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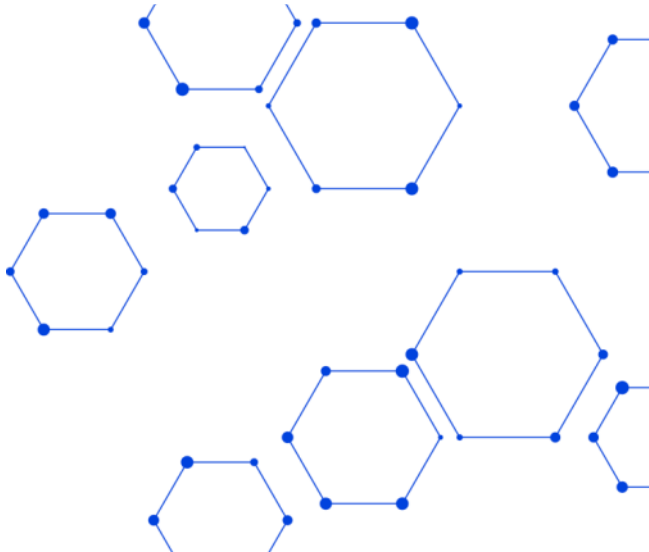
Future Control System Architecture Enabling Industrie 4.0 / Smart Manufacturing

Service-oriented (Machine) Control Architecture in the Context of Smart Manufacturing

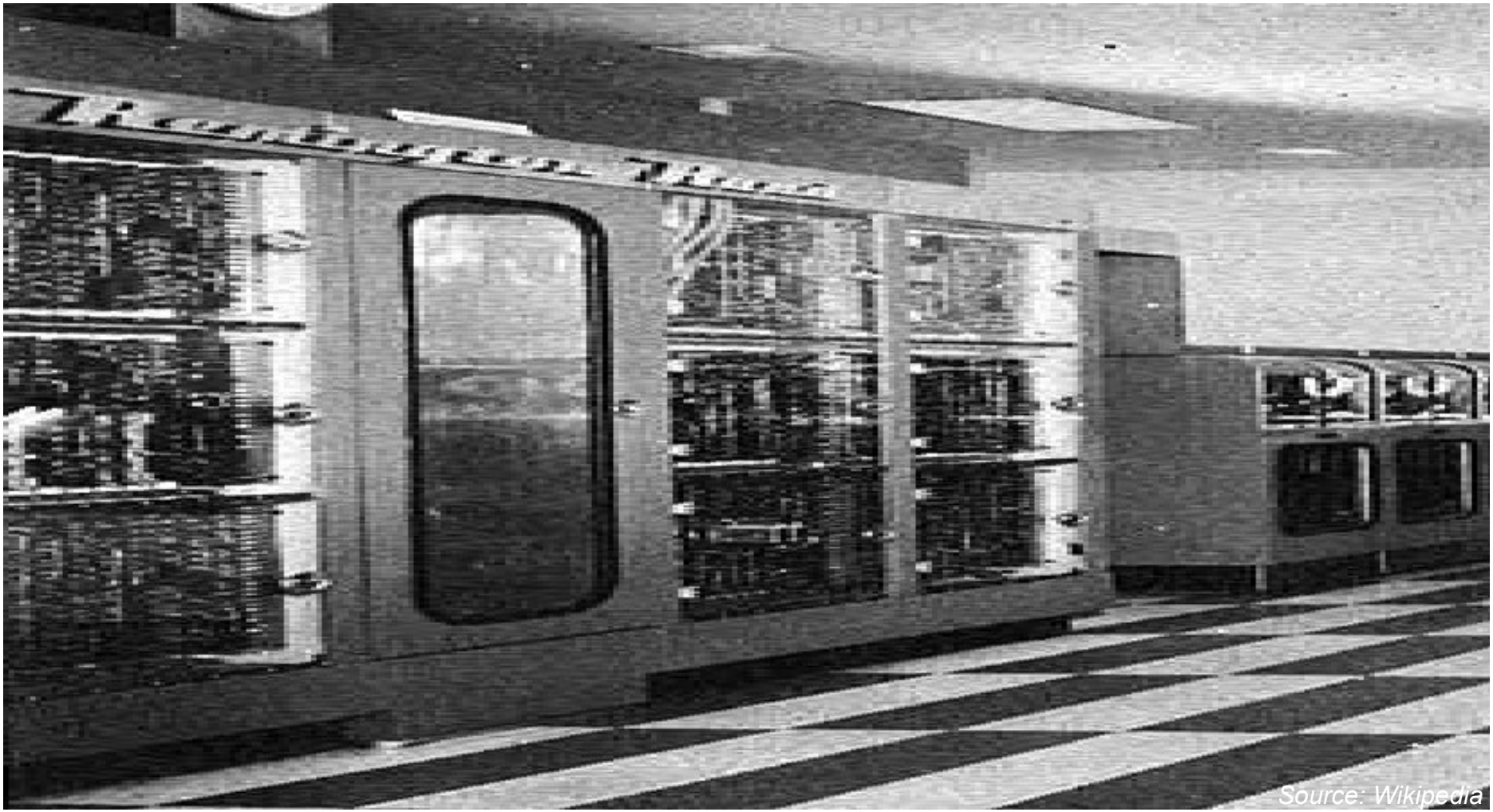
Dr. Alois Zoitl

fortiss GmbH
An-Institut Technische Universität München



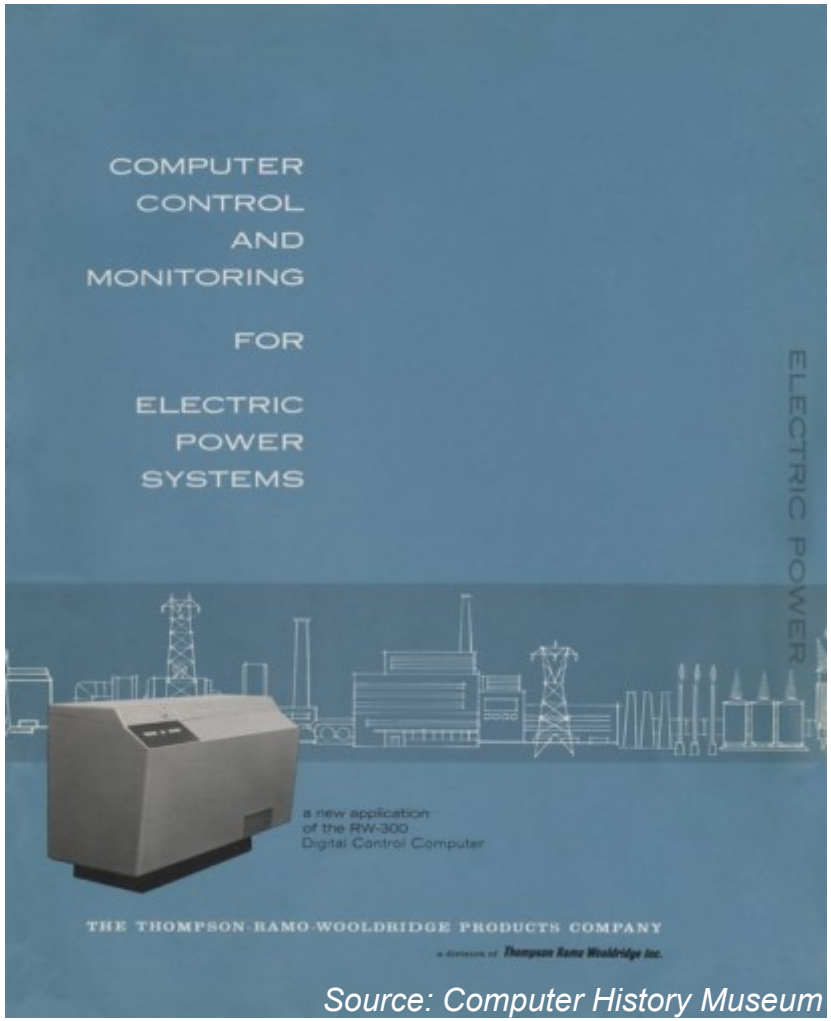
How long did it take untill Electricity significantly changed production?

1951: UNIVAC I, First Commercial Computer



1959: RW-300

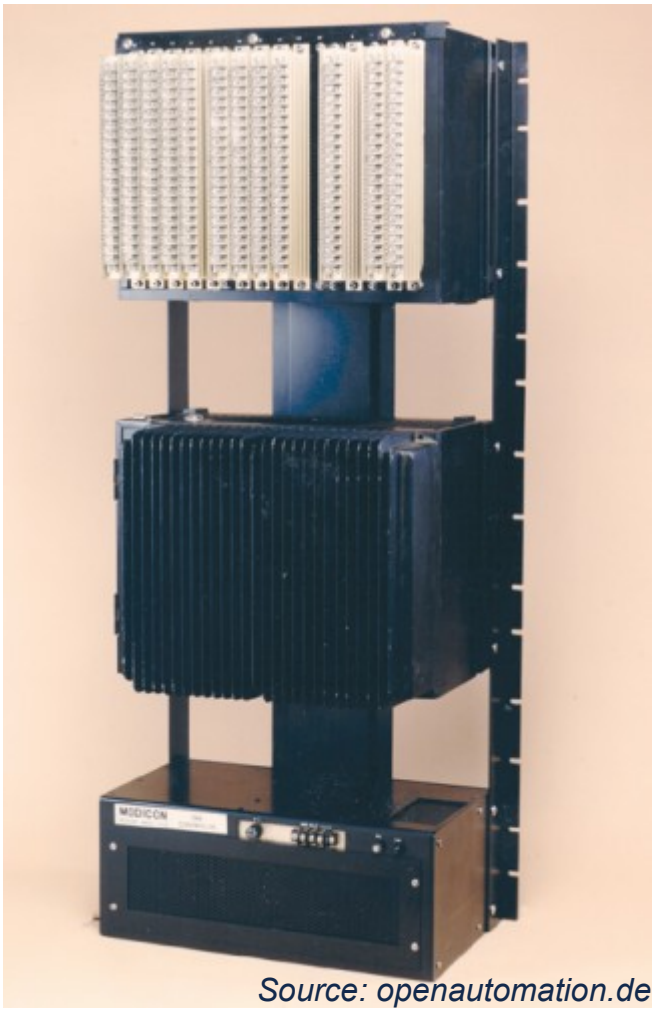
Process Control System



Source: Computer History Museum

1968: Modicon 084

First PLC



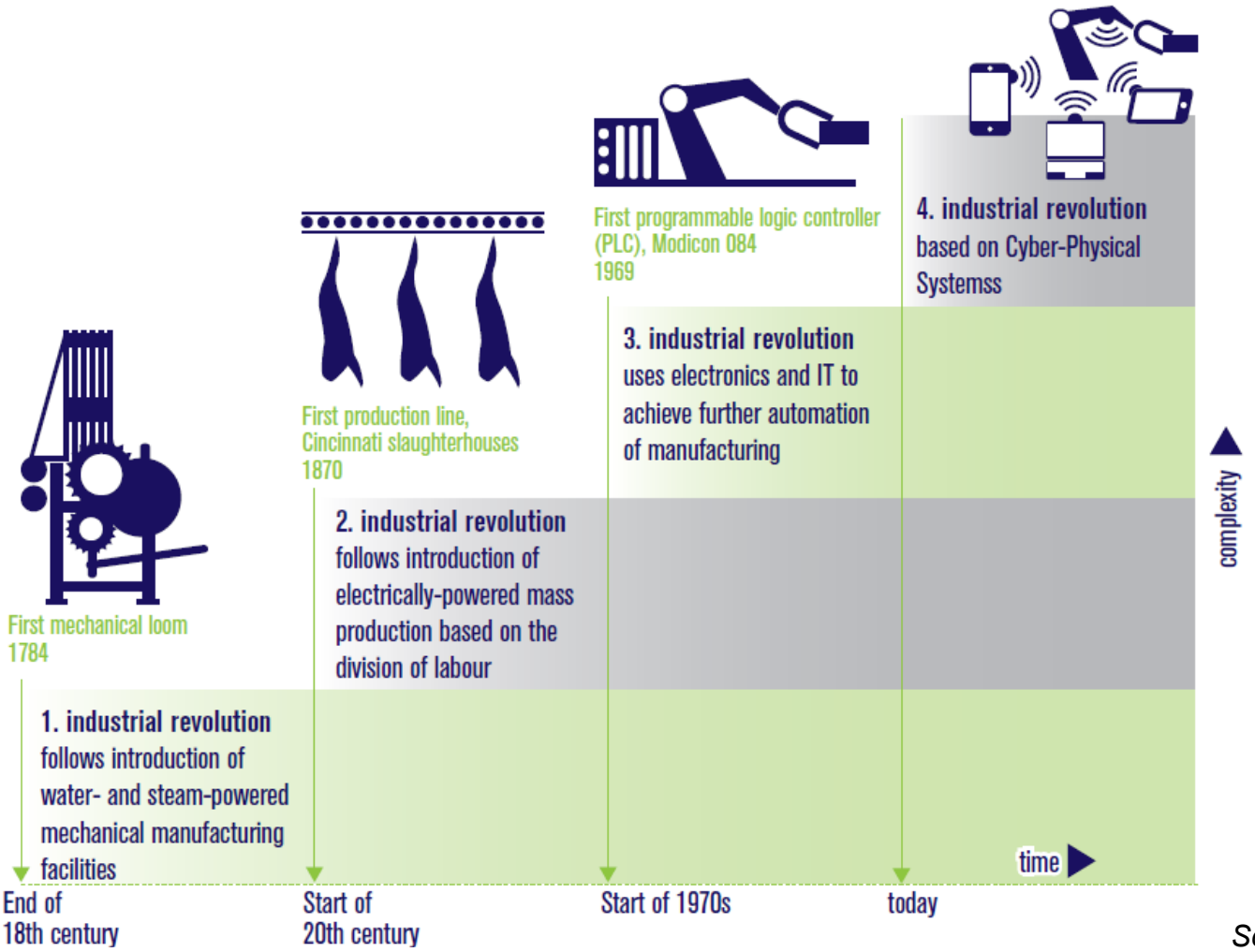
Source: openautomation.de

New Technologies and Architectures

- IoT:
  Internet of Things
- CPS:
  Cyber Physical Systems
- ...

Source: AgendaCPS

New Paradigms: Industrie 4.0



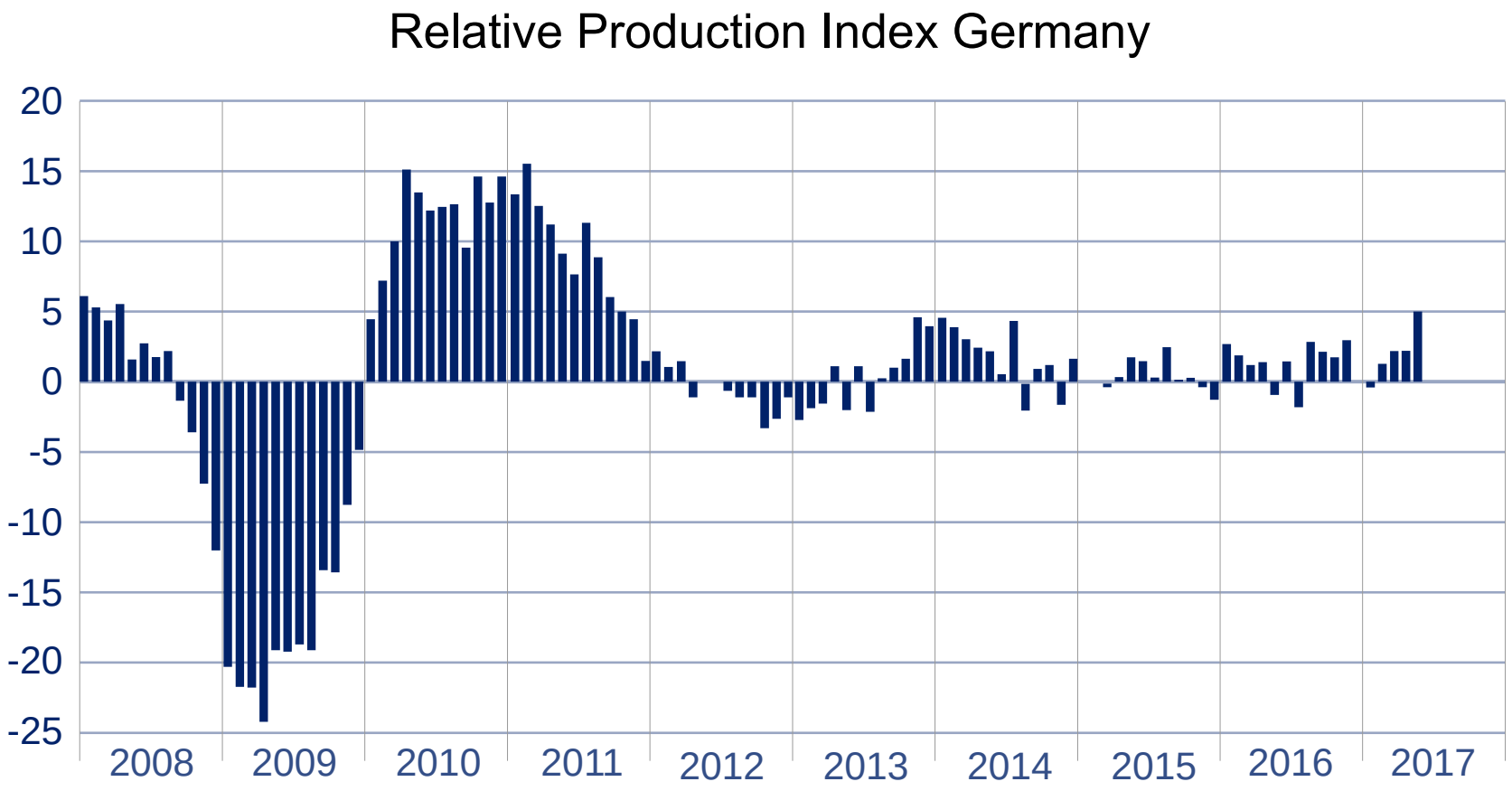
Source: DFKI

And now?

"I keep six honest serving-men
(They taught me all I knew);
Their names are What and Why and When
And How and Where and Who."

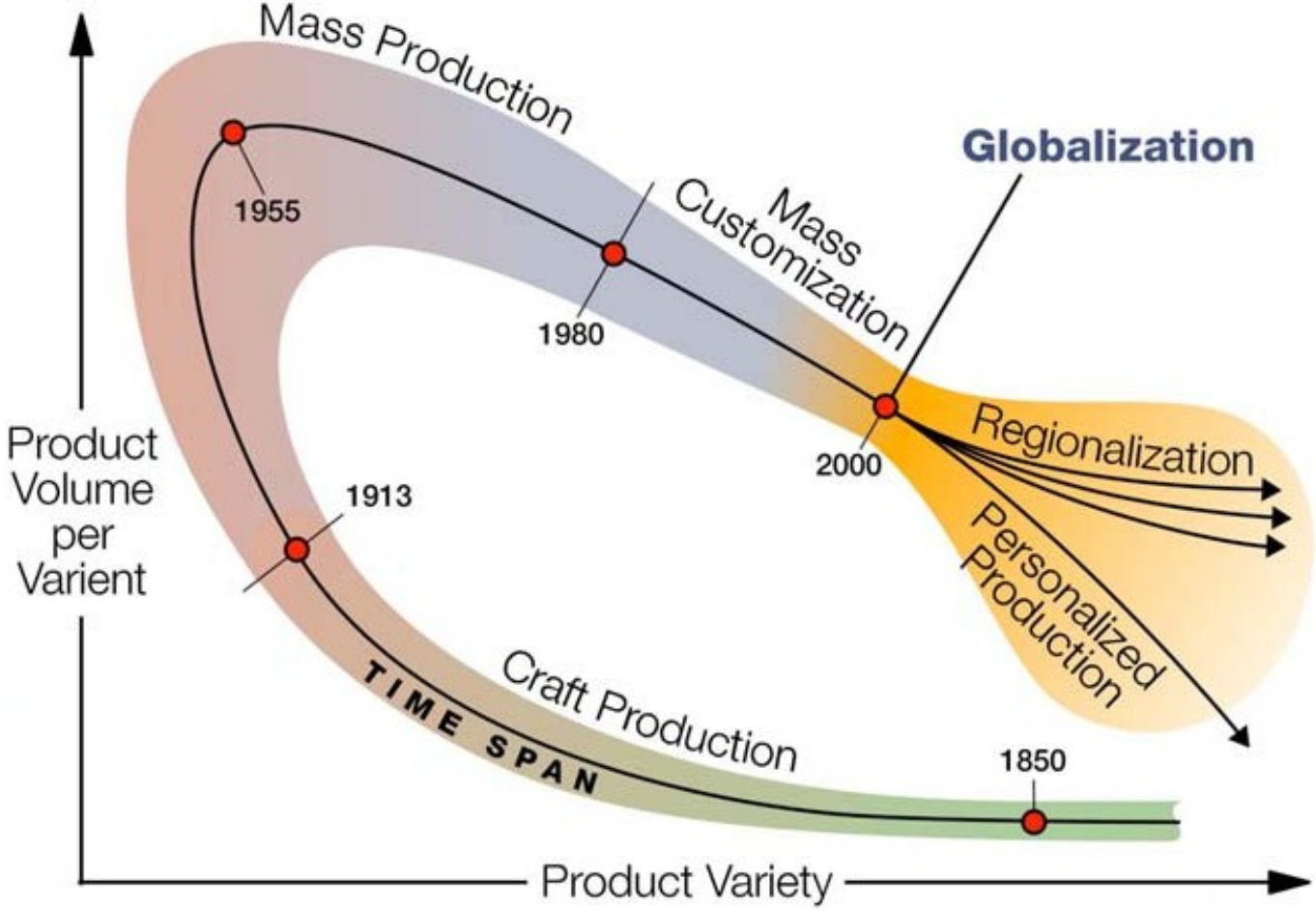
Rudyard Kipling

Production Challenge: Highly Volatile Markets



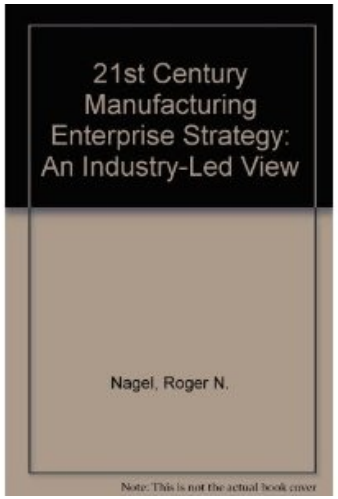
Source: German Federal Statistical Office, ifo Institute

Production Challenge: High Product Variety



Source: Yoram Koren, The Global Manufacturing Revolution, 2010

Potential Approaches



Source: Amazon

Agile Manufacturing Systems

- Developed 1991 by Iacocca Institute
- Vision:
  - Production to Order
  - Lot/Batch size > 1 Unit
- Main Theme: Dynamic Reconfiguration
  - Physical Reconfiguration
  - Logical Reconfiguration
  - Not just Parametrization

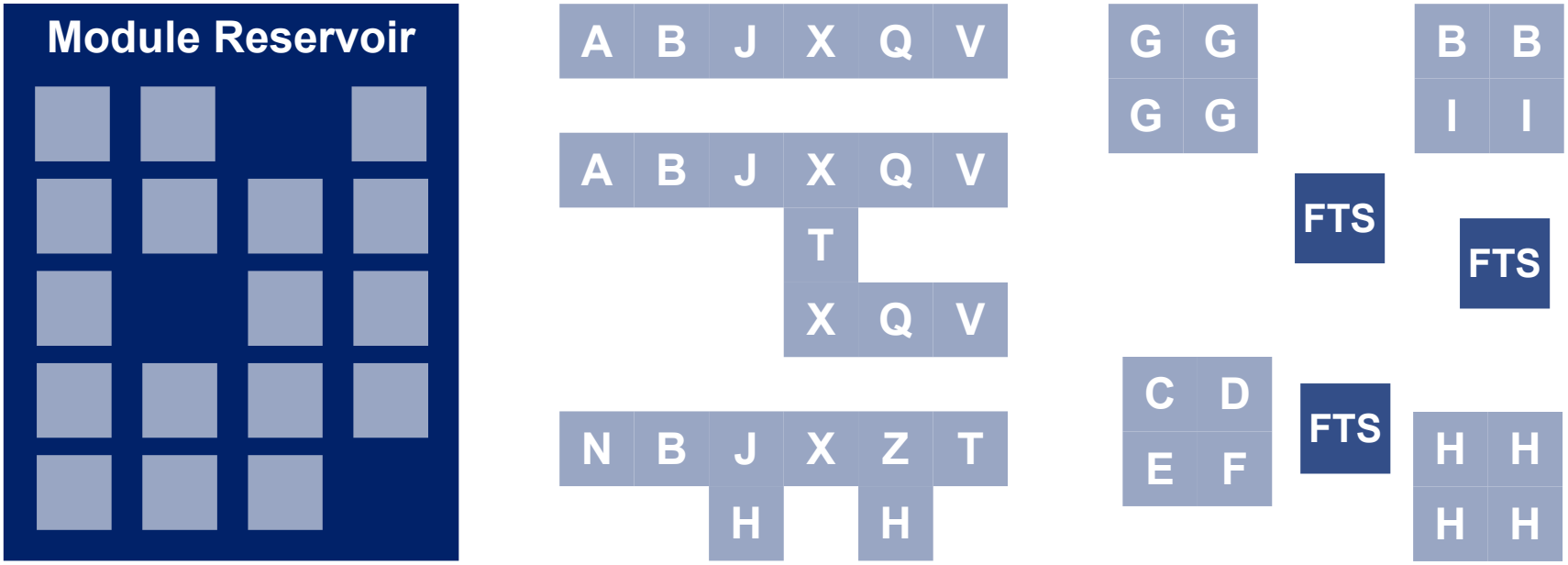
Source: HMS Project

Self-organizing Production: Holonic Manufacturing Systems

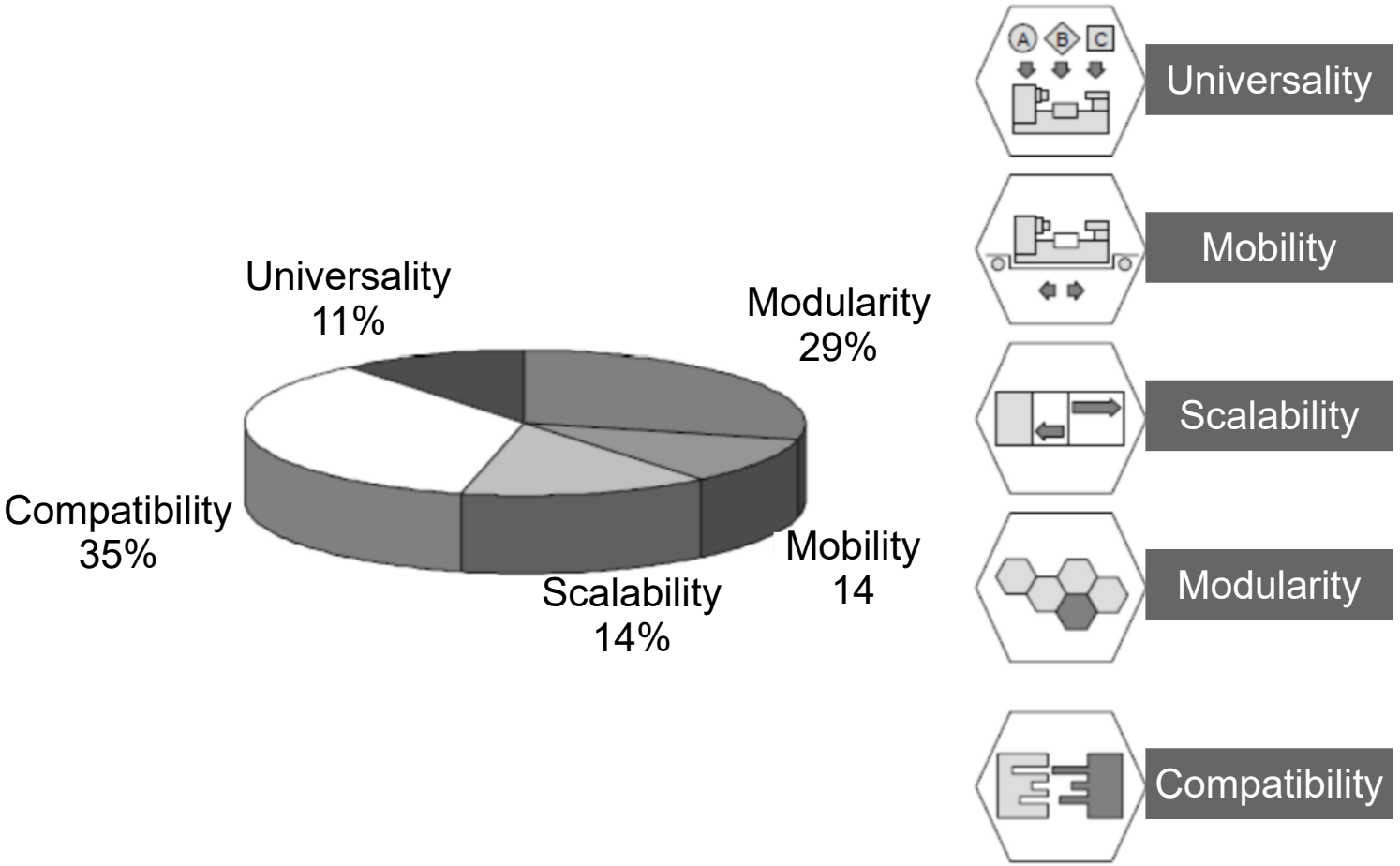
- Holonic → Cooperative distributed problem solving
- Distributed units (holons) with autonomous behavior to solve global problem
- Holons with a priori cooperation functionality

Goal: (Re-)Configuration on Process Module Level

- Break-up production cells in standardized production process modules (e.g., assembling, gripping, positioning, transport)
- Flexible combination and configuration of modules



Enabling Factors for Mutability



[Source: Nyhuis, P. Wandlungsfähige Produktionssysteme: Heute die Industrie von morgen gestalten]

Service-Oriented Architecture (SOA)

Definition according to OASIS[1]:

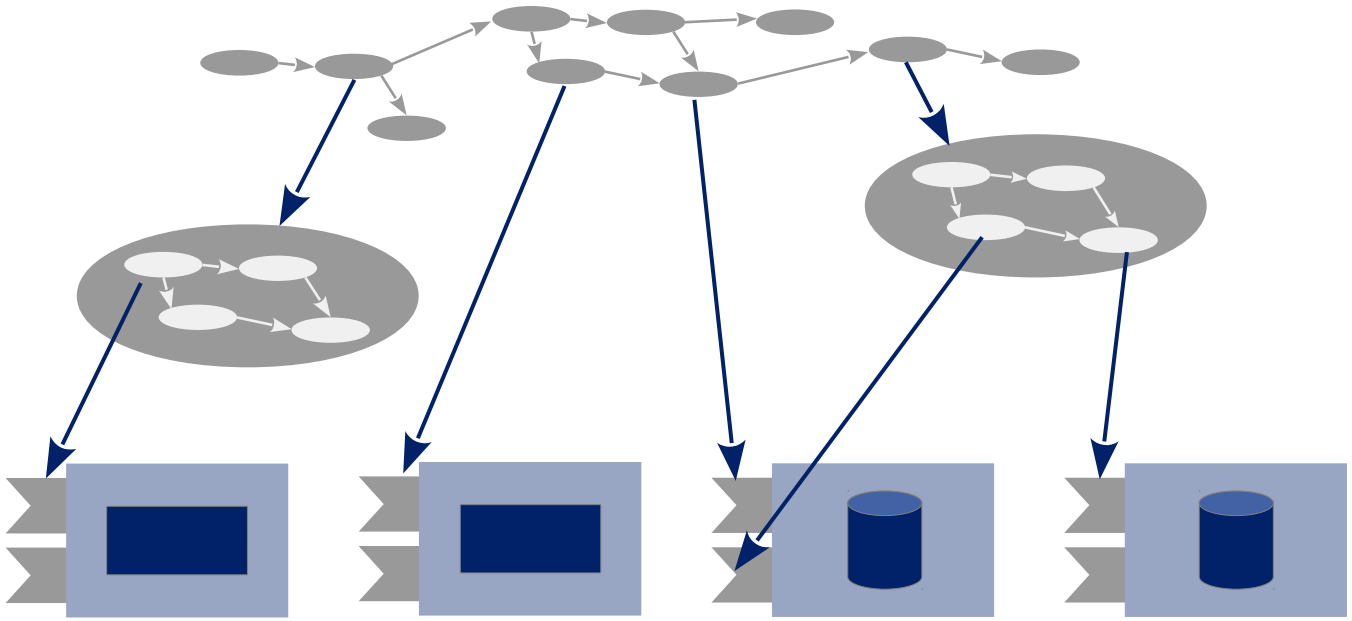
„SOA is a paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains.“[2]

User

Workflows / Processes

Service-Components

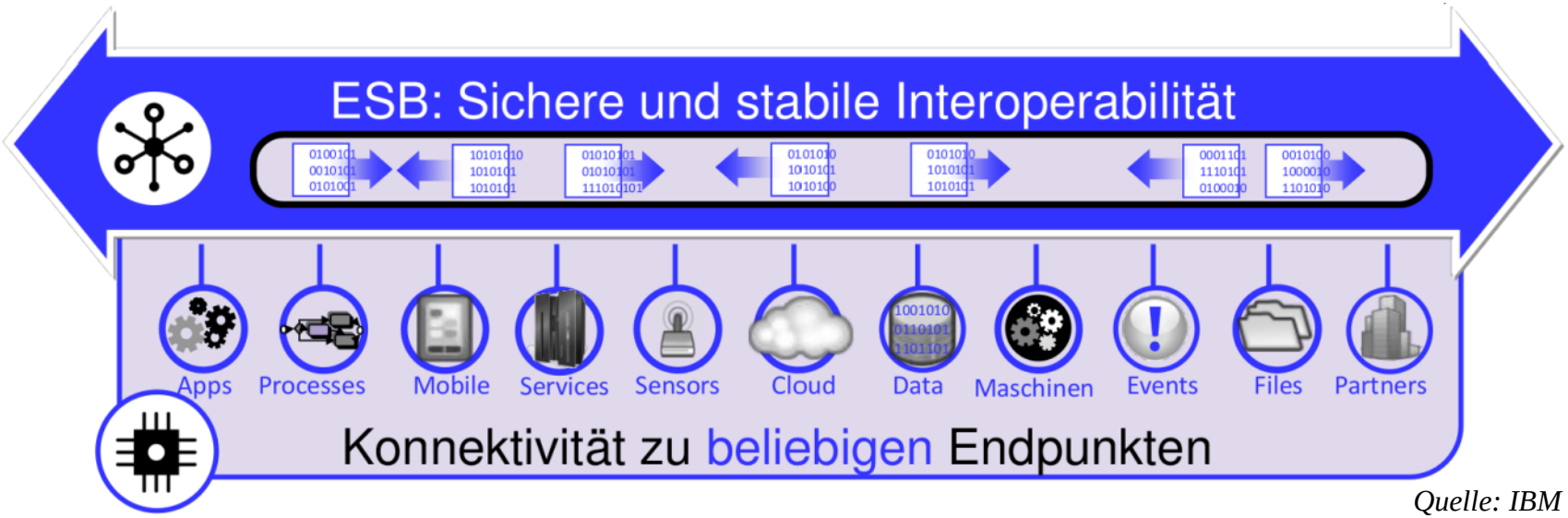
Operational IT-Systems



1 Organization for the Advancement of Structured Information Standards
2 Reference Model for Service Oriented Architecture 1.0, Committee Specification 1, 2 August 2006

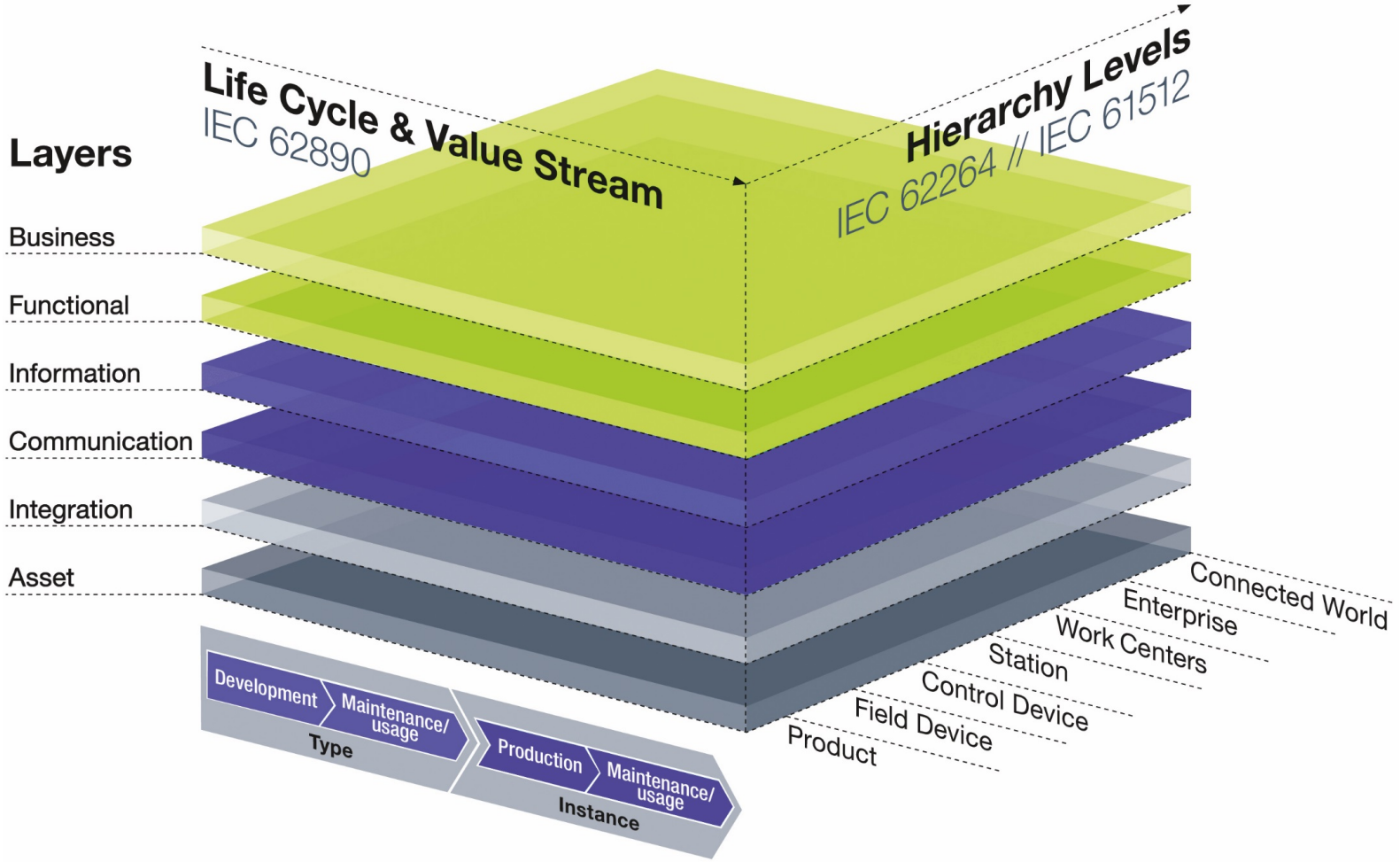
Experiences from Business IT

- Service Orientation is an important step but not enough
- Approaches for further decoupling of system parts
  - Technical decoupling through **Enterprise Service Bus** concept
  - Functional decoupling through **Complex Event Systems**

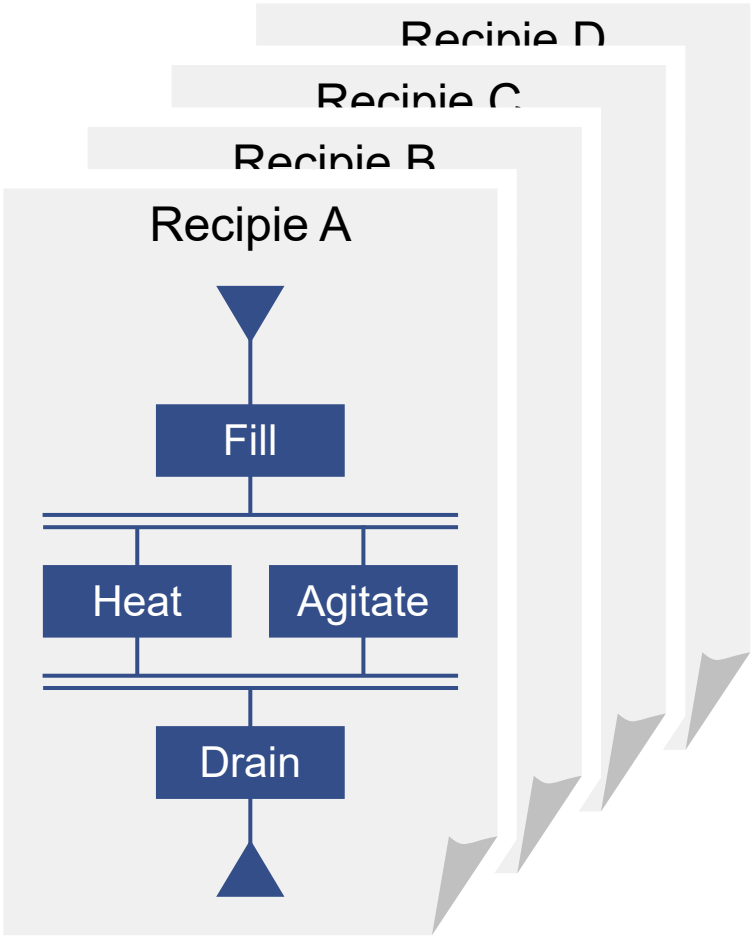


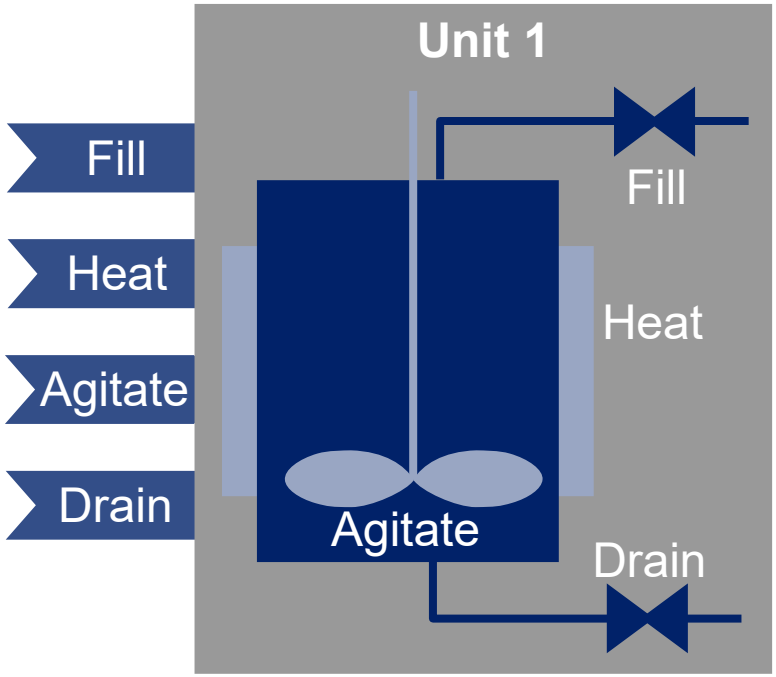
Quelle: IBM

Reference Architecture Industrie 4.0 (RAMI4.0)

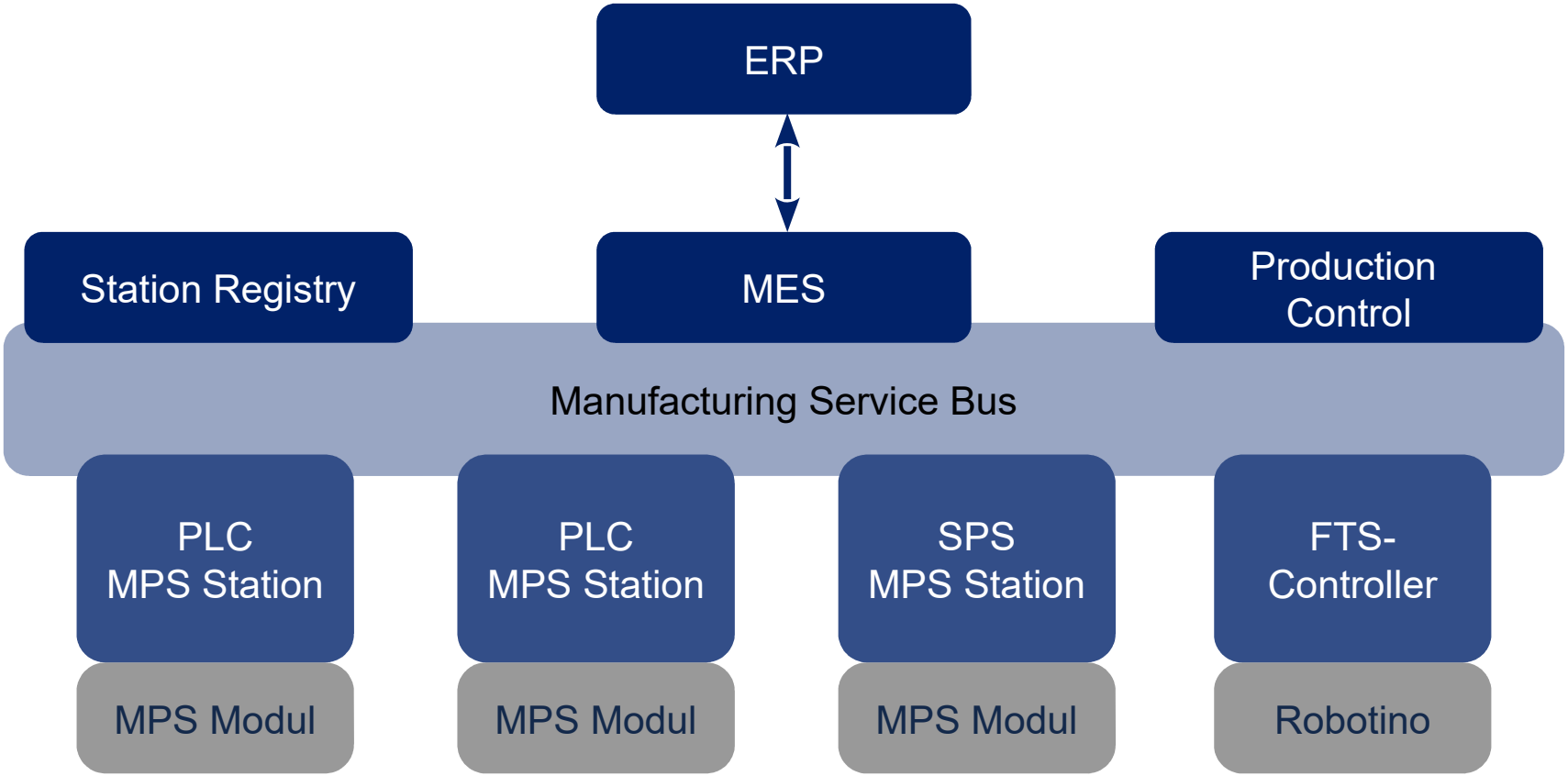


Starting Point:
Batch Management according to ISA-88 / IEC 61512



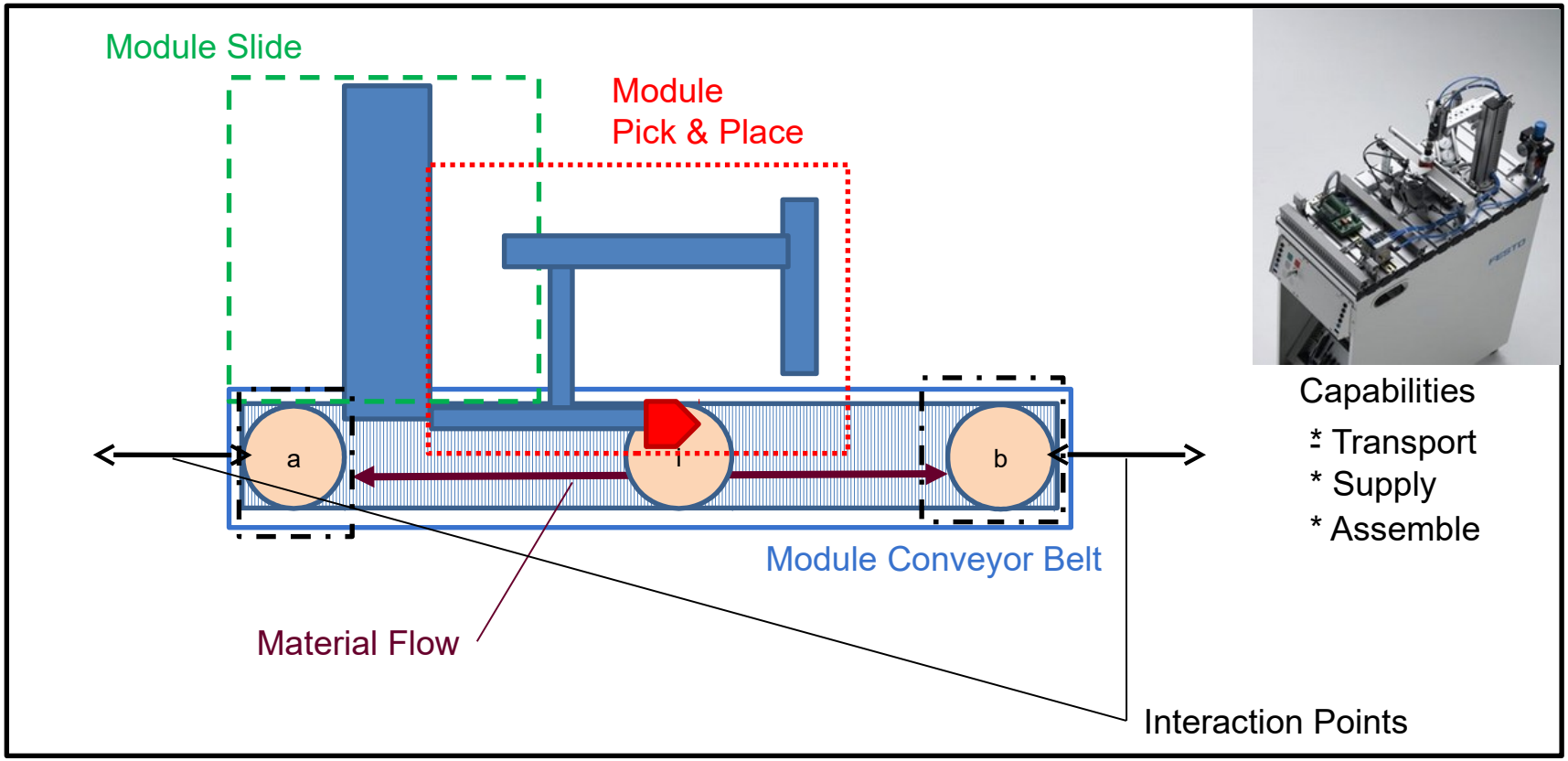


Decoupling of System Elements



Modeling Production Resources

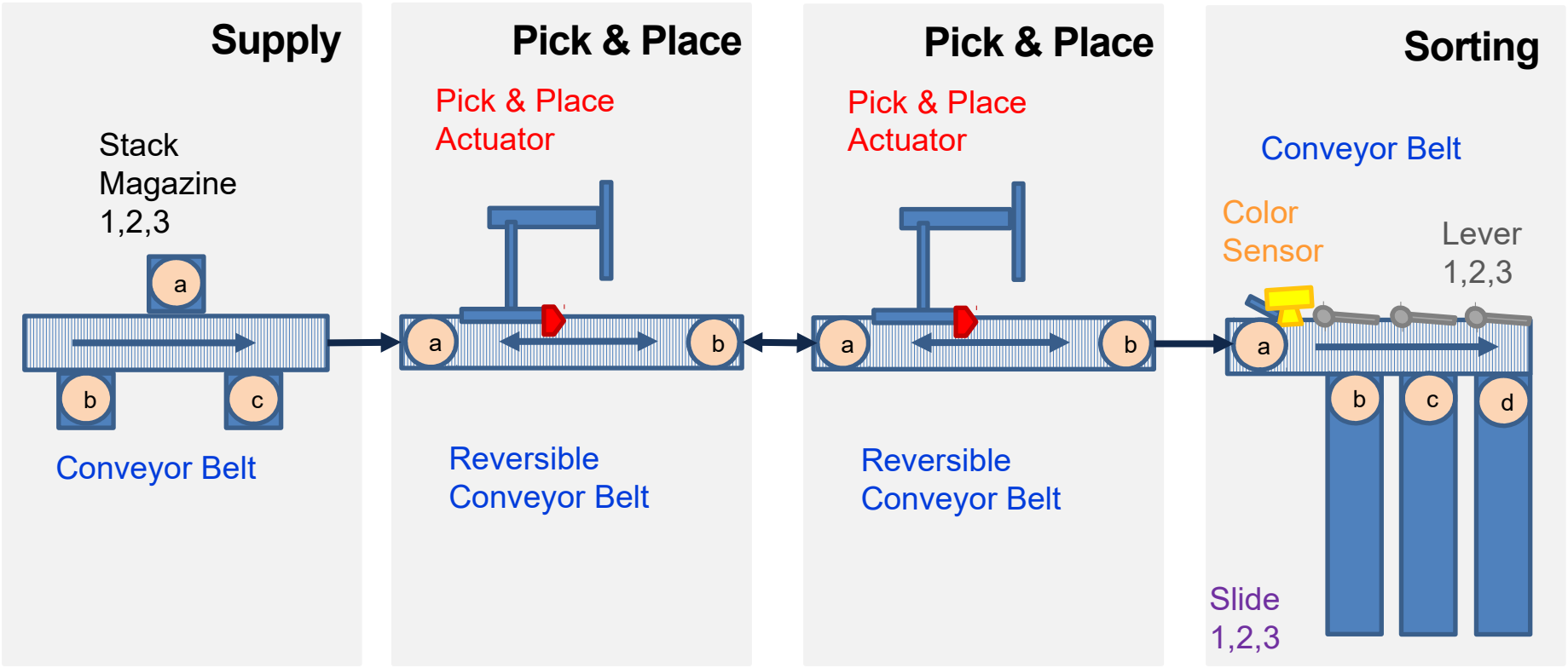
Example: Assembly Station



Factory Model

Material Flow Modeling

- Material can flow between connected resources
- Direction of flow determined by types of two connected interaction points
- Automatic detection of Stations and Neighborhood

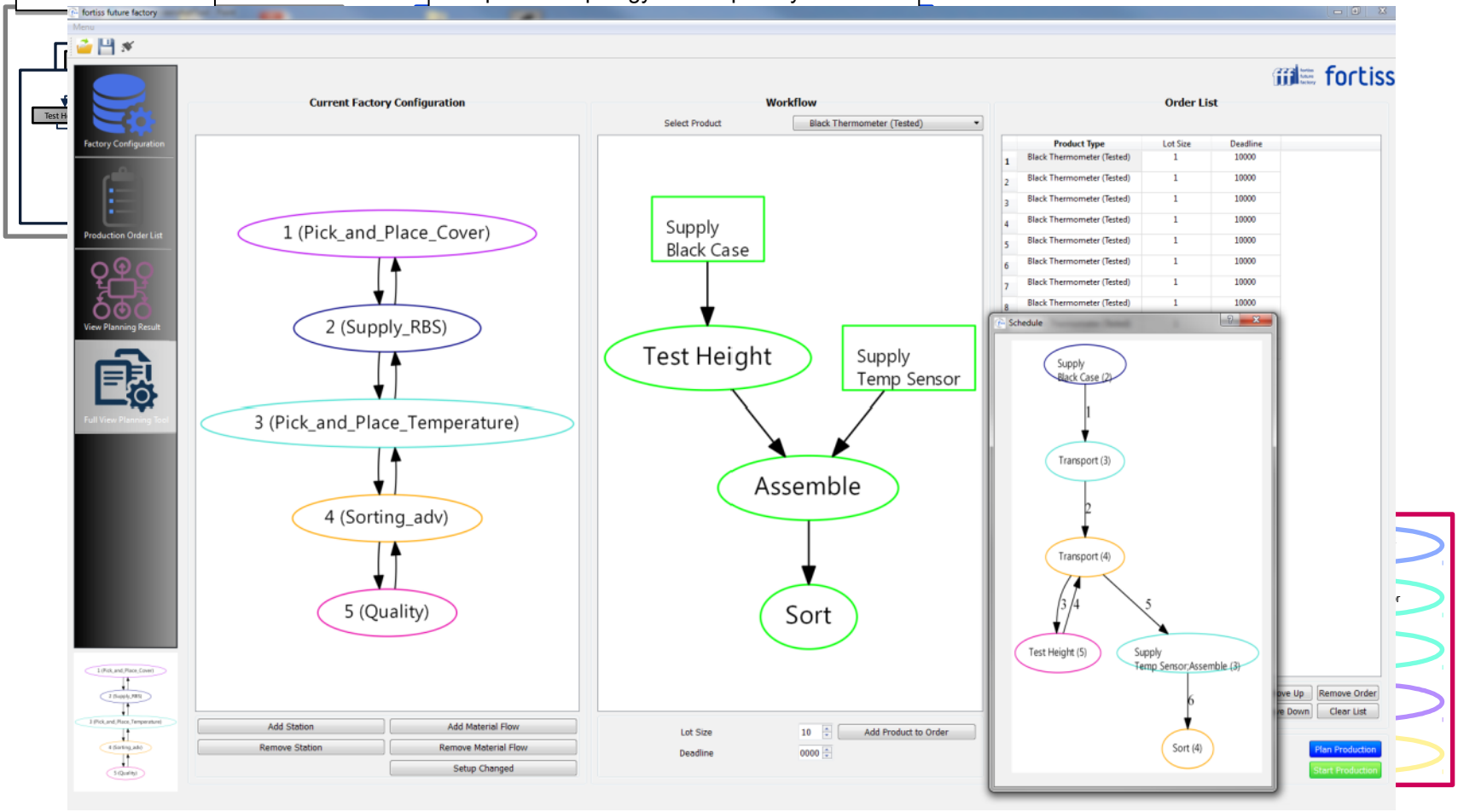


Automated Production Planning and Control

fortiss future factory

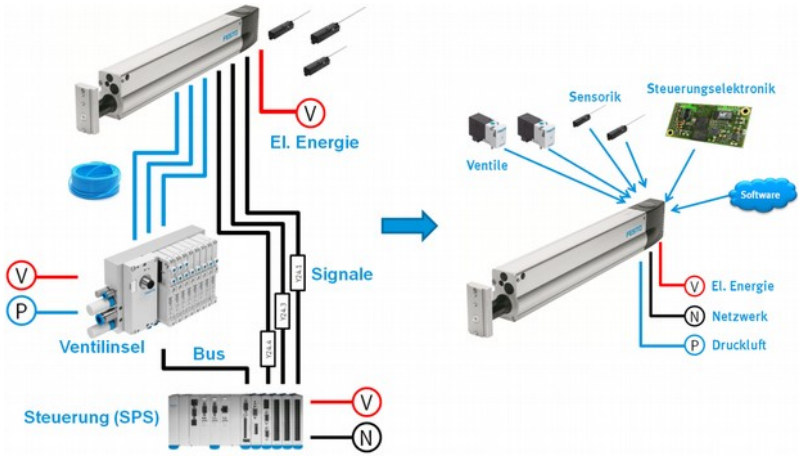
Product Plans

Shop Floor Topology and Capability Models



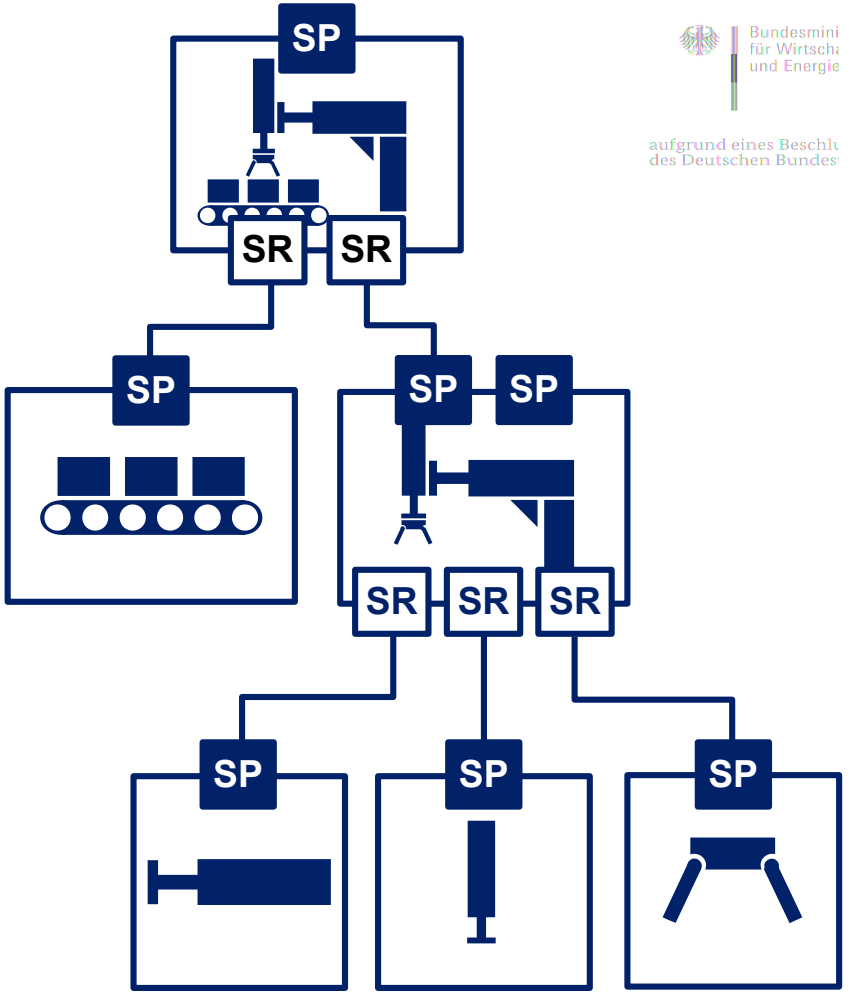
Bringing Modularity and Adaptivity into Production Cells

Gefördert durch:
Bundesmini
für Wirtscha
und Energie
aufgrund eines Beschlu
des Deutschen Bundes

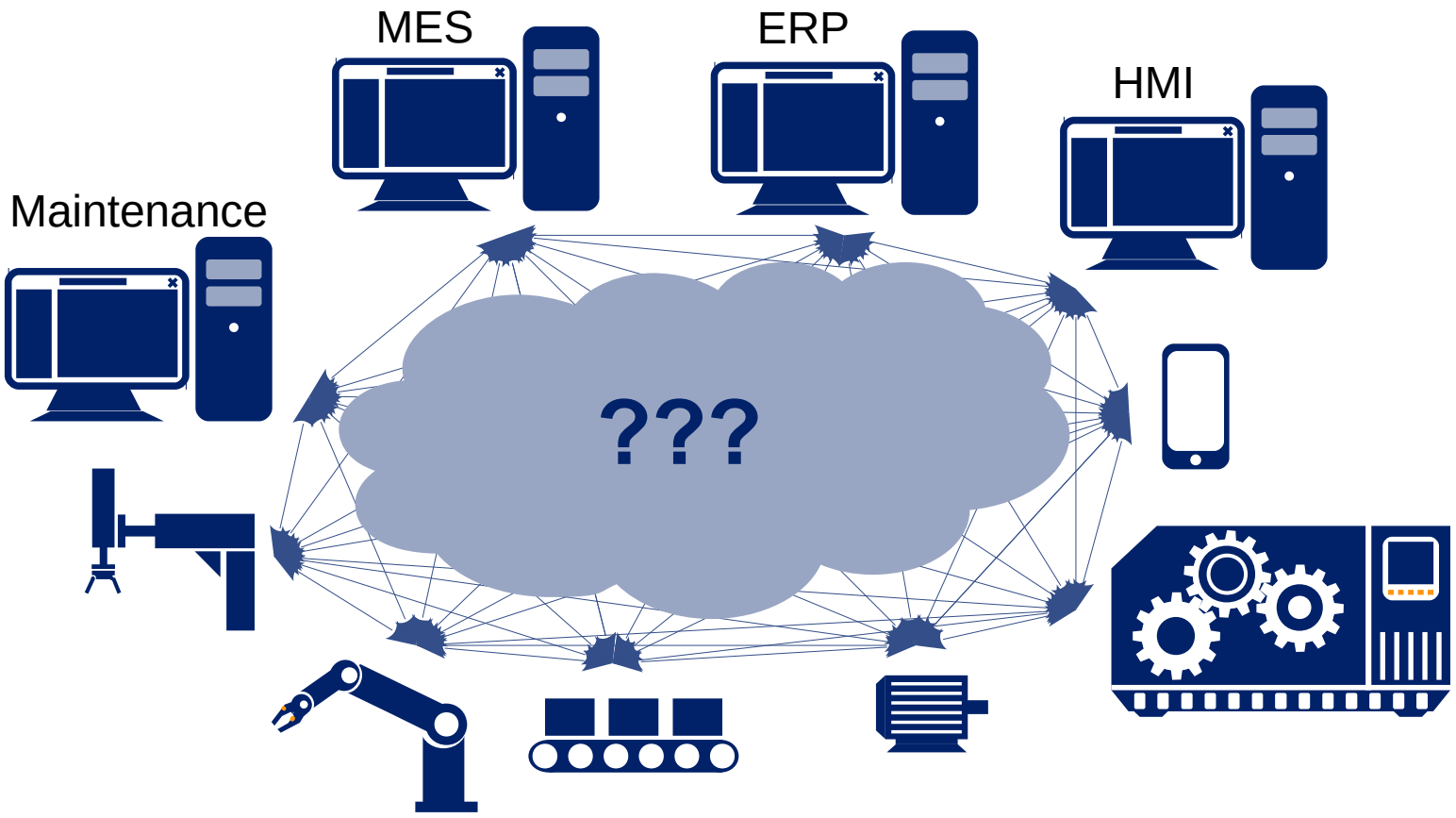


Source: Festo

Source: Festo



Communication Needs



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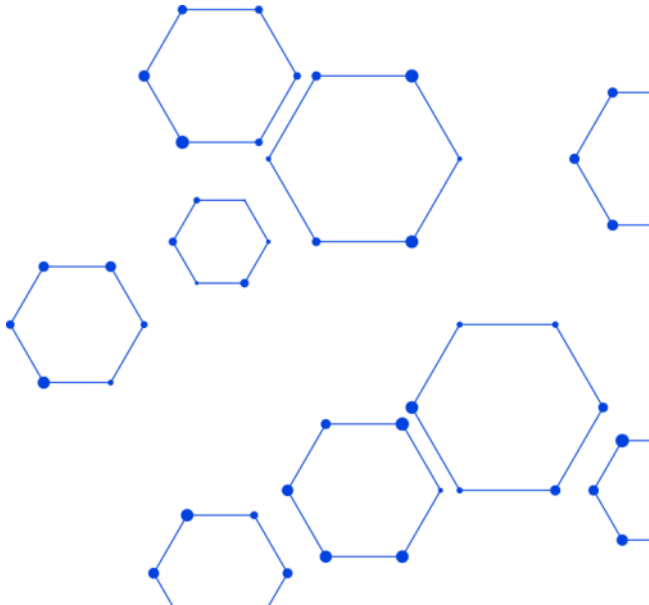
OPC Unified Architecture IEC 62451

Standard defining a Service-oriented Communication Architecture



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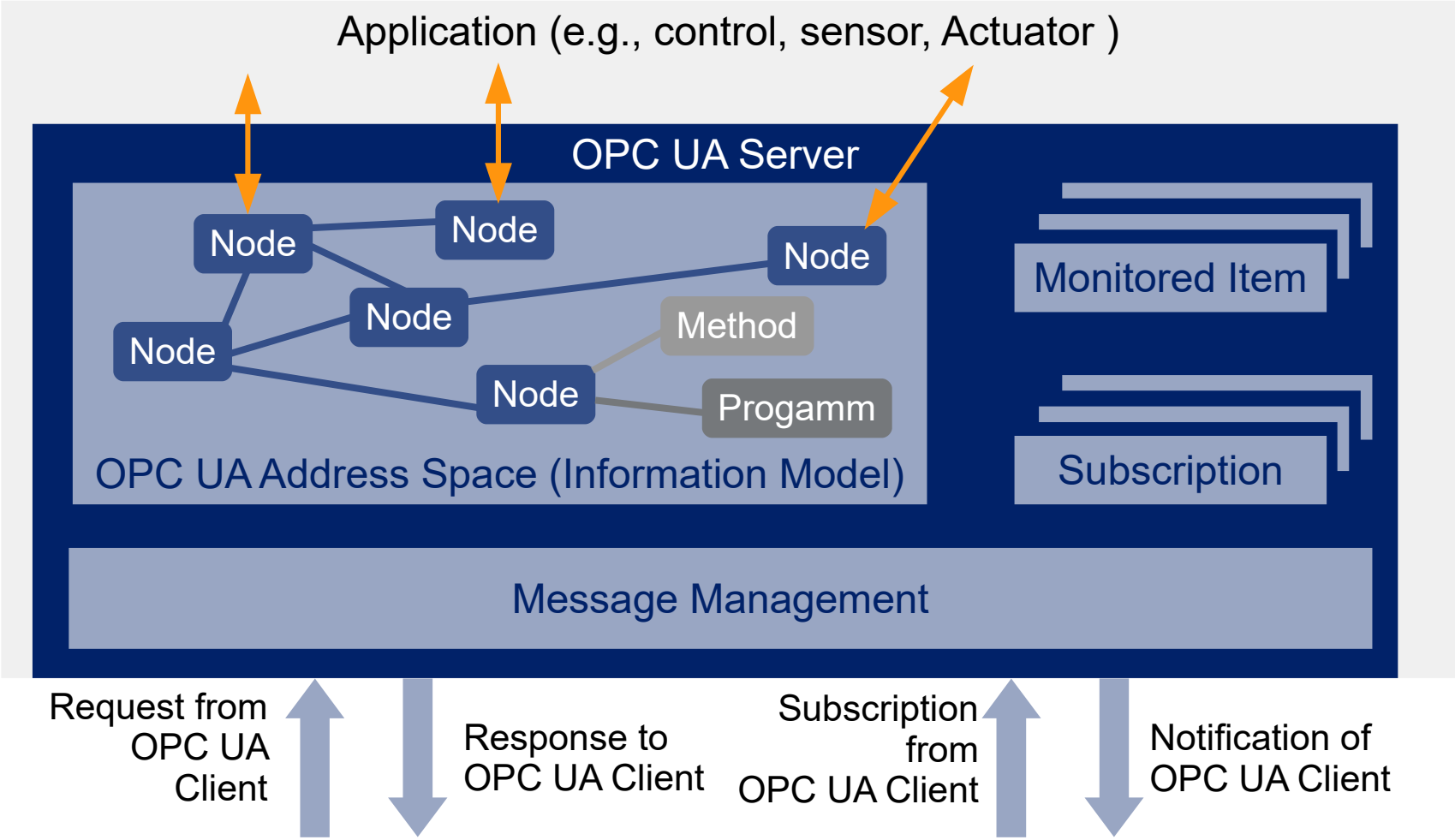
OPC UA Server Architecture



VDMA represents the broad manufacturer industry

Many companies are on the way to Industrie 4.0

- Agricultural Machinery
- Air Conditioning and Ventilation
- Air Pollution Control
- Air-handling Technology
- Building Control and Management
- Cleaning Systems
- Compressors, Vompressed Air and Vacuum Technology
- Construction Equipment and Building Material Machines
- Drying Technology
- Electrical Automation
- Electronics, Micro and Nano Technologies
- Engine Systems for Power and Heat Generation
- Engines and Systems
- Fire Fighting Equipment
- Fluid Power
- Food Processing Machinery and Packaging Machinery
- Foundry Machinery
- Gas Welding
- Hydro Power
- Integrated Assembly Solutions
- Large Industrial Plant Manufacturing
- Lifts and Escalators
- Machine Tools and Manufacturing Systems
- Machine Vision
- Materials Handling and Intralogistics
- Measuring and Testing Technology
- Metallurgical Plants and Rolling Mills
- Metallurgy
- Micro Technologies
- Mining
- Plastics and Rubber Machinery
- Power Systems
- Power Transmission Engineering
- Precision Tools
- Printing and Paper Technology
- Process Plant and Equipment
- Productronic
- Pumps + Systems
- Refrigeration and Heat Pump Technology
- Robotics
- Robotics + Automation
- Security Systems
- Software
- Surface Treatment Technology
- Textile Care, Fabric and Leather Technology
- Textile Machinery
- Thermal Turbines and Power Plants
- Thermo Process Technology
- Valves
- Waste Treatment and Recycling
- Wind Energy
- Woodworking Machinery

OPC UA CS under development

Awareness existent

Problem: Software Development Effort

„... increases the software-engineering portion of the overall Manufacturing costs of a machine: Starting from currently 50% share for electronics and software the share will rise in 2020 up to 80%. “

translated from IEE 01-2006

*„We have so far mastered most topics and could **save** up to **70%** of the engineering effort.* What makes us still problems is the **software effor**t.

translated from SPS Magazin 08-2012

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IEC 61499

Domain-specific Modelling language for Distributed Industrial Process Measurement and Control Systems

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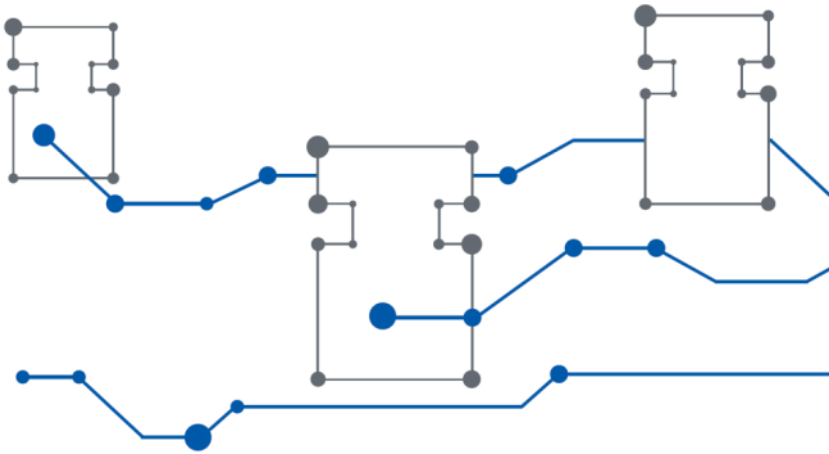
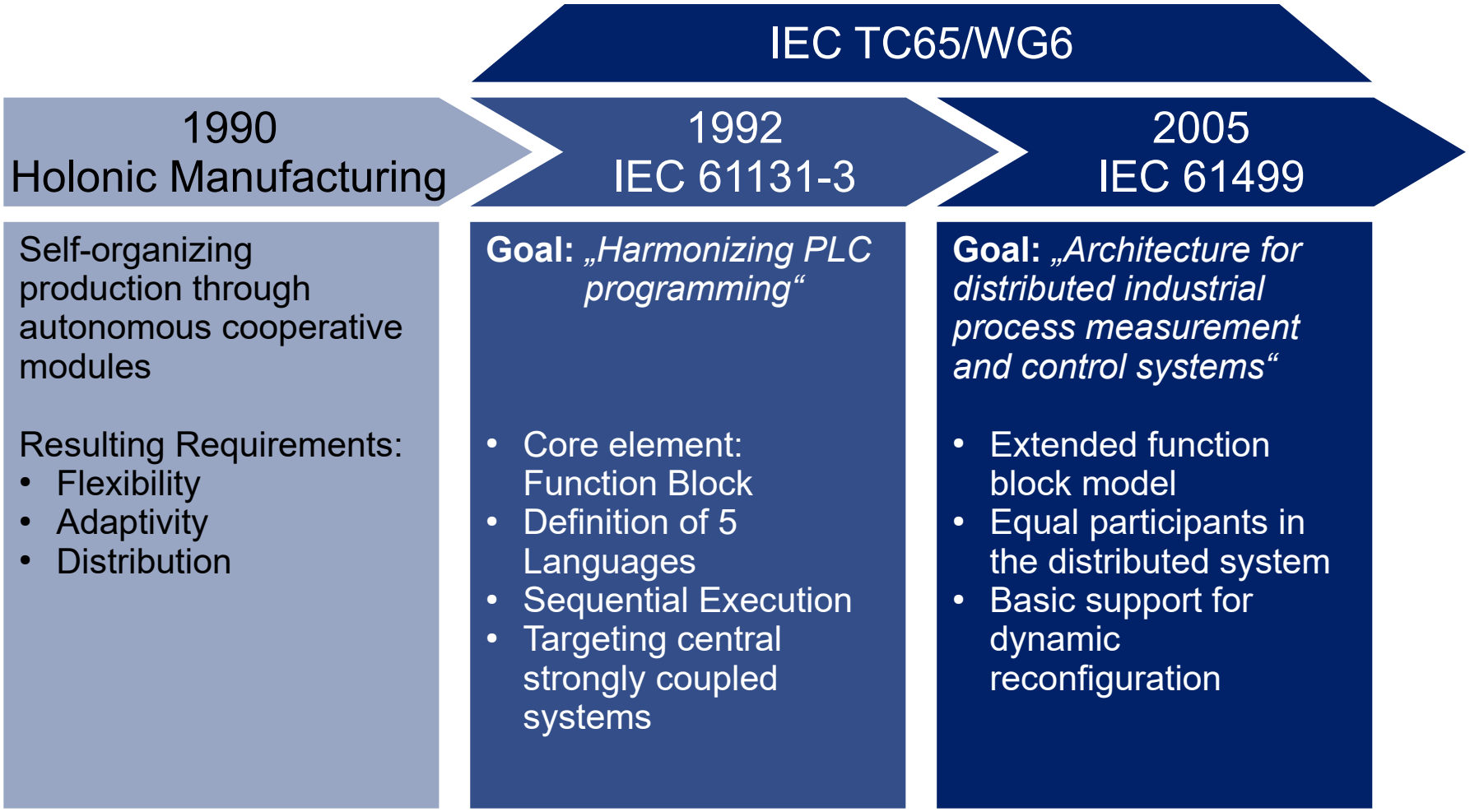
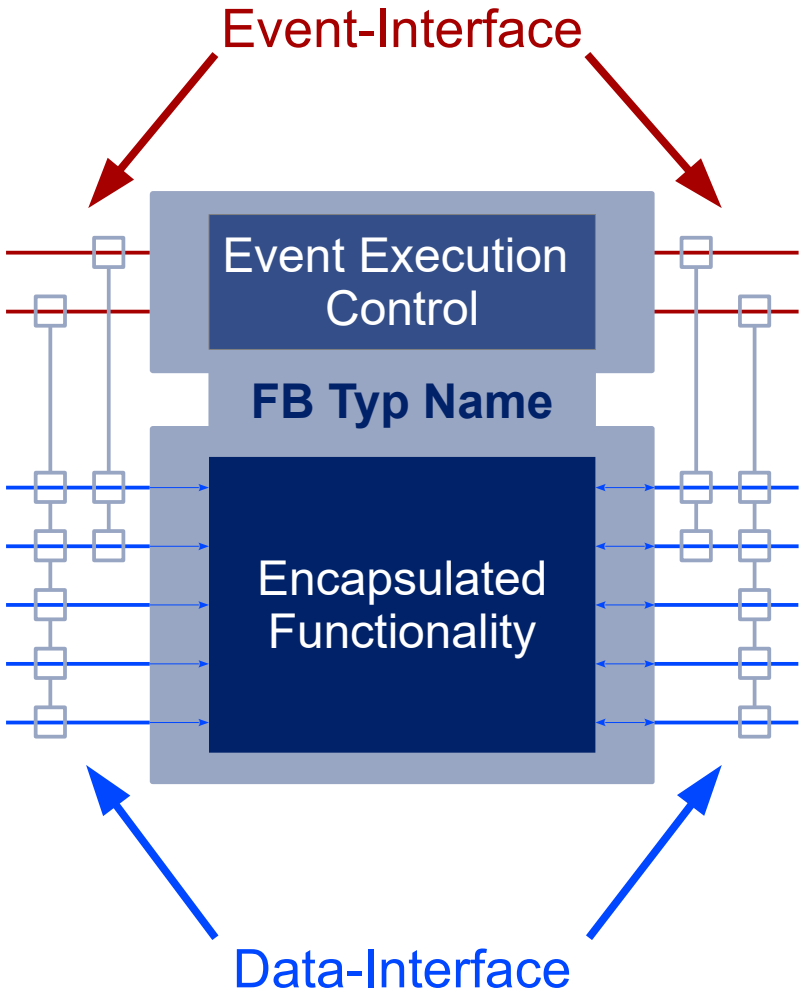


Background IEC 61499



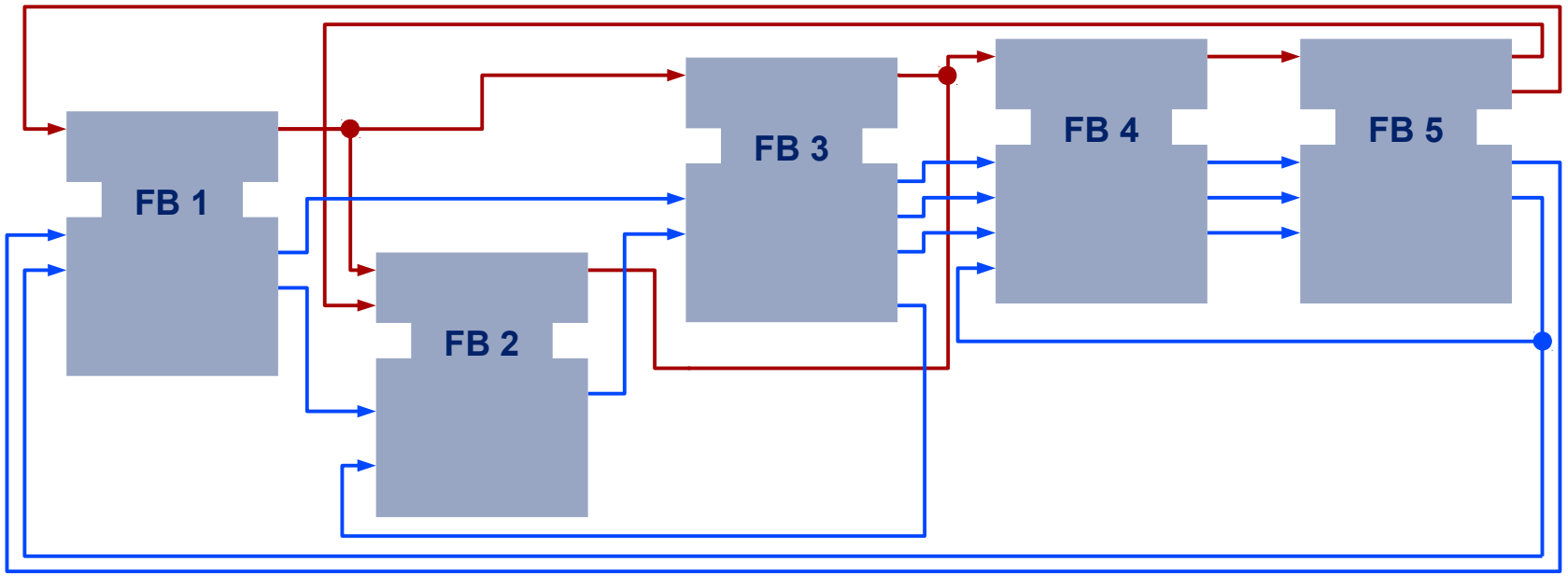
Core Element: Function Block

- Function Blocks extended with event interface
- Pure **event-driven** execution model
- Data types based on **IEC 61131-3**
- Focus on **encapsulation** and **reuse**
- No global or directly addressed variables
- Hardware access with special function block type: **Service Interface Function Block**



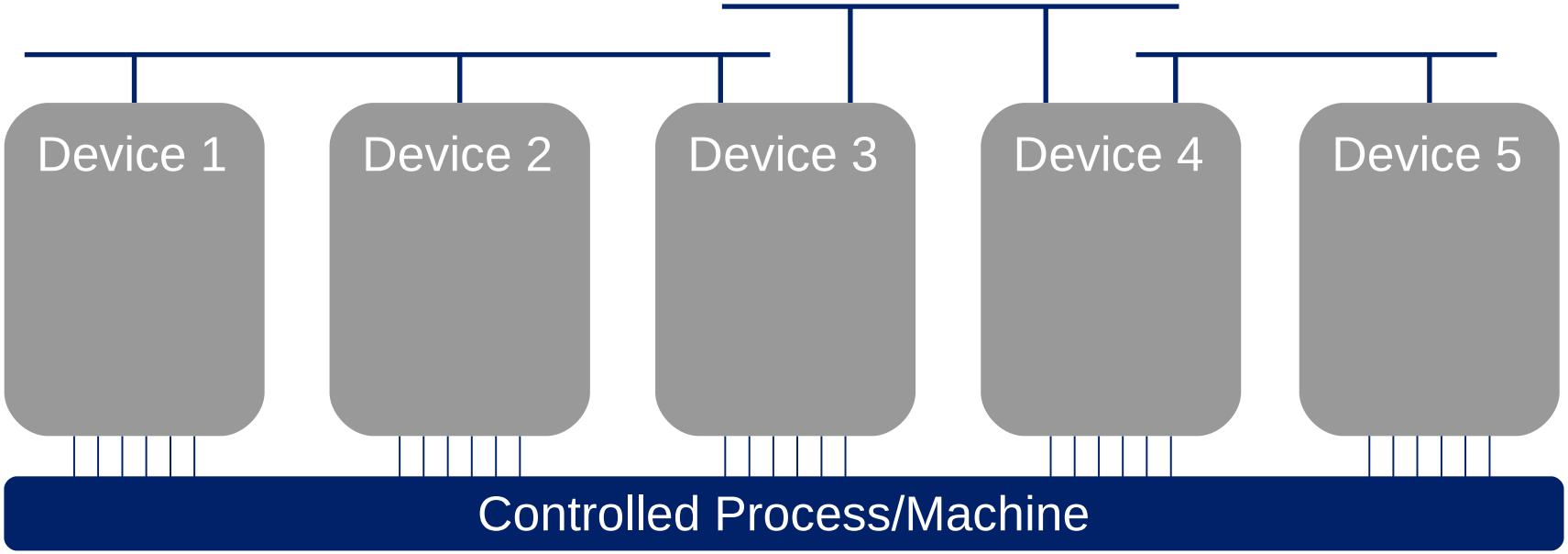
IEC 61499 Application Model

- Function Blocks instances
- Event connections
- Data connections

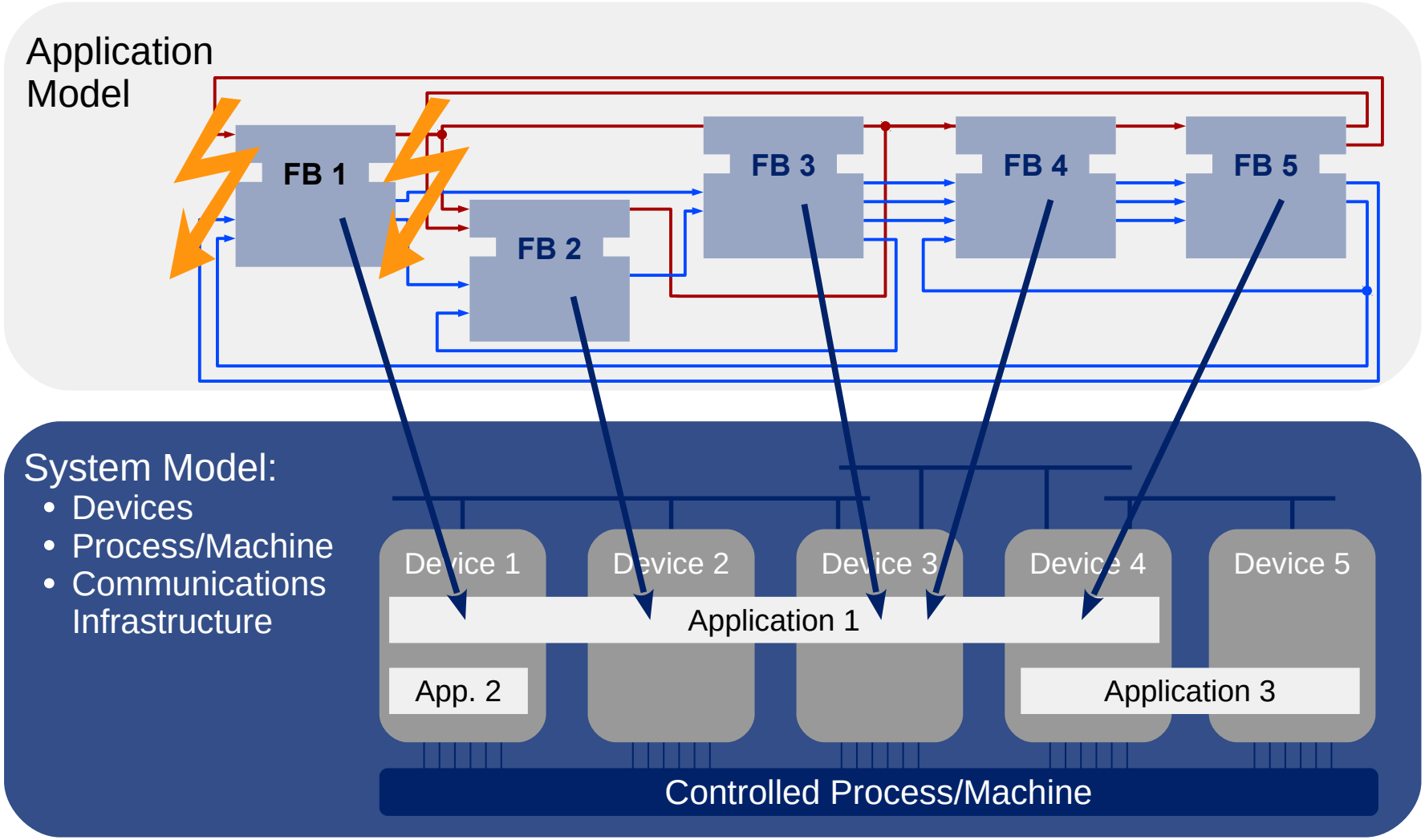


System Model

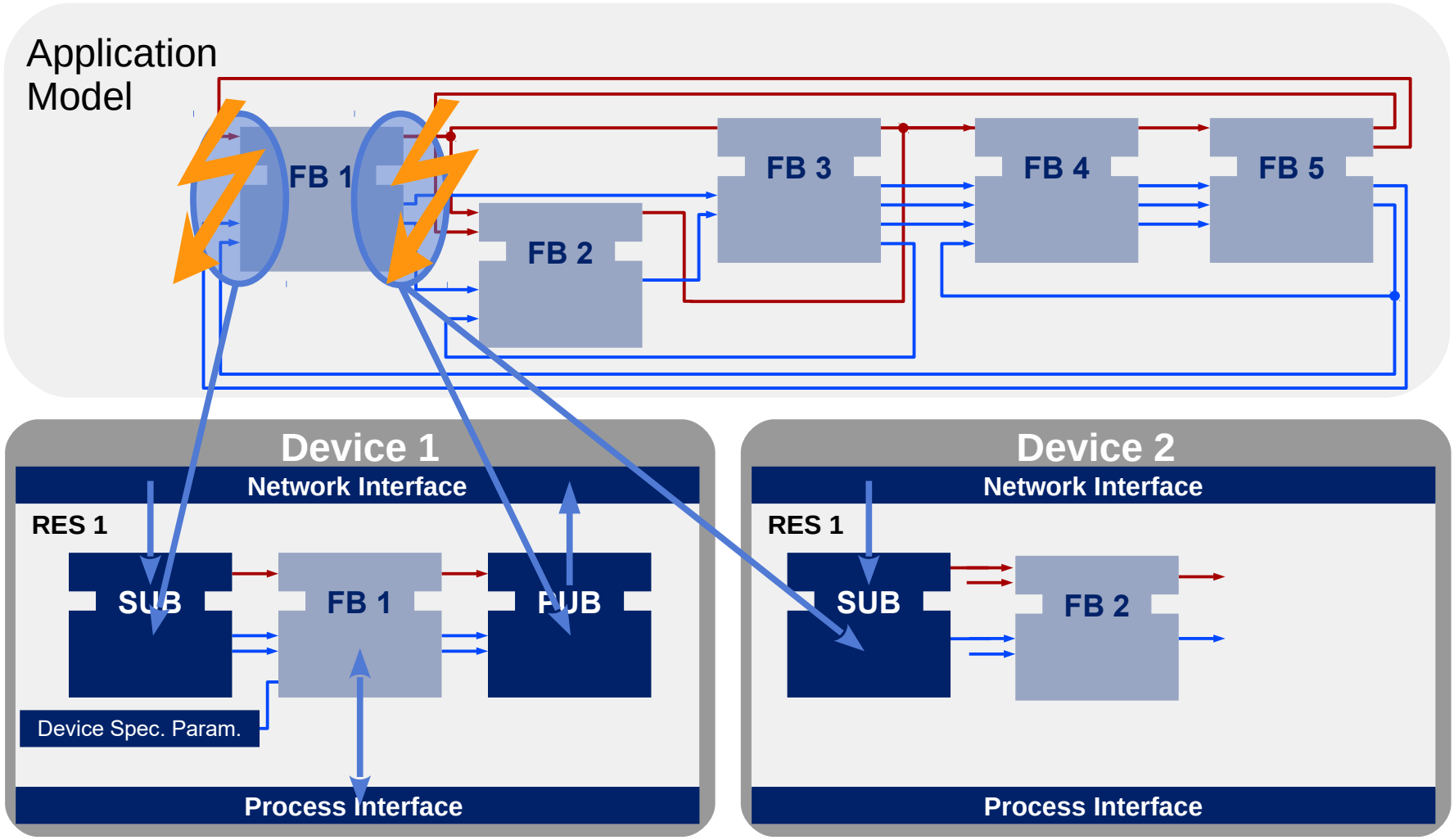
- Devices
- Process/Machine
- Communication infrastructure



Distribution Model



Device Specific Adjustments and Parameters



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First Experiences:
Service-oriented Machine Control with IEC 61499 and OPC UA

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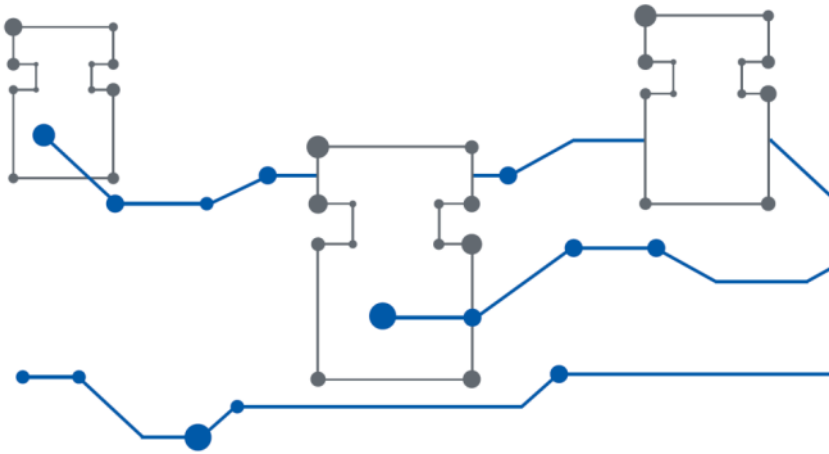
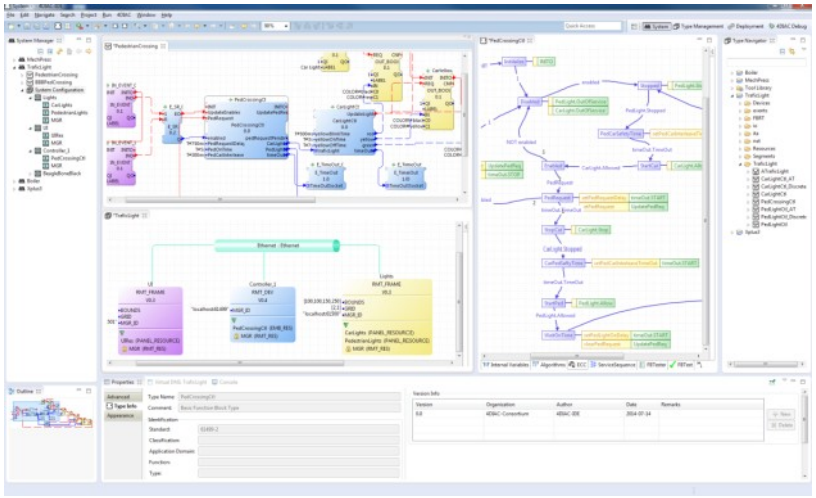


www.fordiac.org

- Open source solution for **IEC 61499**
  - Founded 2007
  - Since 2015 Eclipse project
- Main components
  - Development Environment: **4diac-ide**
  - Device abstracting run-time environment: **4diac-rte**
    - Increasing device support, several PLCs
    - Integrated IoT and industrial communication
- Open Source License
  - Eclipse Public License
  - Allows usage in products and proprietary extensions



Source: LEGO

Source: Insys ICOM

Source: Bosch Rexroth

Source: Bachmann

Source: Wago

Source: Kunbus

Source: microcontrol

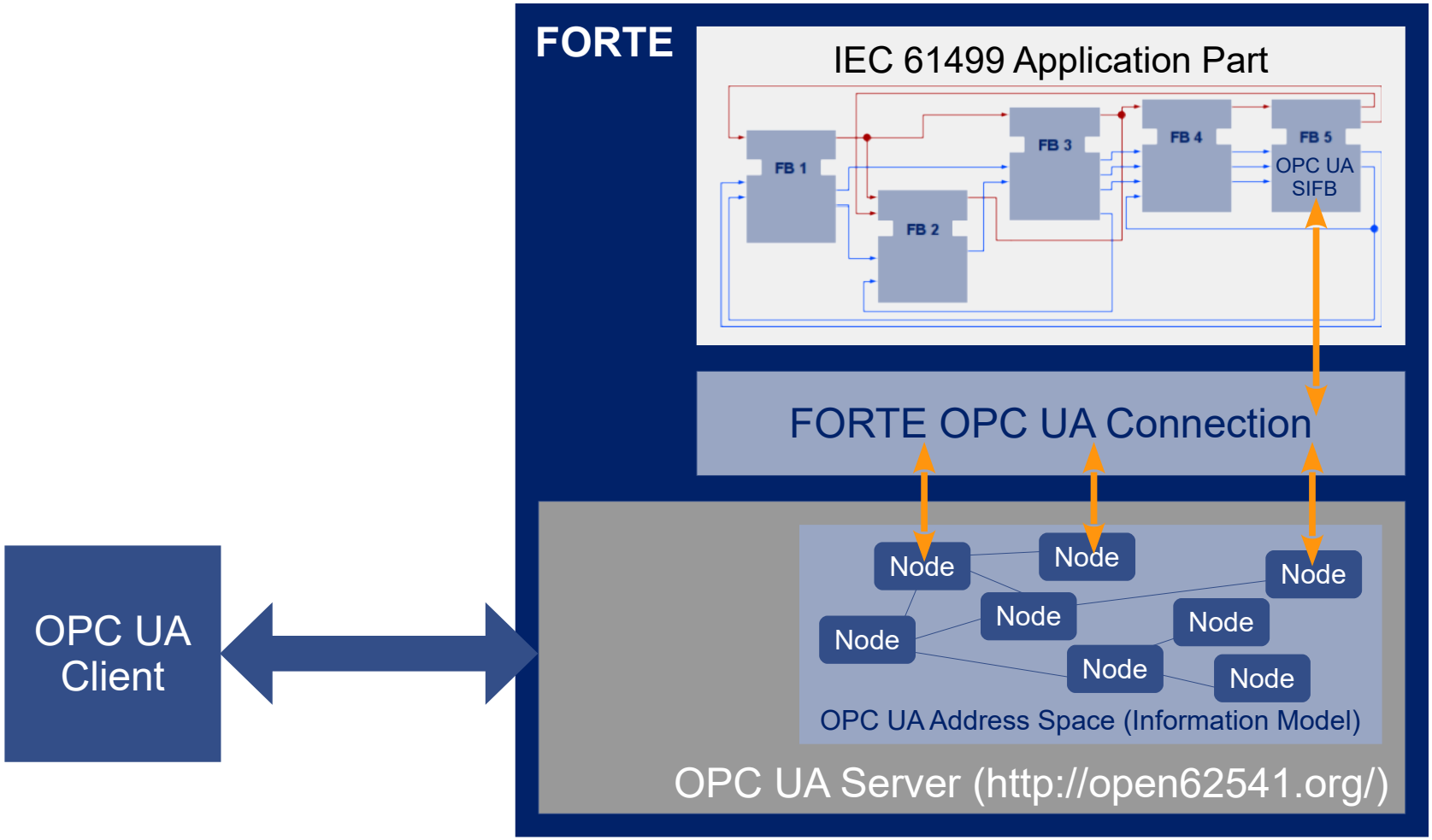
Source: digi

Source: RaspberryPi

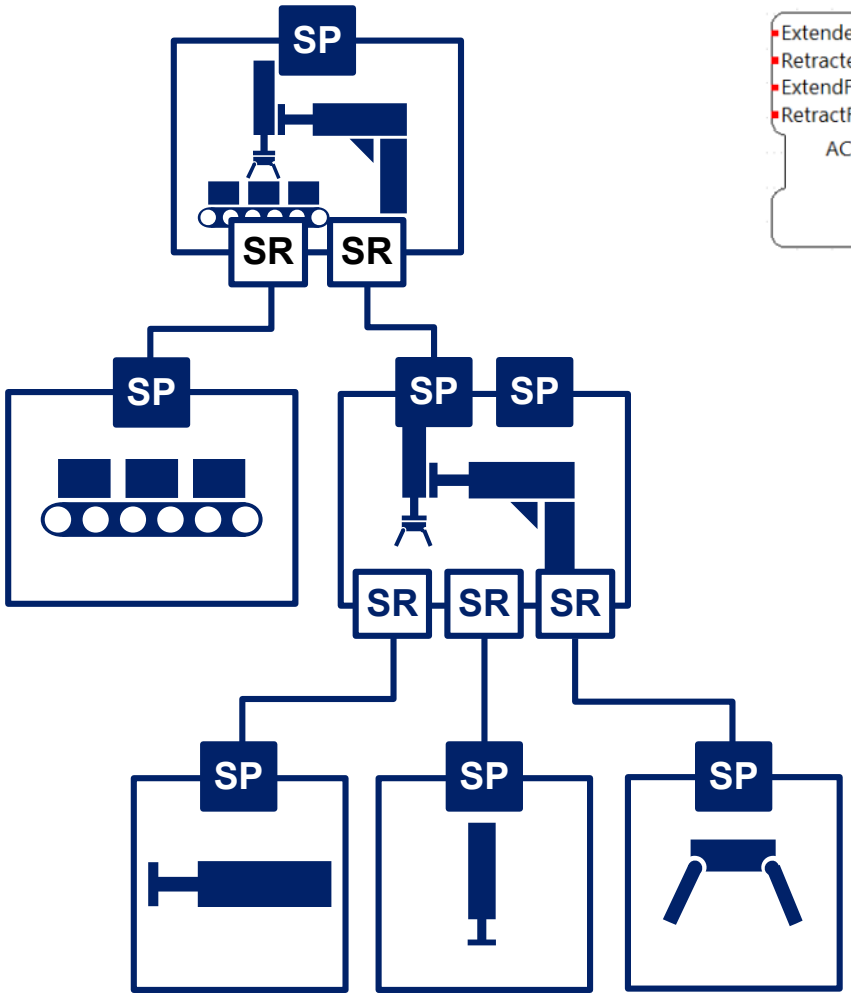
Source: BeagleBoard

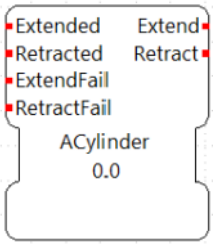
Source: Conmeleon

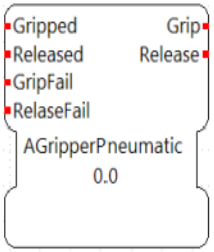
Integration of OPC UA with 4diac

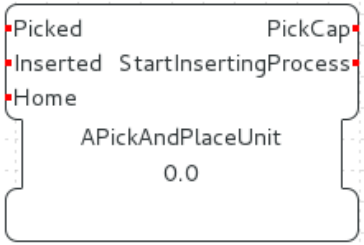


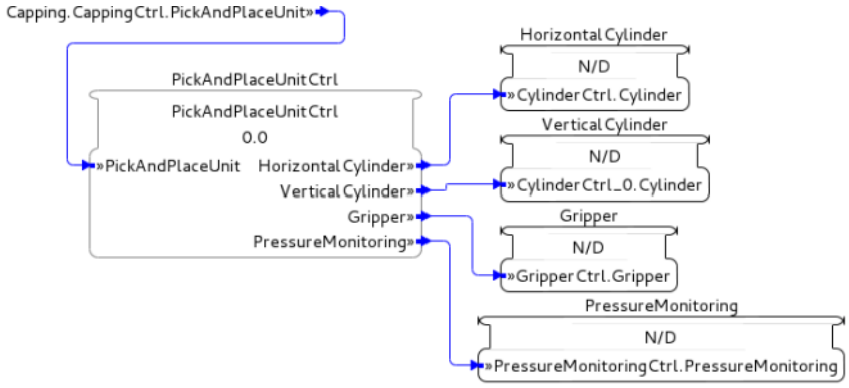
Modelling of Services in IEC 61499



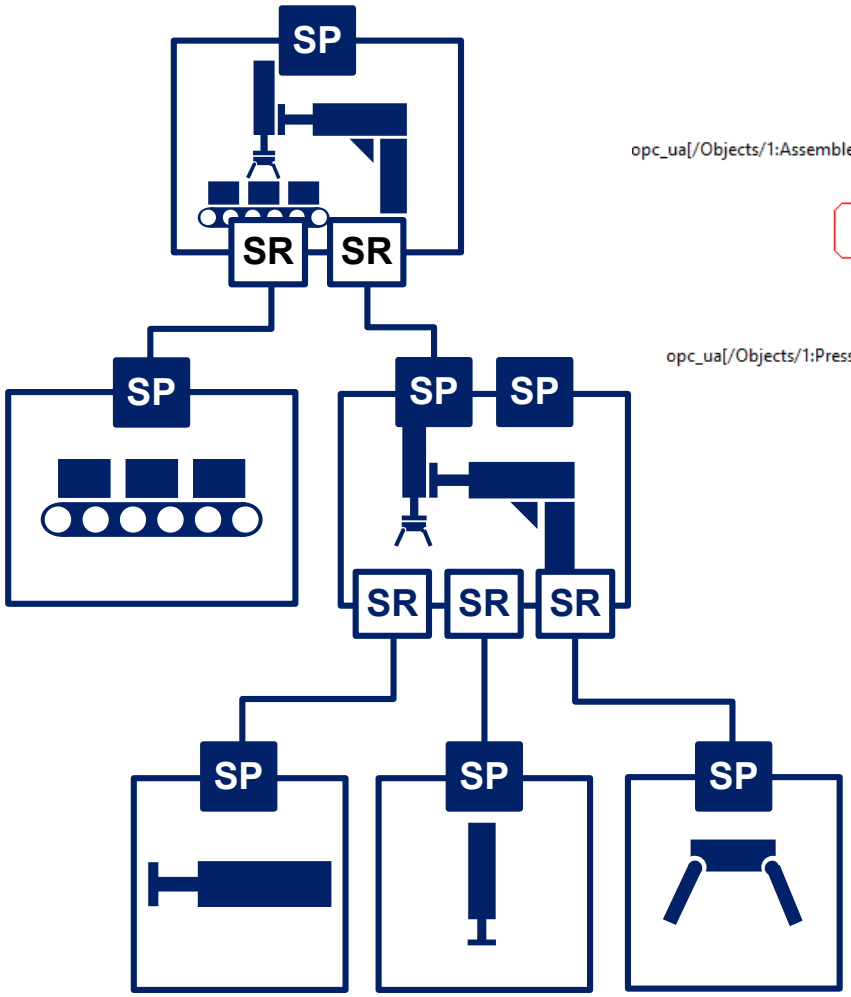


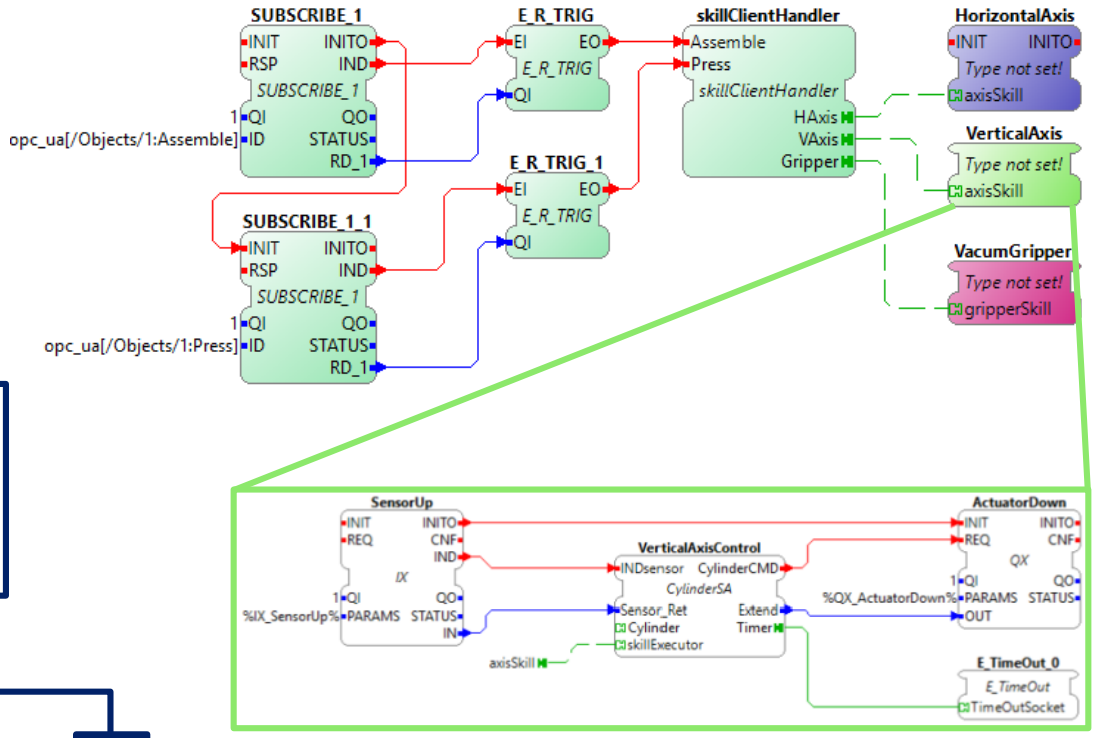






Application Structure Follows Mechatronic Structure






IEC 61499 and
OPC UA in Action
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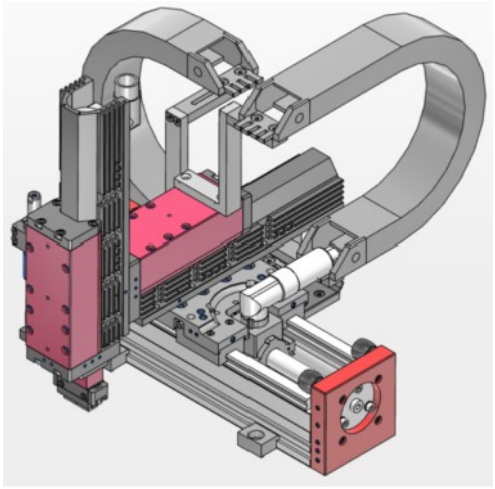
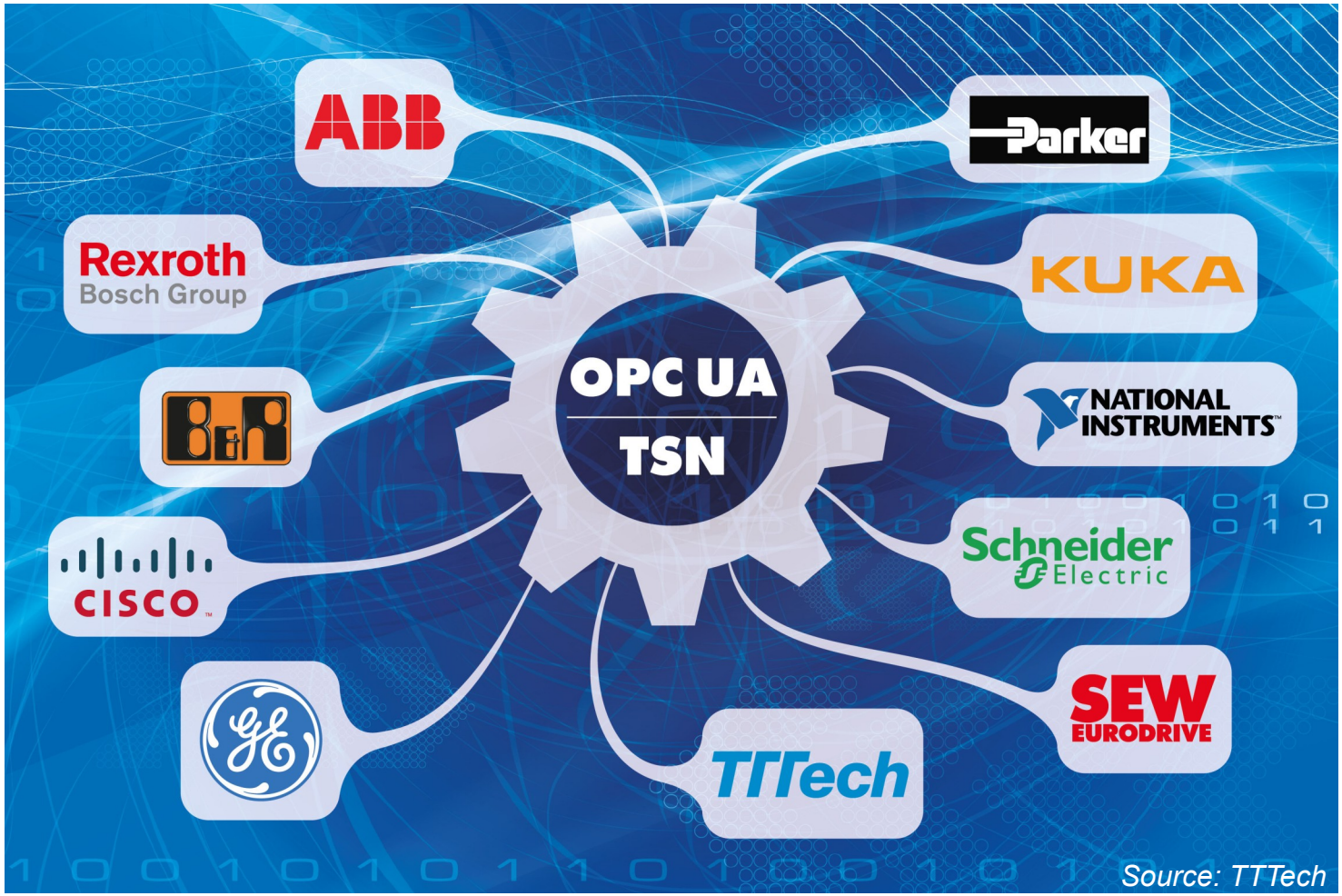
Outlook: VDMA IAS OPC UA Demonstrator

See it live at

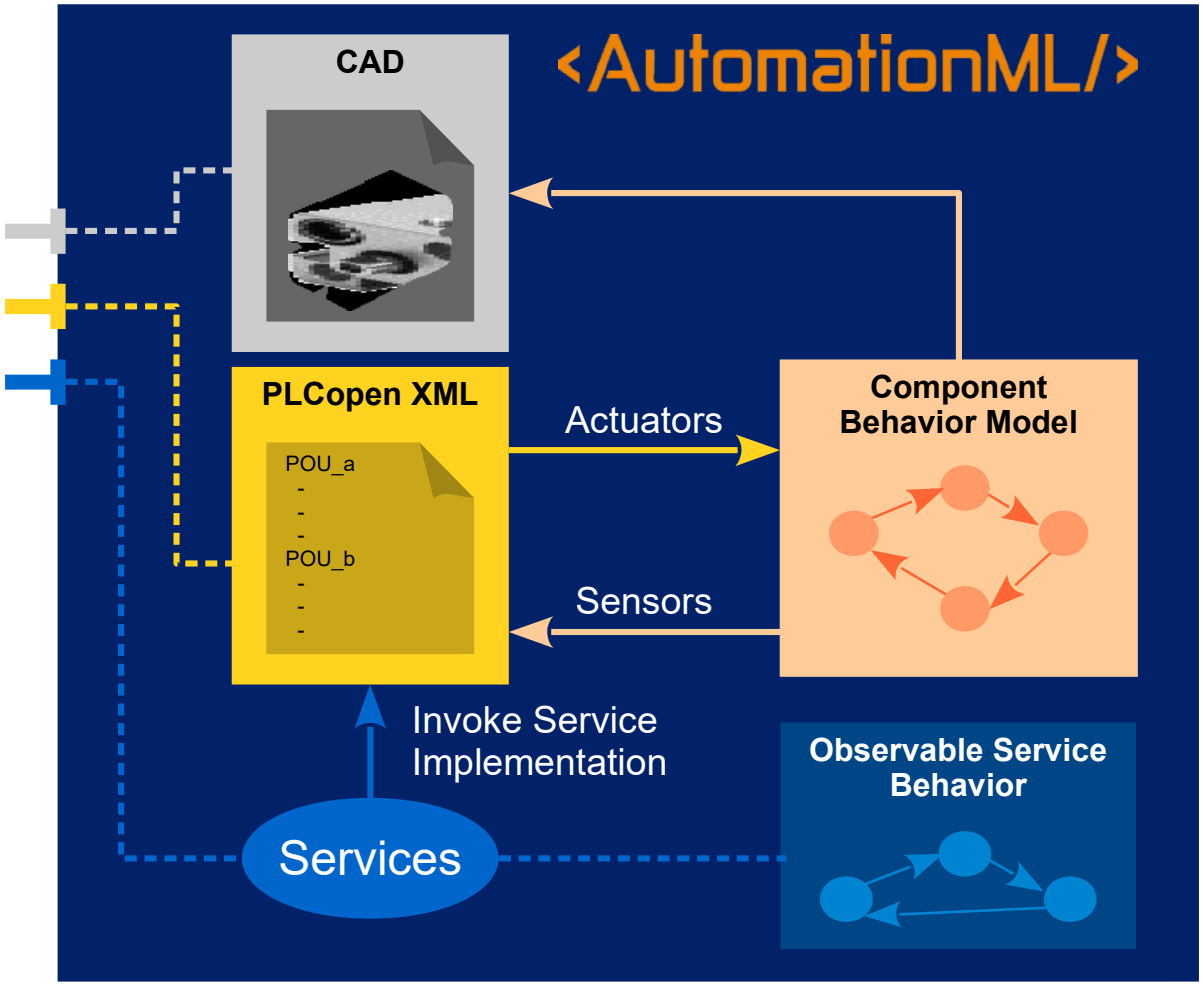
automatica
Optimize your Production



Outlook: OPC UA over Time Sensitive Networking Ethernet Extension



Outlook: Interconnecting Engineering Models and Use them during Run-Time



Are we there yet?

Don’t wait for all of the standards to be completed before moving to Smart Manufacturing

Veröffentlicht: 6. September 2017

David Vasko
Director Advanced Technology at Rockwell Automation

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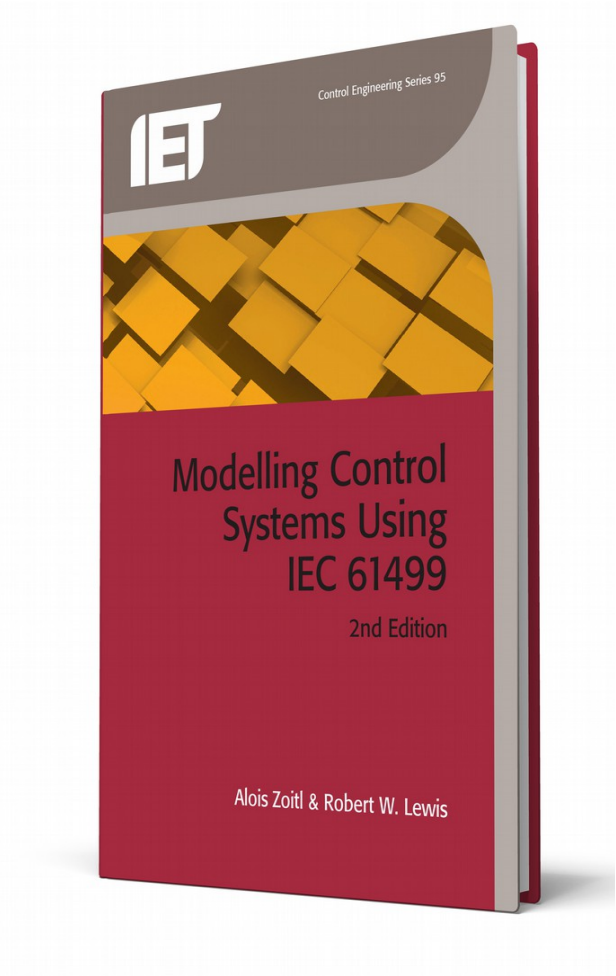
Contact

Dr. Alois Zoitl

fortiss GmbH
Guerickestraße 25,
80805 München, Germany

Tel +49 89 3603522 535
Fax +49 89 3603522 50

alois.zoitl@fortiss.org
www.fortiss.org



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