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

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ISD
Cyber-Physical & IoT Systems Design

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Build Trust Vision

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

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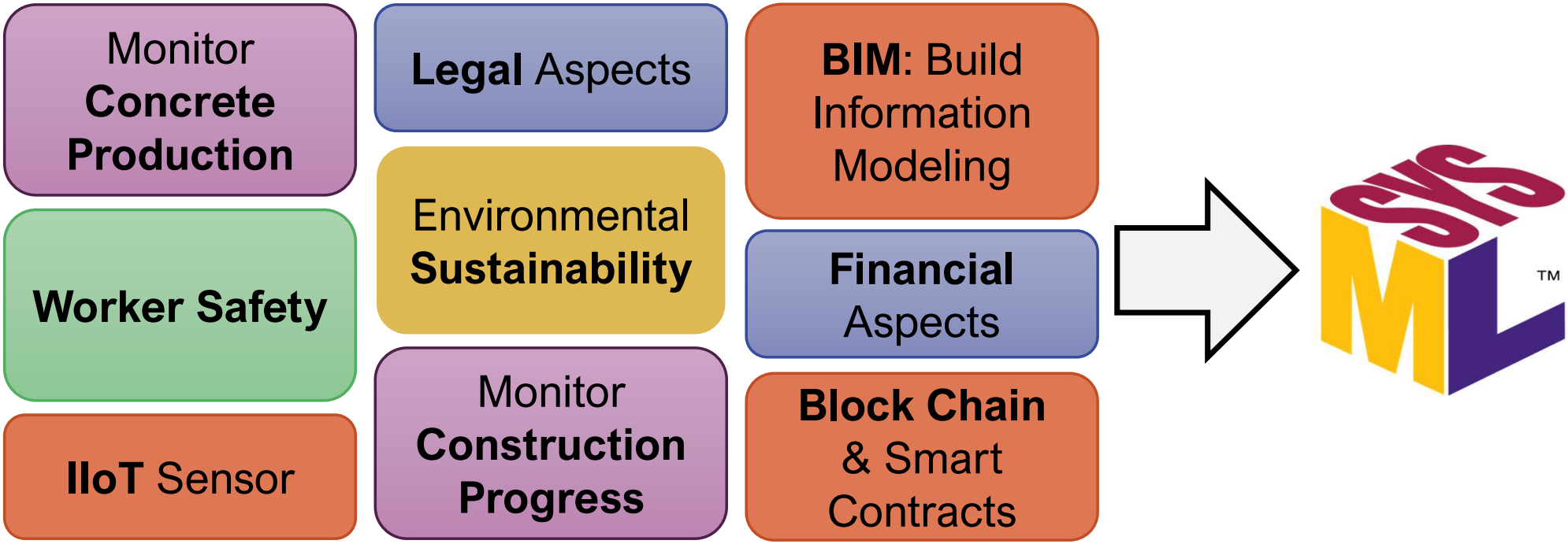
- Inherent **complexity** and **diverse operations** of large-scale construction projects
- Construction projects are often:
  - Delayed, overbudget, inefficient
  - Lack of transparency
- Use of **outdated processes** & **technologies**

Build Trust Vision (cont'd)

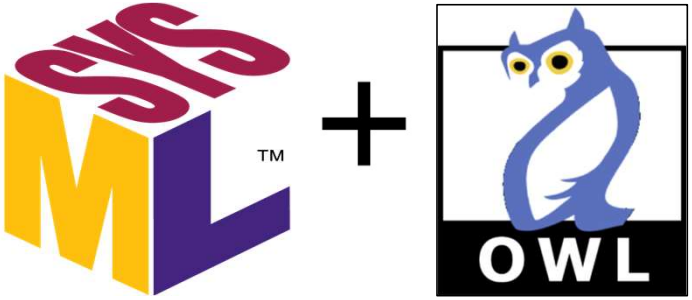
"Make information across the entire value chain available on a secure and immutable platform"



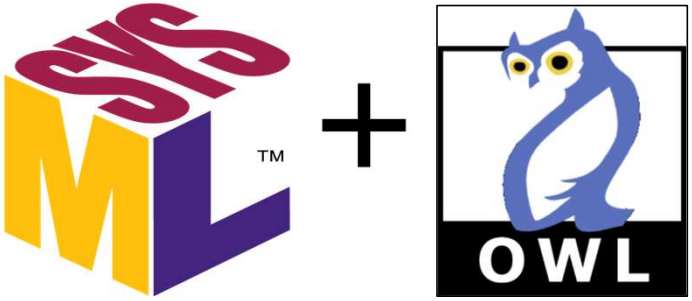
Motivations

- **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

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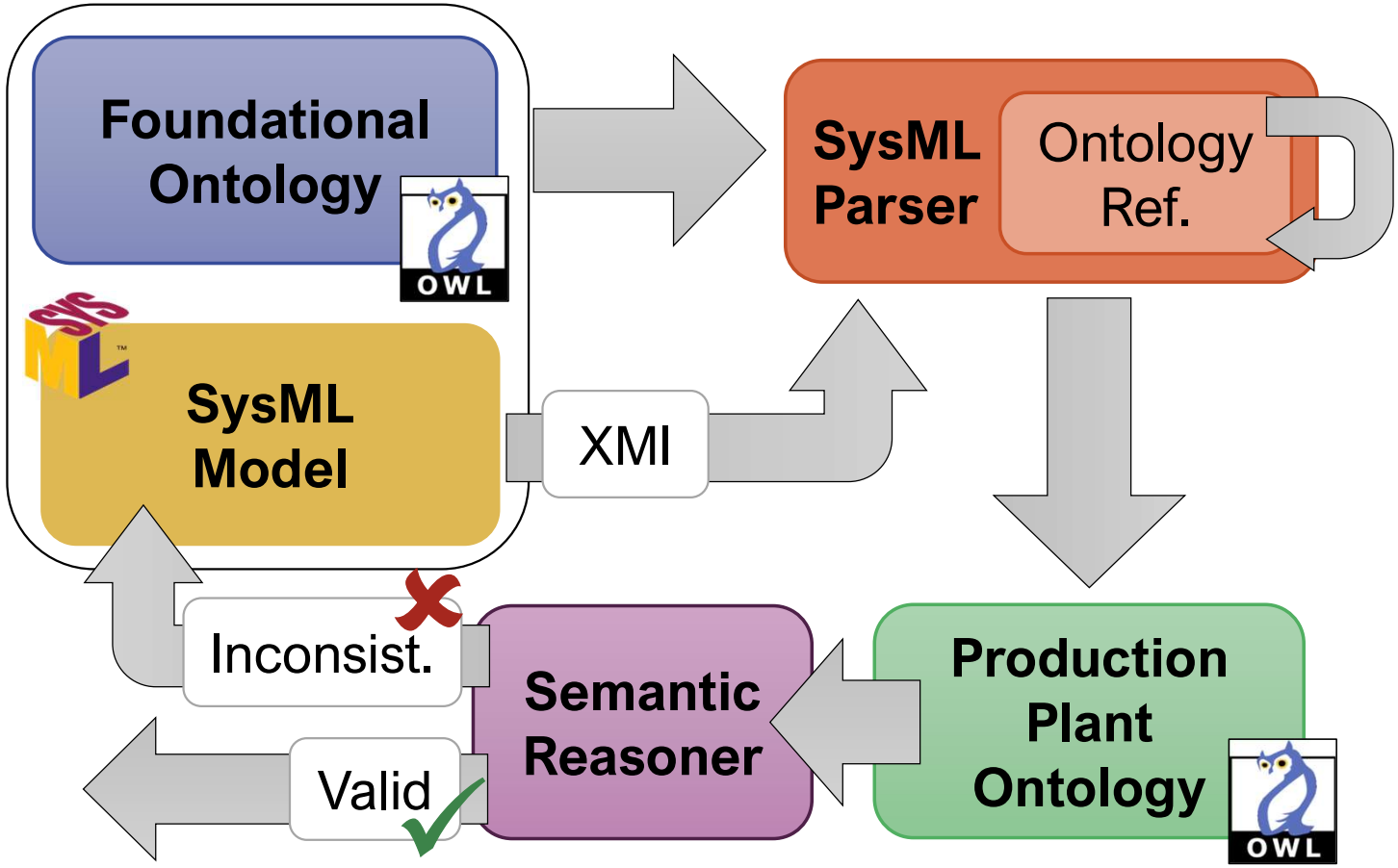
Methodology Overview

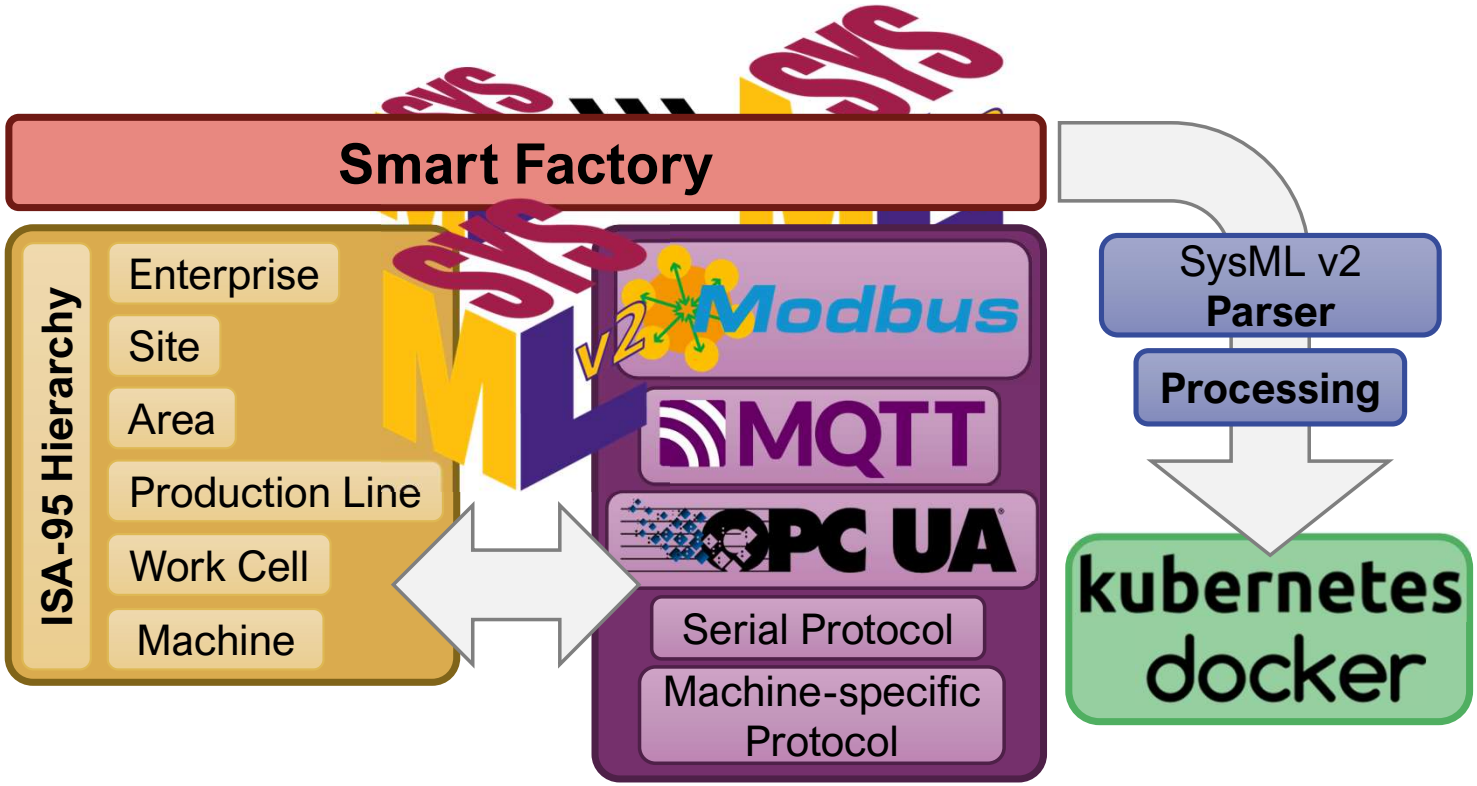
Enrich SysML models **with ontologies**, providing formal support

Make the **usage of ontologies more accessible**

Check the consistency and **feasibility** of production recipes



SysML v2 Modeling



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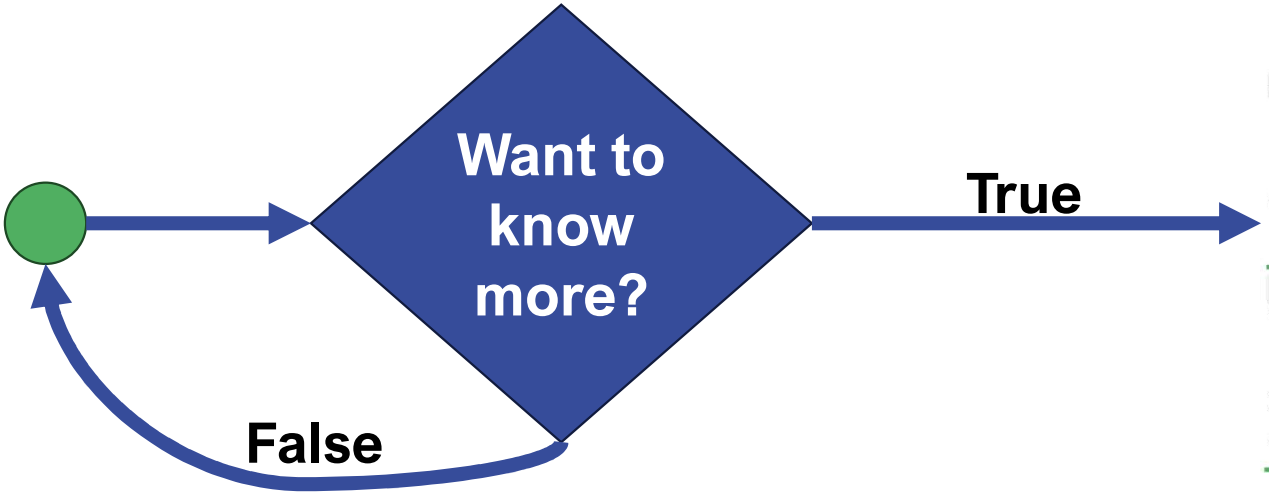
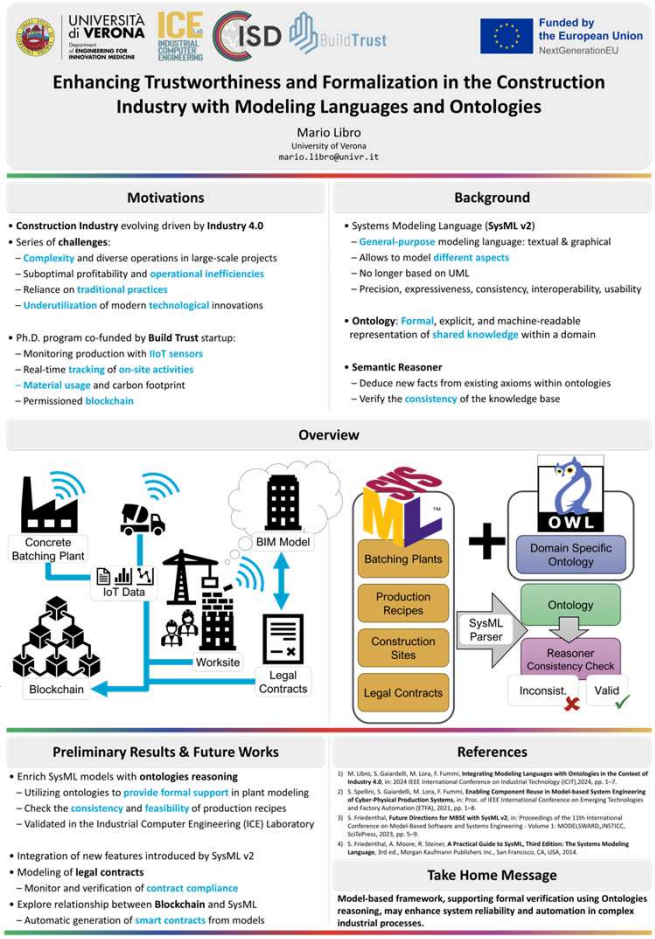
Research Interests

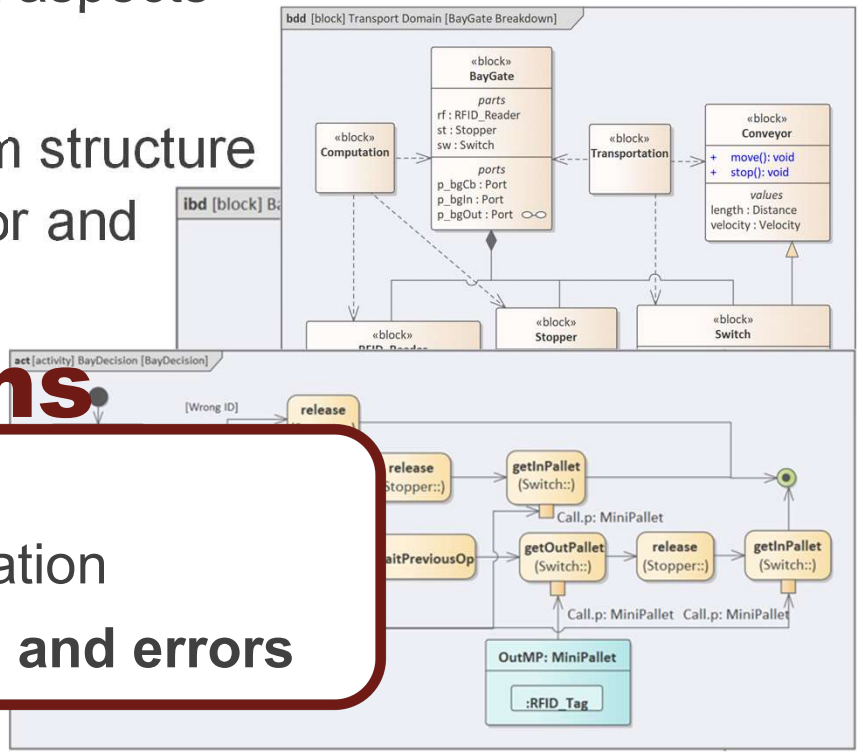
- Model Based System Engineering
- Knowledge Representation: Ontologies
- Cyber-Physical Production Systems
- Industrial Internet of Things
- Block Chain & Smart Contracts





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

tologies

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ICELab – Case study

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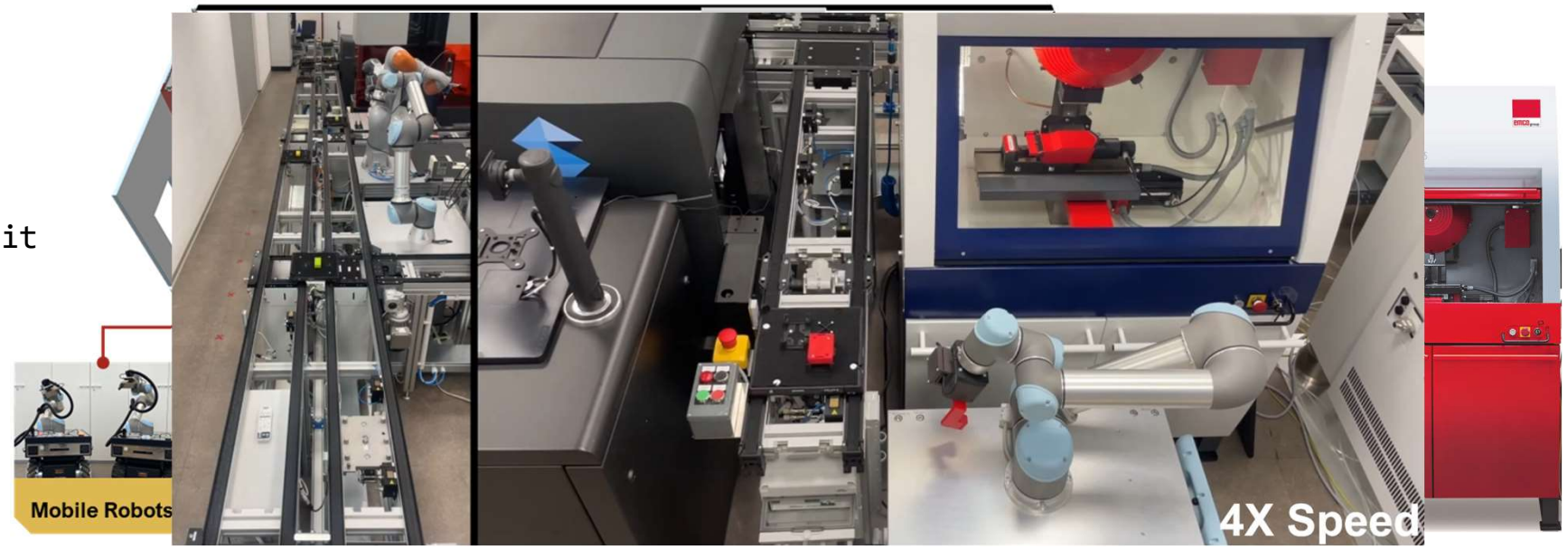
ICE Lab
INDUSTRIAL COMPUTER ENGINEERING



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

Consistent SysML Model

Inconsistent SysML Model ← Constraint Violation

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**