Identifying Reference Architecture Types for Stakeholder Groups in Industry 4.0

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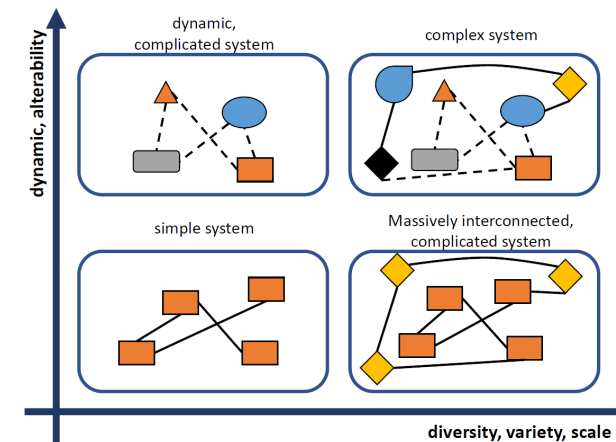*Josef Ressel Center for Dependable System-of-Systems Engineering, Austria*
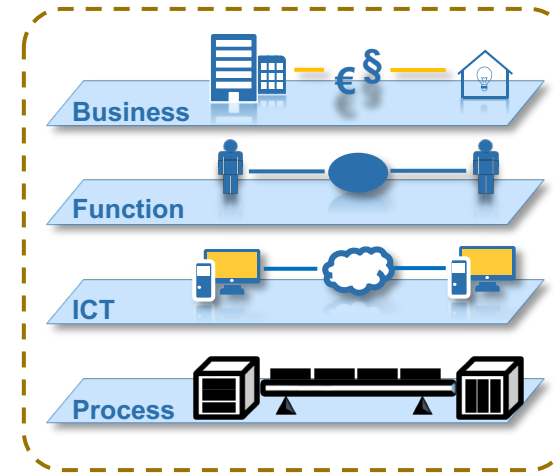
Industry 4.0: Increasing Complexity

- Increasing complexity of production systems

- Production of individualized products (lot size 1)

- Increased complexity hindering manageability

➡️ **Model-based Systems Engineering**

Managing Complexity with MBSE by...

…visualizing interconnections and data flow between Industry 4.0 components

… the system model beeing the single-point-of-truth

…providing various stakeholder perspectives

…establishing a shared understanding about the system

So why is MBSE not a common practice in Industry companies?
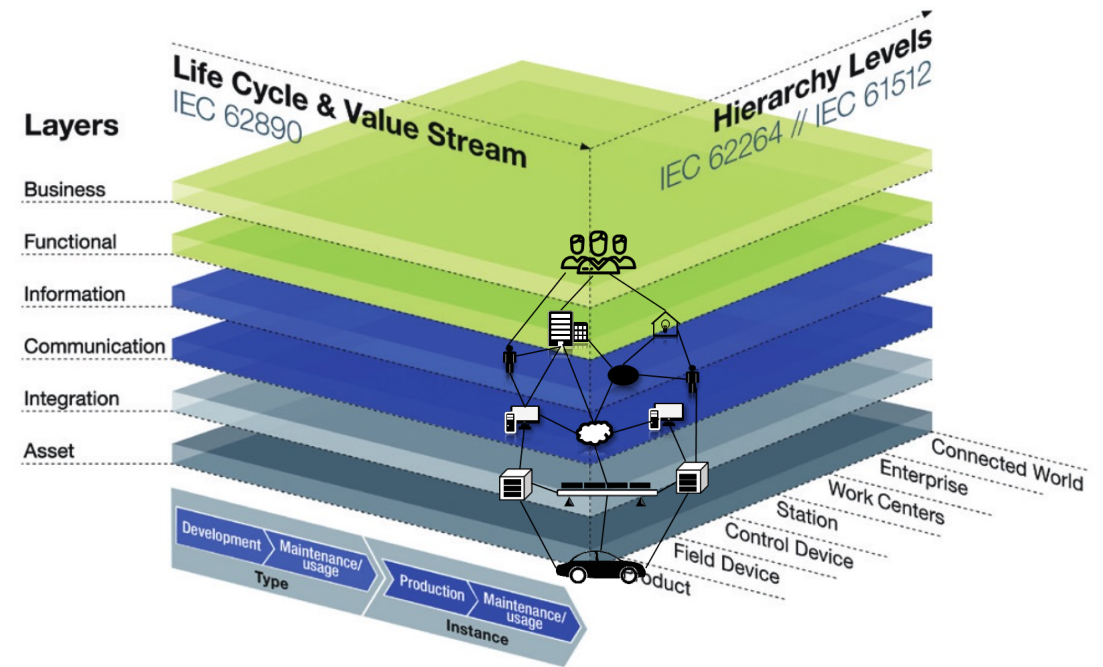
Struggles with MBSE

- Good MBSE needs practice and experience
- Developing a holistic system architecture takes time
- No direct benefit when first establishing MBSE in a company
- Few guidelines and best practice models for MBSE in Industry 4.0

➡ **Reference Architecture Model Industry 4.0**

Reference Architecture Model Industry 4.0

- Abstract Framework for industrial systems engineering

- Establishes shared understanding and different stakeholder perspectives

- Illustrates interconnection in industrial systems

However: Standardized since 2016 BUT limited adoption in industry

Struggles with RAMI 4.0

- High level of abstraction
- Difficult to apply for many stakeholders due to the abstract nature
- Limited number of industrial applications to use as guideline

So how can we help industry companies to get started with MBSE?

Reference Architecture Models

- Collection of knowledge and best practices for developing system architectures

- Serve as blueprints for new systems and promote standardization

- Enhance the architecture development process

Categorization

Low-level	High-level
Non-domain-specific	Domain-specific
Single-organization	Multiple-organization

Goal: Developing Stakeholder-specific Reference Architectures

- Developing a more detailed Reference Architecture which can be used by the targeted stakeholders as blueprint and modelling guideline

- Developing a Reference Architecture using RAMI 4.0 as guideline to ensure standardization and utilize this already established framework

Approach: Developing Stakeholder-specific Reference Architectures

1) Perform Stakeholder Analysis
2) Evaluate interests and tasks of Stakeholders in RAMI 4.0 context
3) Cluster similar Stakeholder types
4) Evaluate different types of Reference Architectures for the identified Stakeholder clusters
5) Proof-of-concept Reference Architecture development for one Stakeholder group

Common Stakeholder types

Stakeholder types by Antunes, Barateiro, Becker, Borbinha & Vieira, 2011:

- **Producer/Depositor:** The entity responsible for the object to be produced;
- **Consumer**: The user consuming or accessing the produced object;
- **Executive Management:** Responsible for strategic decision making and monitoring the repositories;
- **Repository Manager**: Defines strategies and goals in the respective repository;
- **Technology Manager:** Responsible for all technological concerns to achieve the respective repository goals;
- **Operational Manager:** Ensures policy-compliant operation of the repository;
- **Regulator**: External entity responsible for monitoring the compliance with rules and legislation;
- **Auditor**: Responsible for monitoring the compliance with standards and regulations;
- **Repository Operator**: Business worker mainly concerned with upkeeping the daily business;
- **Technology Operator:** Responsible for the operation and maintenance of technical components;
- **System Architect:** Responsible for the design of the system architecture;
- **Solution Provider:** Entity providing components or services required in the system;
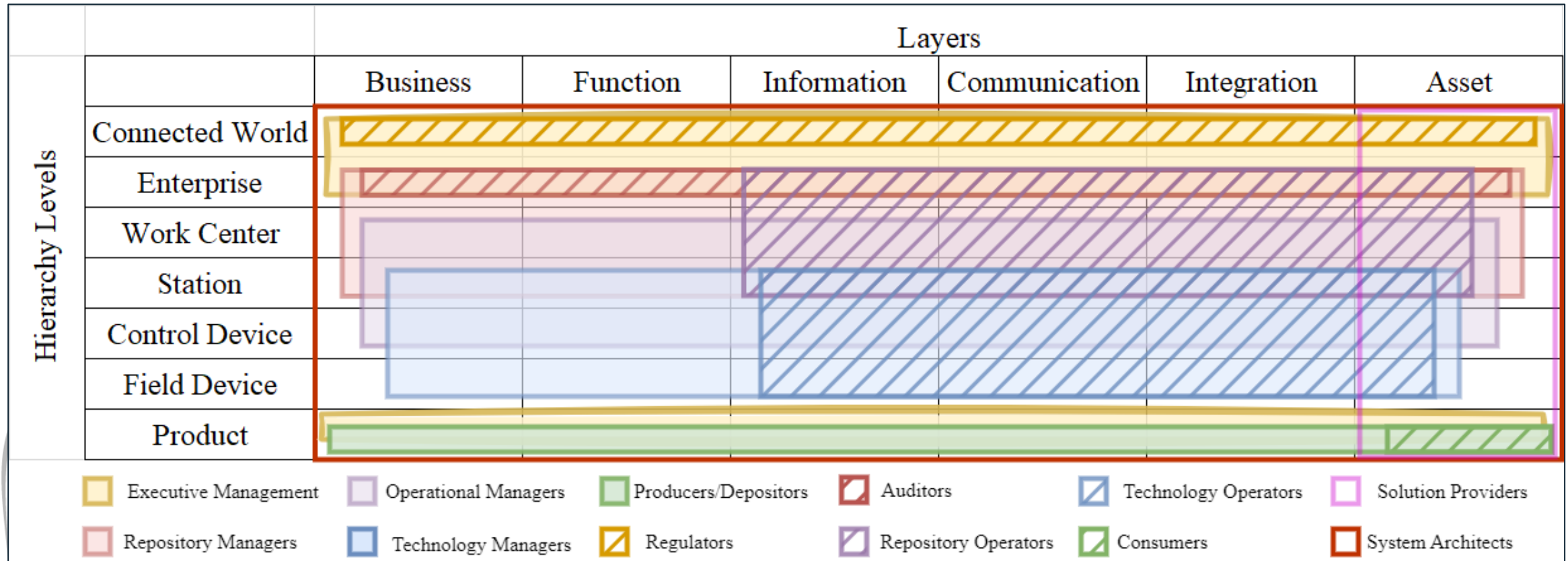
Stakeholder concerns

- **Producer/Depositor:**
  As a producer/depositor, I want to manage and evaluate the design and production of a product, so that the final production plan of the product can be handed over to production

- **Consumer**:
  As a consumer, I want to use the produced product, so that it fulfills my needs.

- **Executive Management:**
  As an executive manager, I want to implement business models, so that we gain profit/margin scheduled as planned with no cost overrun or reduction.

- **Repository Manager**:
  As a repository manager, I want to define strategies, set goals and objectives for the repository, so that the repository meets the general company goals and sustainably achieves its intended purpose.

- **Technology Manager:**
  As a technology manager, I want to manage the technological means within a repository, so that the system continuity is ensured

- **Operational Manager:**
  As an operational manager, I want to manage an operational unit within a repository, so that the requirements of the repository are met and the single operations/functions are coordinated.
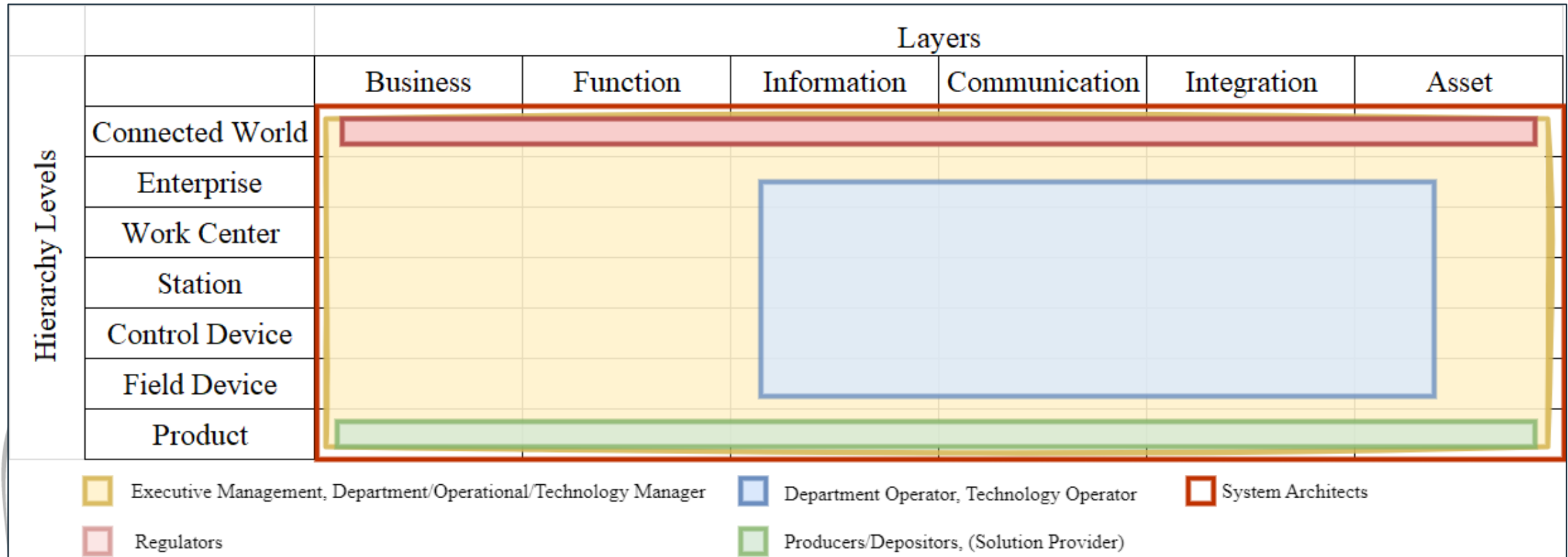
Stakeholder concerns

- **Regulator**:
  As a regulator, I want to ensure compliance with regulations, technical standards, and laws such as environment, health and safety (EHS) regulations.

- **Auditor**:
  As an auditor, I want to evaluate or audit conformance with standards and regulations, so that the company certifies these standards and regulations throughout each life cycle.

- **Repository Operator**:
  As a repository operator, I want to ensure the correct execution of processes within the respective repository, so that the business and repository objectives can be fulfilled.

- **Technology Operator:**
  As a technology operator, I want to operate and maintain the components of the technical infrastructure, so that the system continuity is ensured.

- **System Architect:**
  As a system architect, I want to design and update the architecture of the system, so that an overview of the entire system is given and the interfaces between system components and participants are defined.

- **Solution Provider:**
  As a solution provider, I want to receive the requirements for the components to be implemented in a comprehensible way, so that I can offer and implement the respective solution.

Stakeholder interests and tasks in RAMI 4.0

Stakeholder groups in RAMI 4.0

	Layers					
Hierarchy Levels	Business	Function	Information	Communication	Integration	Asset
Connected World						
Enterprise						
Work Center						
Station						
Control Device						
Field Device						
Product						

Executive Management, Department/Operational/Technology Manager Department Operator, Technology Operator System Architects

Regulators Producers/Depositors, (Solution Provider)

Types of reference architectures

Management
- Reuses established company concepts;
- Baseline for deploying new factories or products

Producer / Depositor
- options for deploying different products or solutions
- 150% architecture for all possible feature combinations
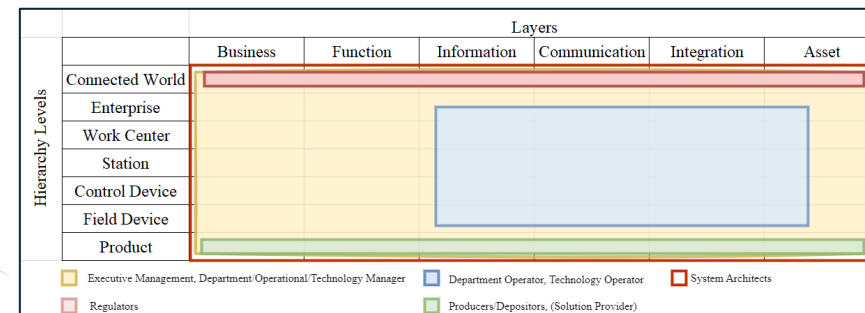
Operator
- Includes machines and manufacturing units for various production processes
- Decision-aid for choosing resources for production requirements

System Architect
- Typical processes requirements, and plants
- concepts for a particular domain

Regulators
- Collection of all standards and regulations in a domain
- Prerequisite for system architects

		Business	Function	Information	Communication	Integration	Asset
				Layers			
Hierarchy Levels	Connected World						
	Enterprise						
	Work Center						
	Station						
	Control Device						
	Field Device						
	Product						

Executive Management, Department/Operational/Technology Manager — Department Operator, Technology Operator — System Architects

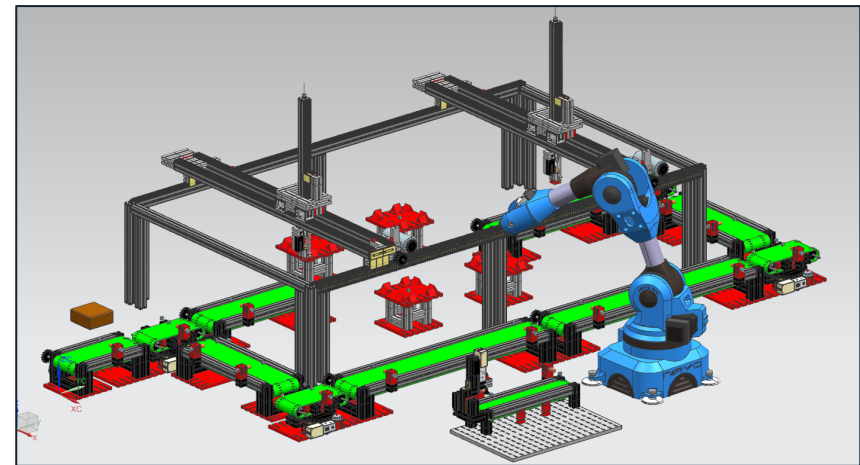Regulators — Producers/Depositors, (Solution Provider)

Proof-of-concept Application for Management Stakeholder group

- RAMI 4.0 as basis
- Case study: Siemens Fischertechnik Plastic housing factory
- AS-IS Architecture Model used as basis for developing a stakeholder-specific reference architecture
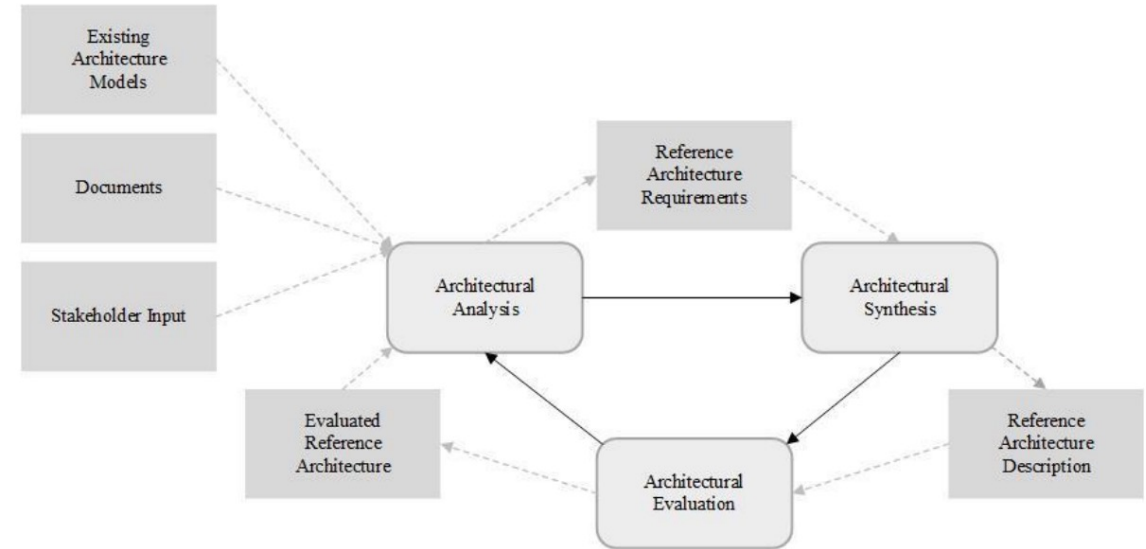
Management
- Reuses established company concepts;
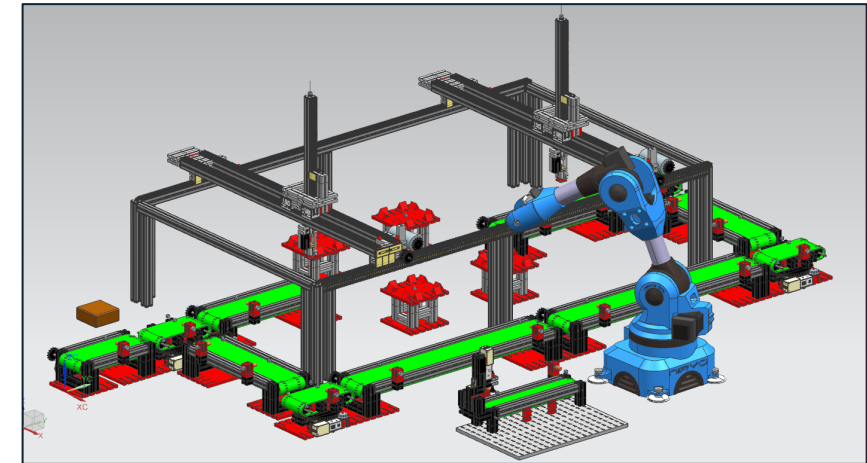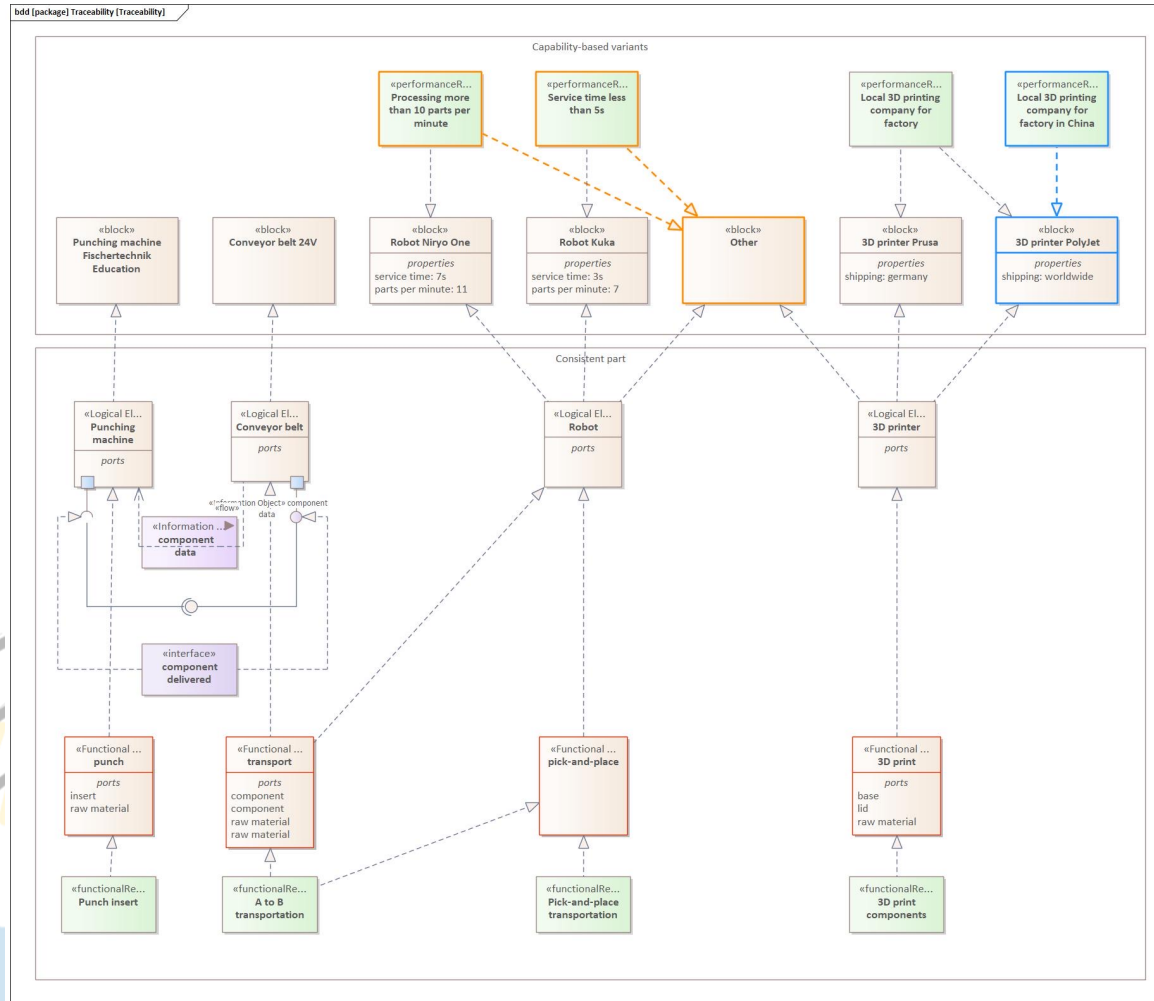- Baseline for deploying new factories or products

Reference Architecture Development Process

- Evaluate existing Architecture Models, Documents and any other form of input
- Create work-in-progress Reference Architecture
- Evaluate Reference Architecture
- Reiterate!

ProSa-RA

Stakeholder-specific Reference Architecture

Conclusion

- RAMI 4.0 alone is too abstract and high level for many industrial applications

- Stakeholder-specific reference architectures are useful for providing guidelines and common domain concepts

- Developing more specific reference architectures based on RAMI 4.0 increases standardization

Thank you for your attention! Questions?