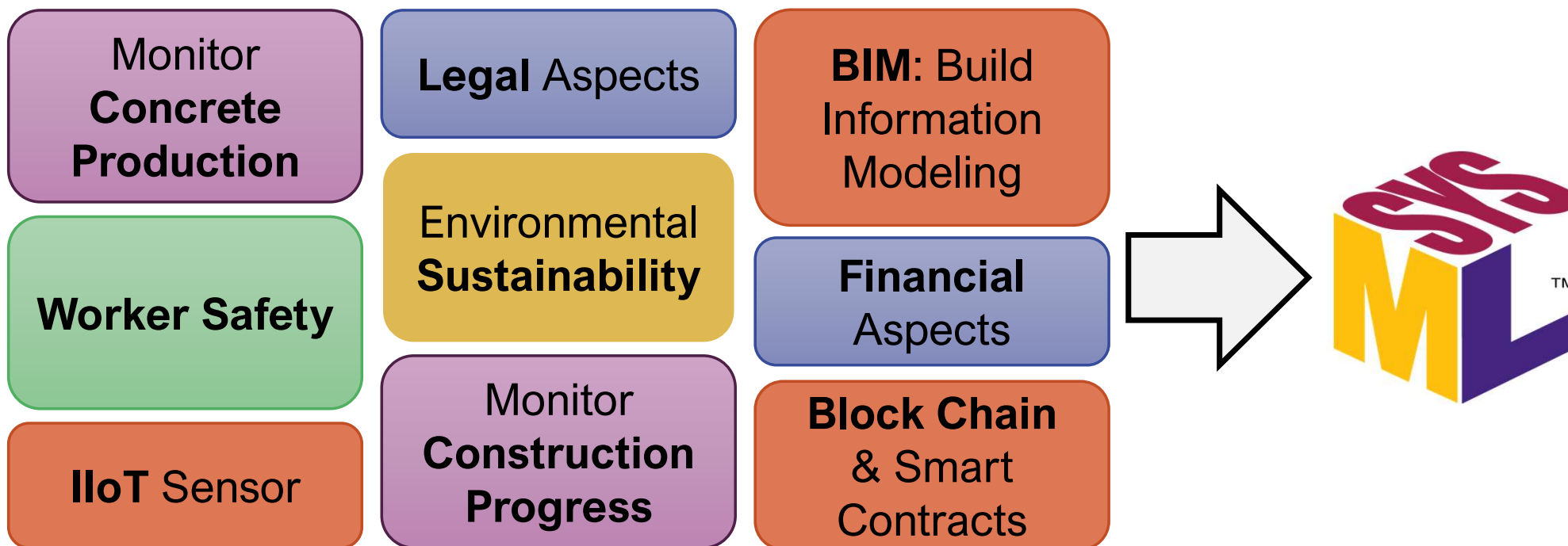


- Inherent **complexity** and **diverse operations** of large-scale construction projects
- Construction projects are often:
  - Delayed, overbudget, inefficient
  - Lack of transparency
- Use of **outdated processes & technologies**



# Build Trust Vision (cont'd)

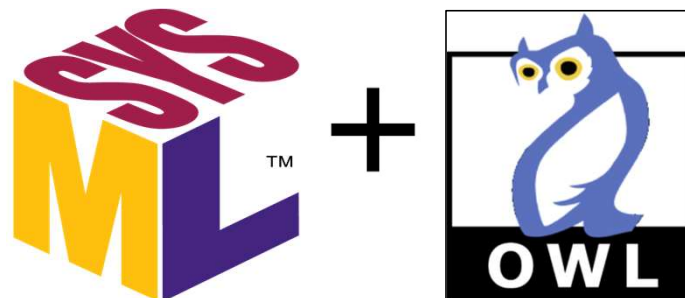
*“Make information across the entire value chain available on a secure and immutable platform”*



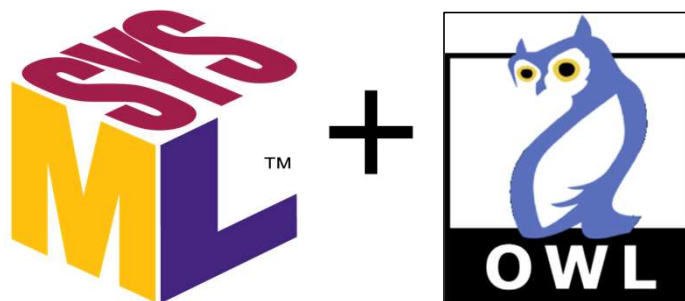
# Motivations

- **Industry 4.0** generates a vast amount of **unstructured** information
- It Introduces the **need** for a better **understanding** of:
  - Factory **operations**
  - Production **constraints**
  - **Capabilities** of industrial machinery

## How can we structure this information?

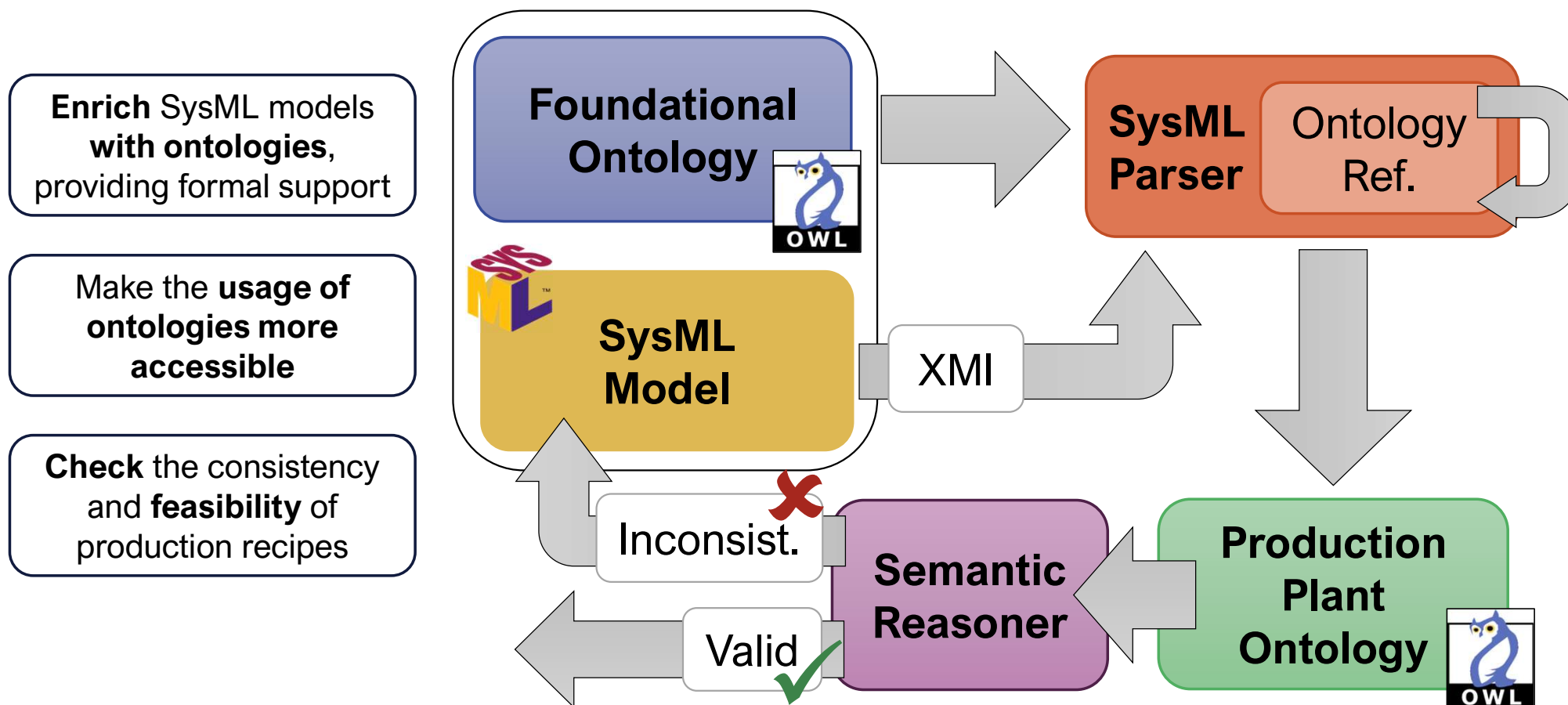


# Objectives

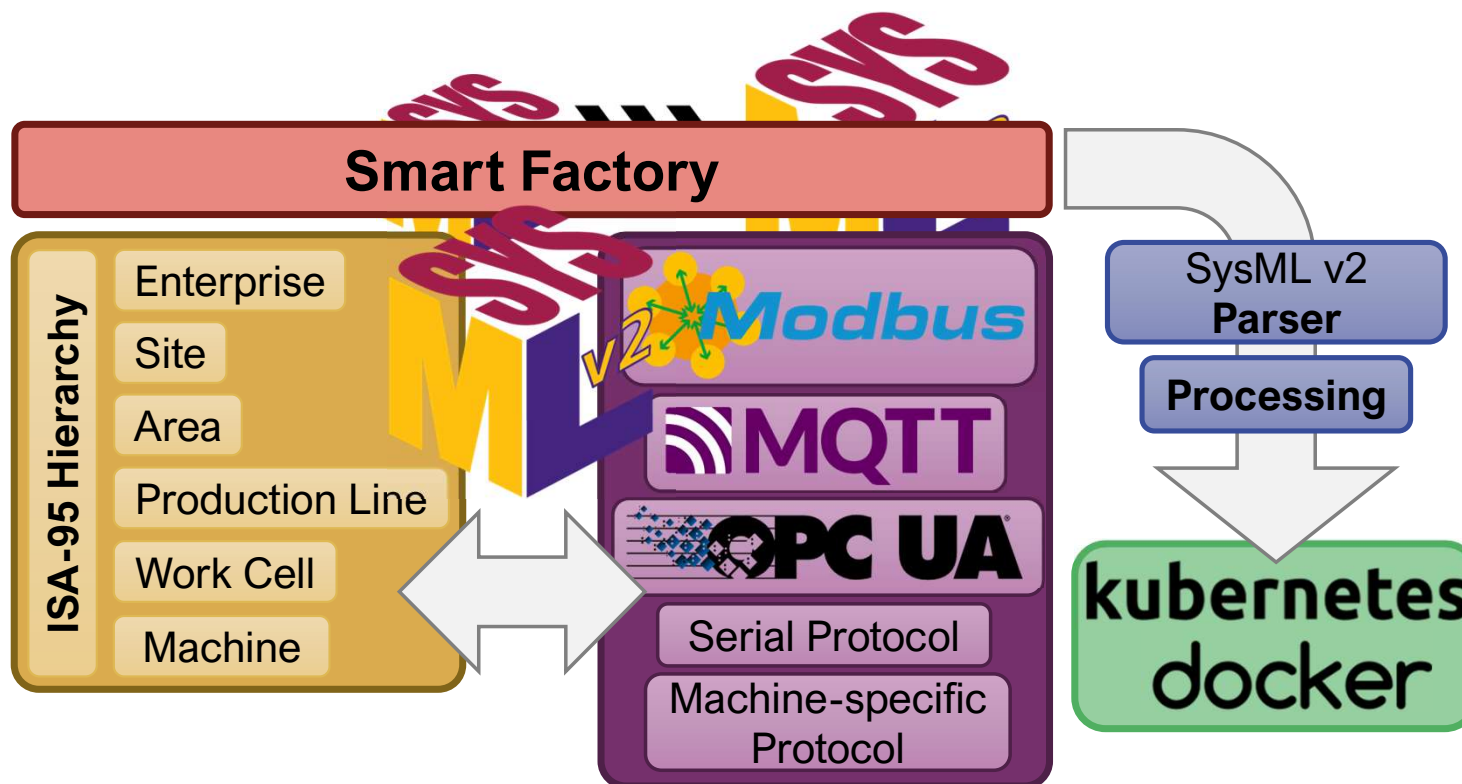


- **Enrich SysML models with ontologies reasoning**
  - A first step to assess the potential benefits of this methodology
- Utilizing ontologies to **provide formal support in plant modeling**
  - Make the usage of ontologies more accessible, regardless of expertise
- **Check the consistency and feasibility** of production recipes
  - Ensures that the **production recipes** are **coherent** and **executable** by the specified production plant

# Methodology Overview

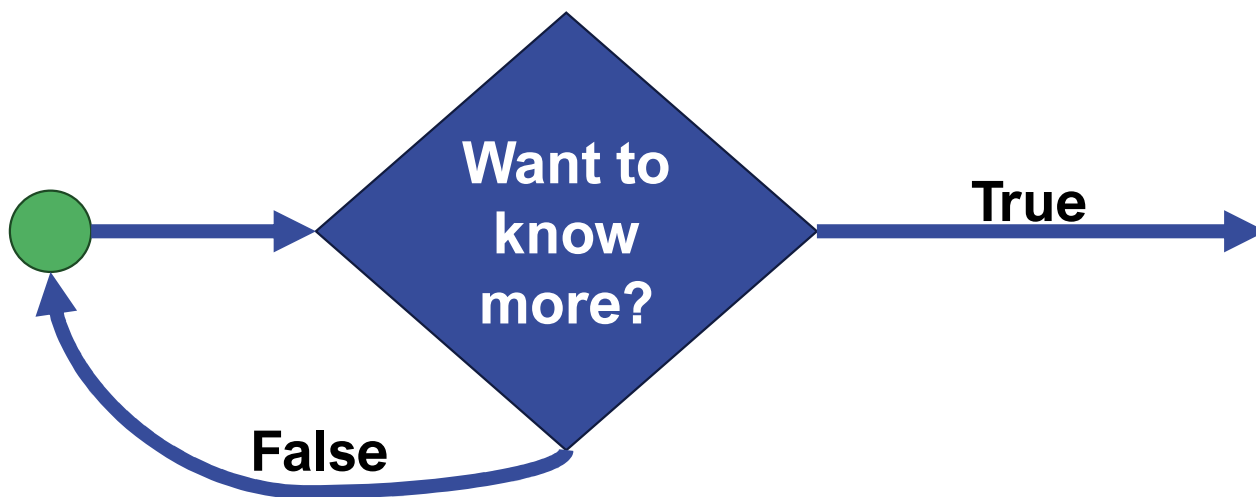


# SysML v2 Modeling



# Research Interests

- Model Based System Engineering
- Knowledge Representation: Ontologies
- Cyber-Physical Production Systems
- Industrial Internet of Things
- Block Chain & Smart Contracts



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Motivations	Background
<ul style="list-style-type: none"> <li>• Construction Industry evolving driven by Industry 4.0</li> <li>• Series of challenges:               <ul style="list-style-type: none"> <li>– Complexity and diverse operations in large-scale projects</li> <li>– Suboptimal profitability and operational inefficiencies</li> <li>– Reliance on traditional practices</li> <li>– Underutilization of modern technological innovations</li> </ul> </li> <li>• Ph.D. program co-funded by Build Trust startup:               <ul style="list-style-type: none"> <li>– Monitoring production with IIoT sensors</li> <li>– Real-time tracking of on-site activities</li> <li>– Material usage and carbon footprint</li> <li>– Permissioned blockchain</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Systems Modeling Language (SysML v2)               <ul style="list-style-type: none"> <li>– General-purpose modeling language: textual &amp; graphical</li> <li>– Allows to model different aspects</li> <li>– No longer based on UML</li> <li>– Precision, expressiveness, consistency, interoperability, usability</li> </ul> </li> <li>• Ontology: Formal, explicit, and machine-readable representation of shared knowledge within a domain</li> <li>• Semantic Reasoner               <ul style="list-style-type: none"> <li>– Deduce new facts from existing axioms within ontologies</li> <li>– Verify the consistency of the knowledge base</li> </ul> </li> </ul>
Overview	
Preliminary Results & Future Works	References
<ul style="list-style-type: none"> <li>• Enrich SysML models with ontologies reasoning               <ul style="list-style-type: none"> <li>– Utilizing ontologies to provide formal support in plant modeling</li> <li>– Check the consistency and feasibility of production recipes</li> <li>– Validated in the Industrial Computer Engineering (ICE) Laboratory</li> </ul> </li> <li>• Integration of new features introduced by SysML v2</li> <li>• Modeling of legal contracts               <ul style="list-style-type: none"> <li>– Monitor and verification of contract compliance</li> </ul> </li> <li>• Explore relationship between Blockchain and SysML               <ul style="list-style-type: none"> <li>– Automatic generation of smart contracts from models</li> </ul> </li> </ul>	<ol style="list-style-type: none"> <li>M. Libro, S. Garavelli, M. Lora, F. Furni, Integrating Modeling Languages with Ontologies in the Context of Industry 4.0, in: 2024 IEEE International Conference on Industrial Technology (ICIT), 2024, pp. 1-7.</li> <li>S. Speltini, S. Garavelli, M. Lora, F. Furni, Enabling Component Reuse in Model-based System Engineering of Cyber-Physical Production Systems, in: Proc. of IEEE International Conference on Emerging Technologies and Factory Automation (ETFA), 2021, pp. 1-8.</li> <li>S. Friedenthal, Future Directions for MBSE with SysML v2, in: Proceedings of the 11th International Conference on Model-Based Software and Systems Engineering - Volume 1: MODELSWARD_INTIC, Split/Dubrovnik, 2023, pp. 9-8.</li> <li>S. Friedenthal, A. Moore, R. Stieve, A Practical Guide to SysML, Third Edition: The Systems Modeling Language, 3rd ed., Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 2014.</li> </ol>
Take Home Message	
<p>Model-based framework, supporting formal verification using Ontologies reasoning, may enhance system reliability and automation in complex industrial processes.</p>	

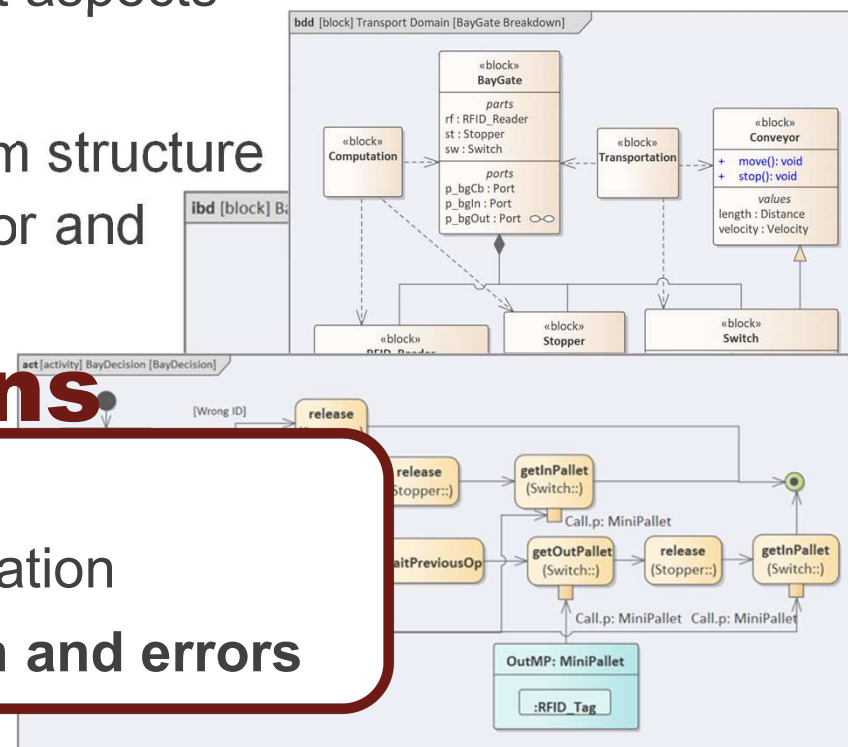


# SysML - System Modeling Language

- General-purpose **graphical** modeling language
  - Multiple types of diagrams to model different aspects
- We rely on two **types of diagrams**:
  - **Block Definition Diagrams** to model system structure
  - **Activity Diagrams** to model system behavior and production recipes

## Limitations

- Lacks **formal** semantics
- Poor support for tool automation
- **Prone to misinterpretation and errors**



# Ontology and Semantic Reasoner

- **Ontology:** Formal, explicit, and machine-readable representation of shared knowledge within a domain
- **Semantic Reasoner** perform automated reasoning to:
  - **Deduce new facts** from existing axioms within ontologies
  - Enable advanced **querying** to retrieve information
  - **Verify the consistency** of the knowledge base



## Limitations

- Ontology specification is **time-consuming**
- **Formal methods expertise** needed
- **Complex and error-prone** modeling

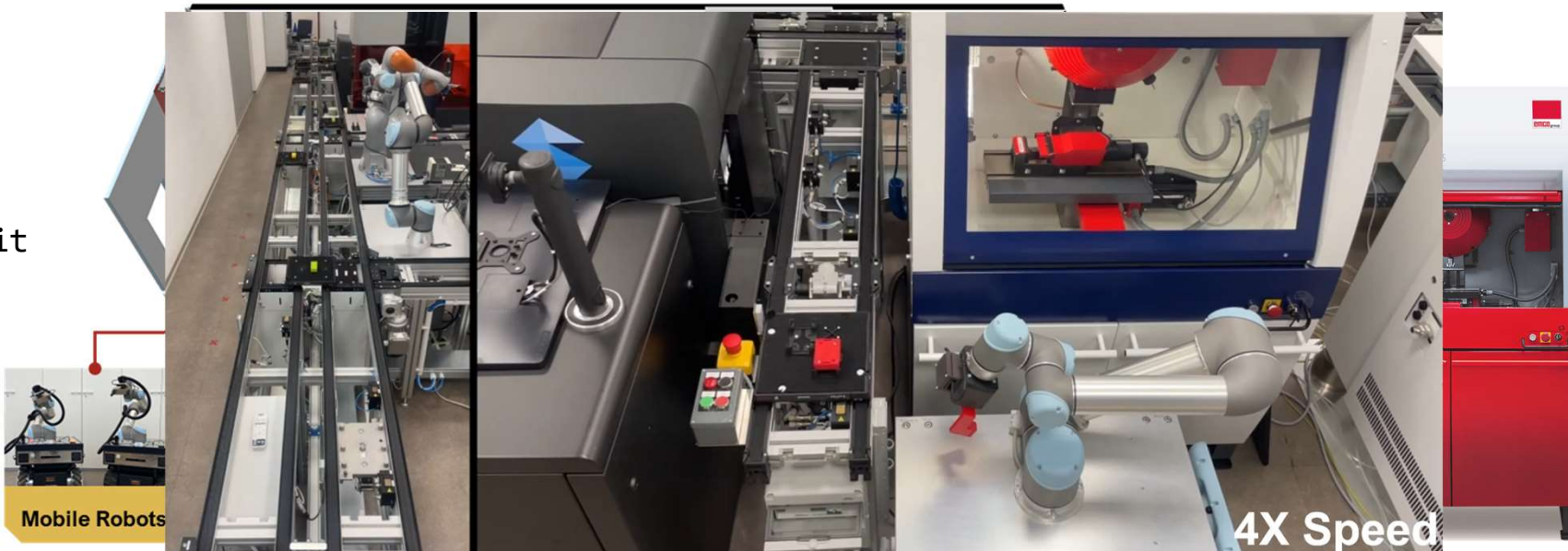
ontologies

# ICELab – Case study



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**ICE** Lab  
INDUSTRIAL  
COMPUTER  
ENGINEERING



- **Methodology effectiveness** has been **verified** with two different experiments:



# Foundational Ontology

- Base knowledge required to **define key elements** within production plants in general:
  - Concepts, terminology, properties, and relations among concepts
- Partially based on the **DIN8580 Standard**

