Aalto University
School of Electrical
Engineering

LULEÅ
UNIVERSITY
OF TECHNOLOGY

Open Distributed Automation with IEC 61499

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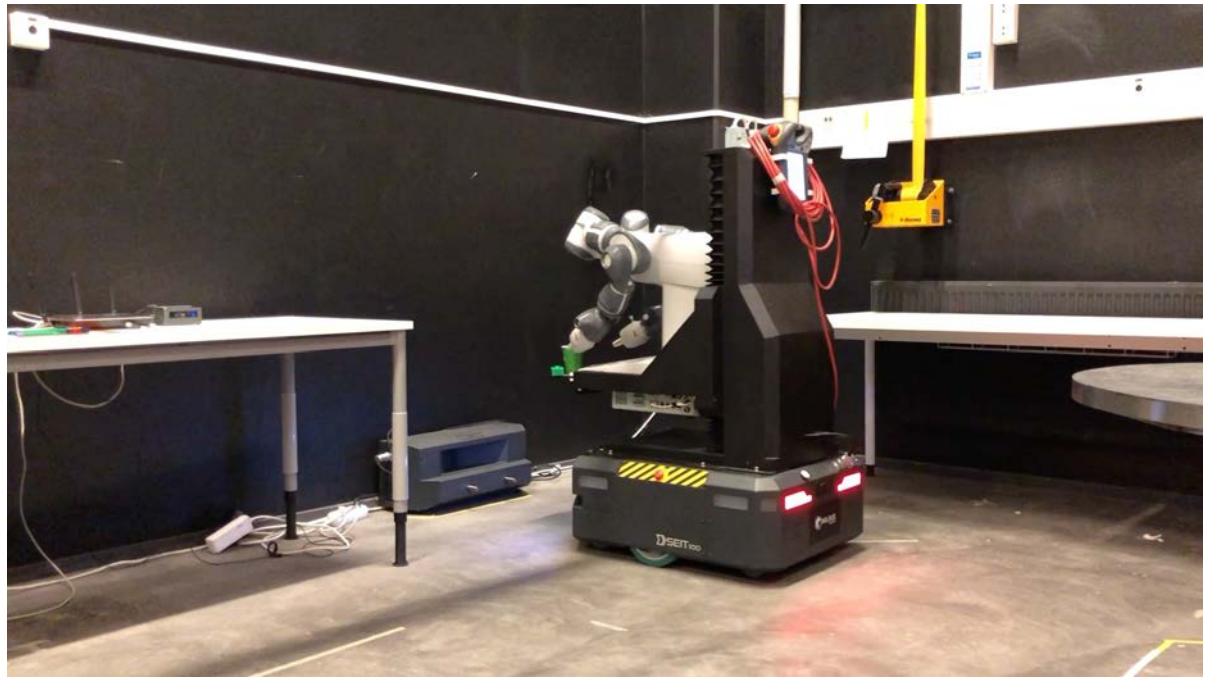
Aalto Factory of the Future

IT, IOT, AI and 5G enabling flexibility.



- Mobile platforms+co-bots in the flexible factory floor
- Impact of wireless communication, AI and cloud computing on dependability
- Human enhanced with IT at the factory floor

https://www.aalto.fi/en/futurefactory

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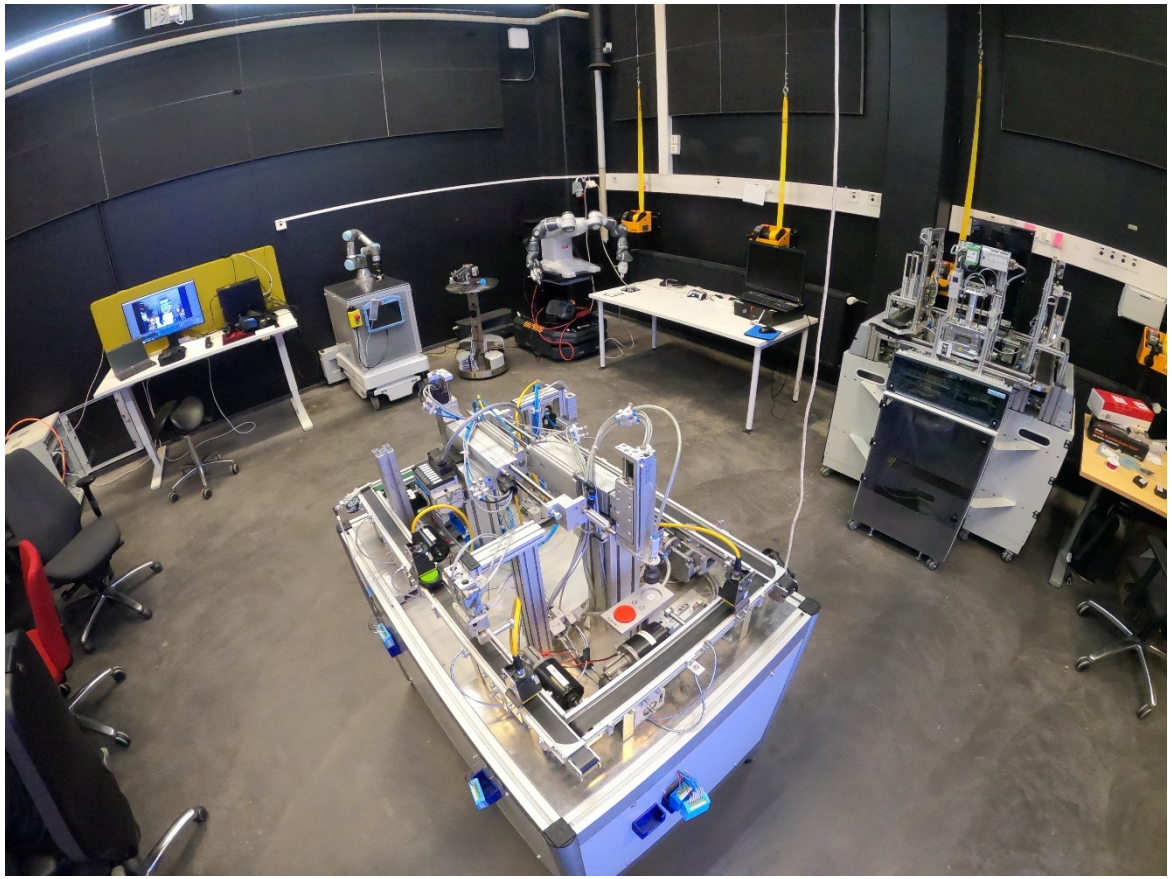

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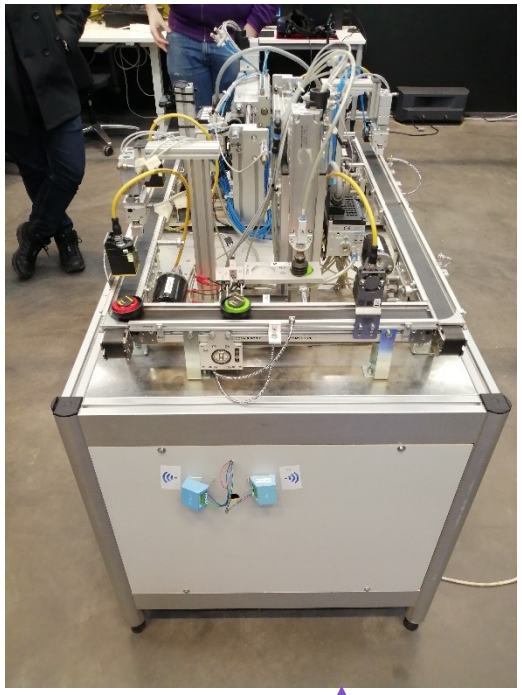

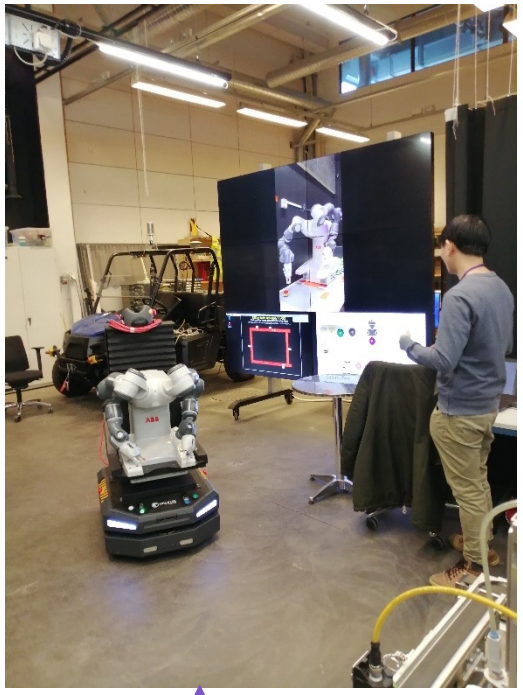

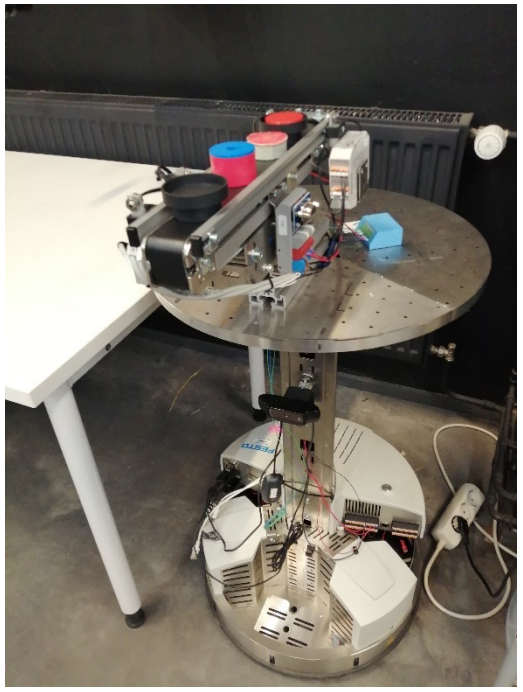

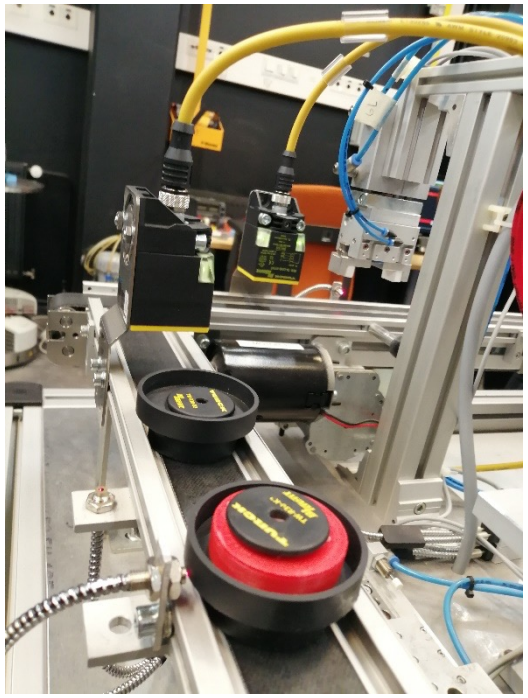

Cloud

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Flexible Assembly Model enabled by IEC 61499

With layout changeable during the operation

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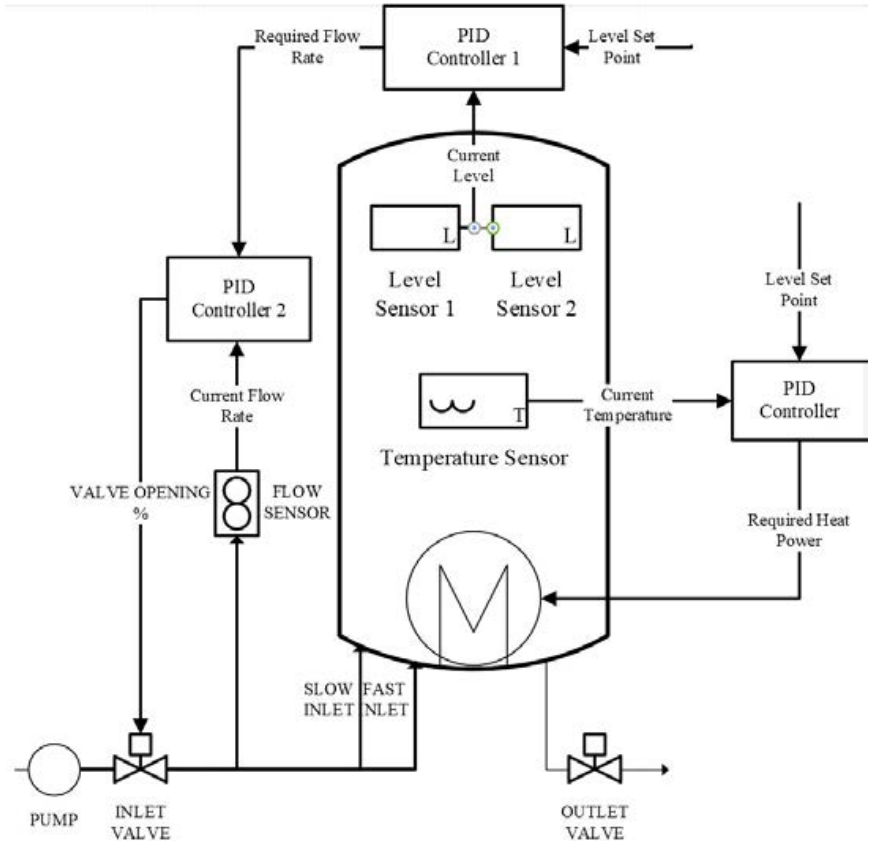
What is IEC 61499?



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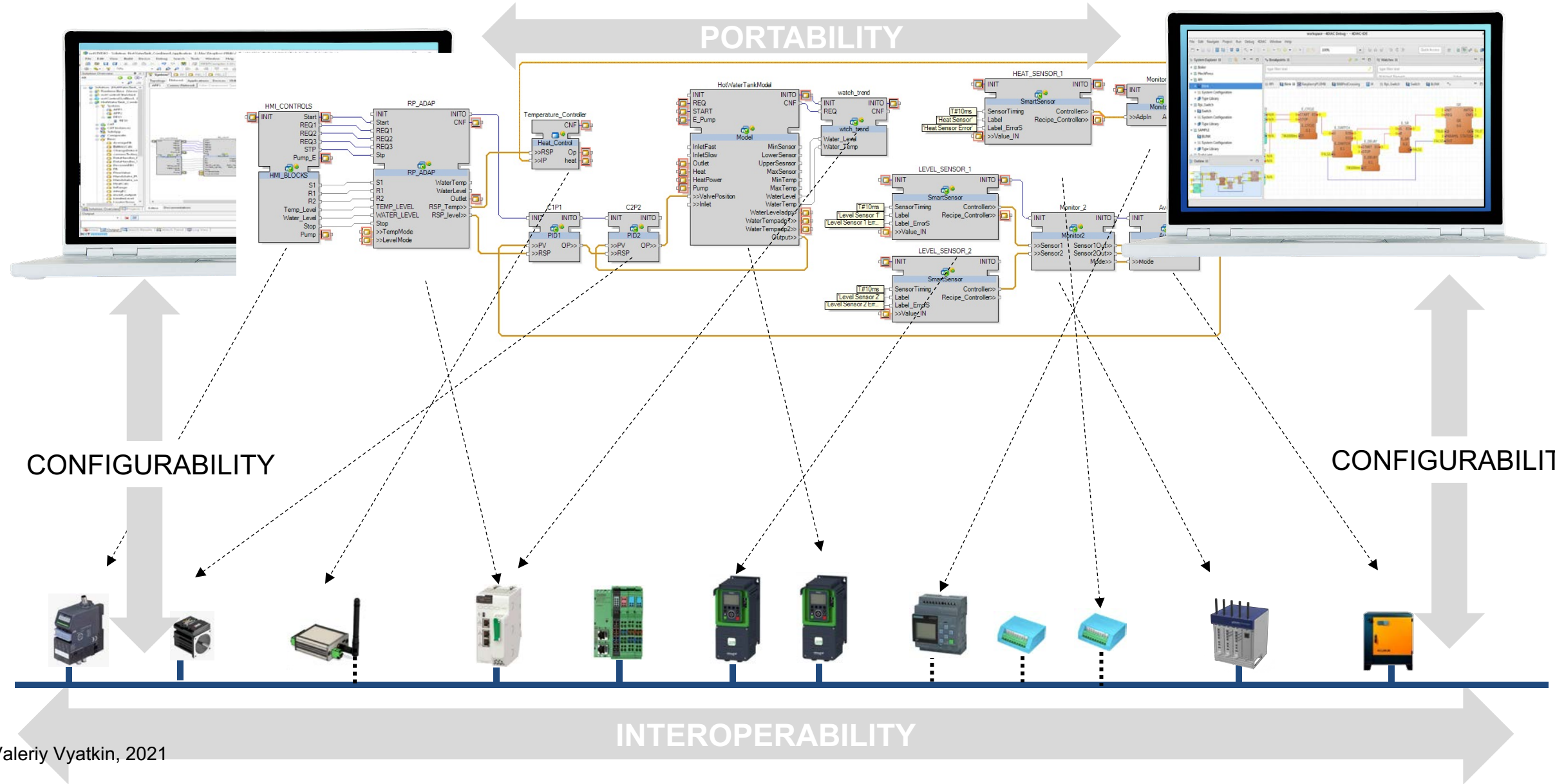

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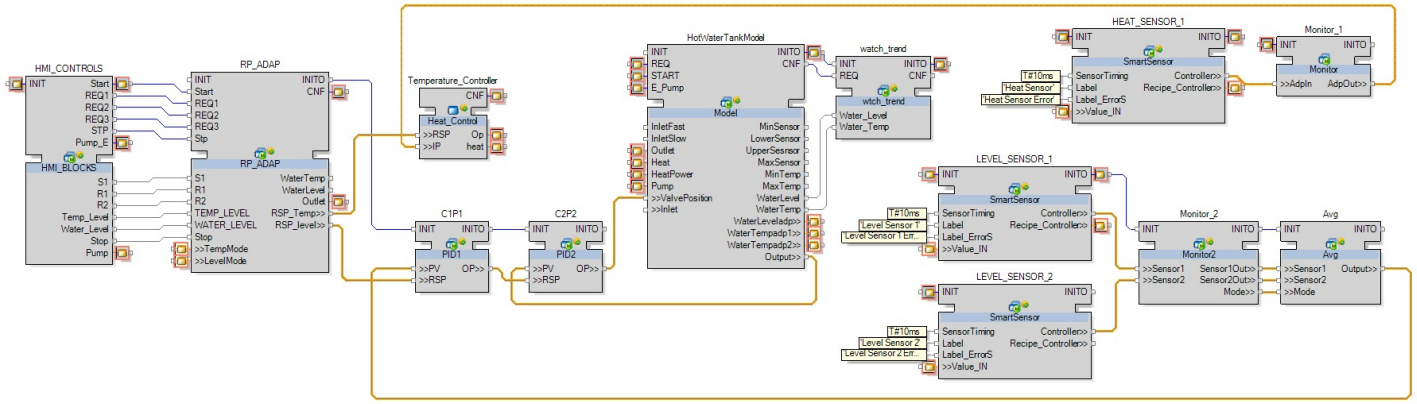
How does it address the needs?

Open Distributed Automation Architecture

Extends IEC 61131 PLC programming with a component design language for distributed automation systems



CAN BE DEFINED IN COMPLIANCE PROFILES

DeviceNet EDSs
Fieldbus DDs
IEC 61915
ISO 15745
ISO 10303
etc.

Import

Project repository

Software Tools

XML

PORTABILITY

Libraries:
IEC 61499
IEC 61131-3

NORMATIVE

Standard management protocols (XML)==>CONFIGURABILITY

Standard data transfer protocol ==>ASN.1 INTEROPERABILITY

Distributed Intelligent Devices and Controllers

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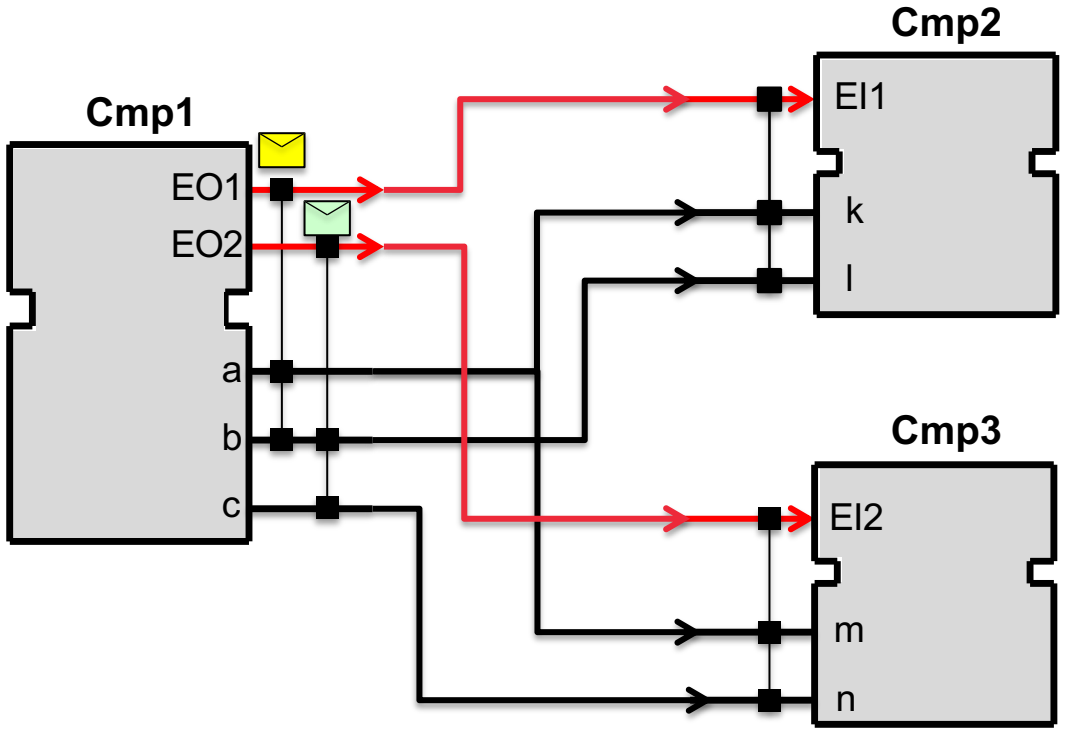
How does IEC 61499 do the trick?

Components communicating via message passing: event-driven execution



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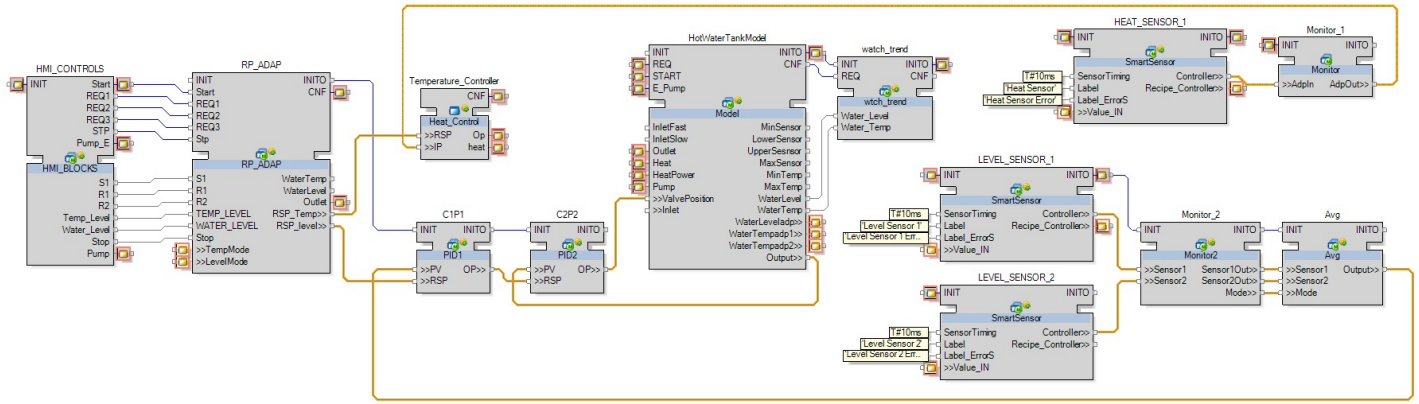
What problems does IEC 61499 solve?

- System-level Architecture that reduces software development complexity in distributed systems
  - Reuse
  - Reconfiguration
  - Validation
- Enables Portability, Interoperability and Configurability of Automation Systems
- One-click distribution of code to multiple controllers
- Towards the Holy Grail of automatic software generation?



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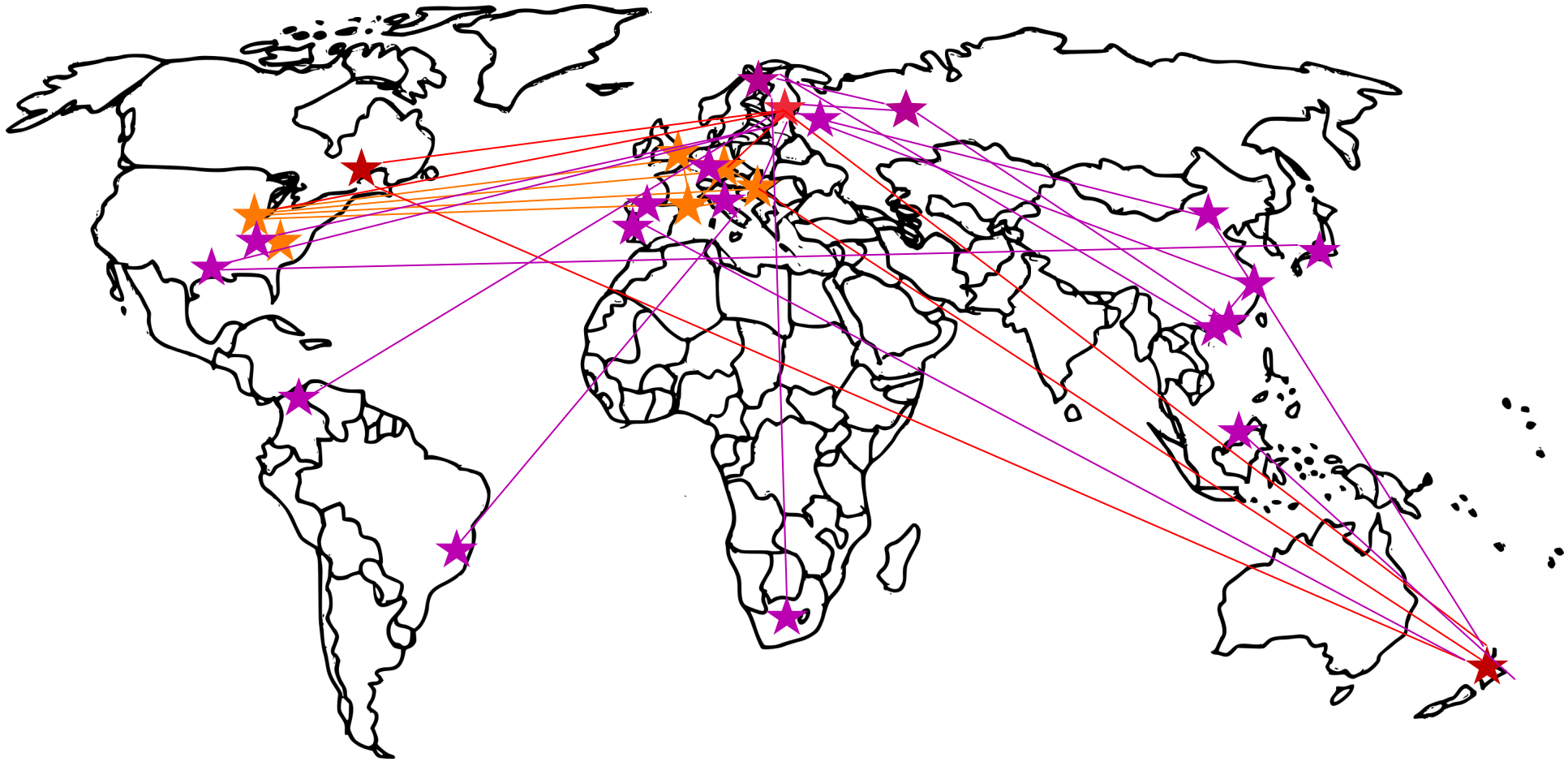
IEC 61499 Global Research Network



2021

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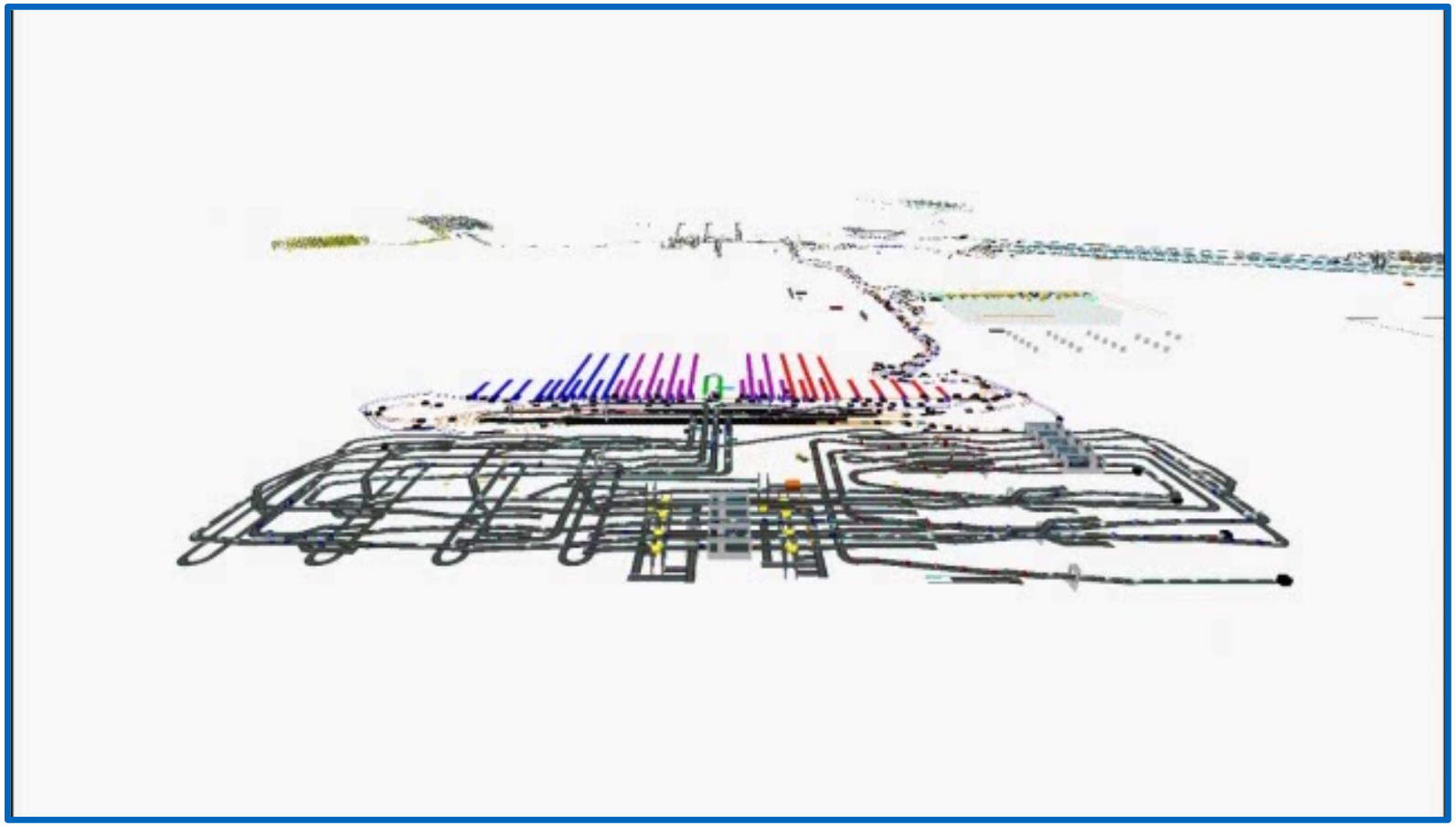
Airport Baggage Handling Systems



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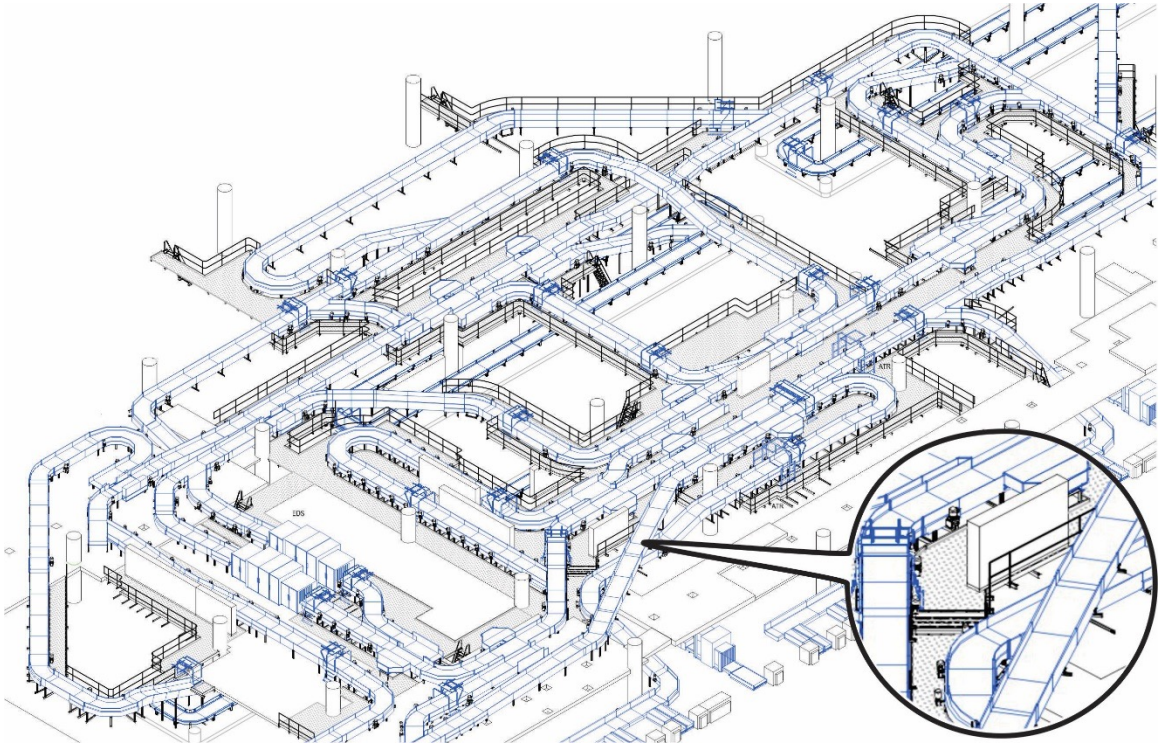
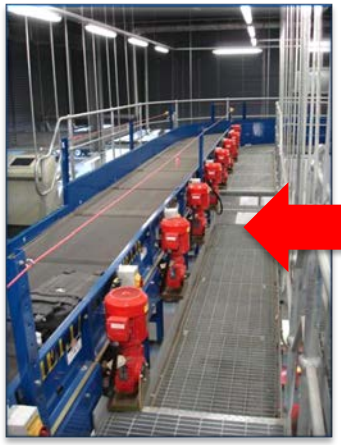
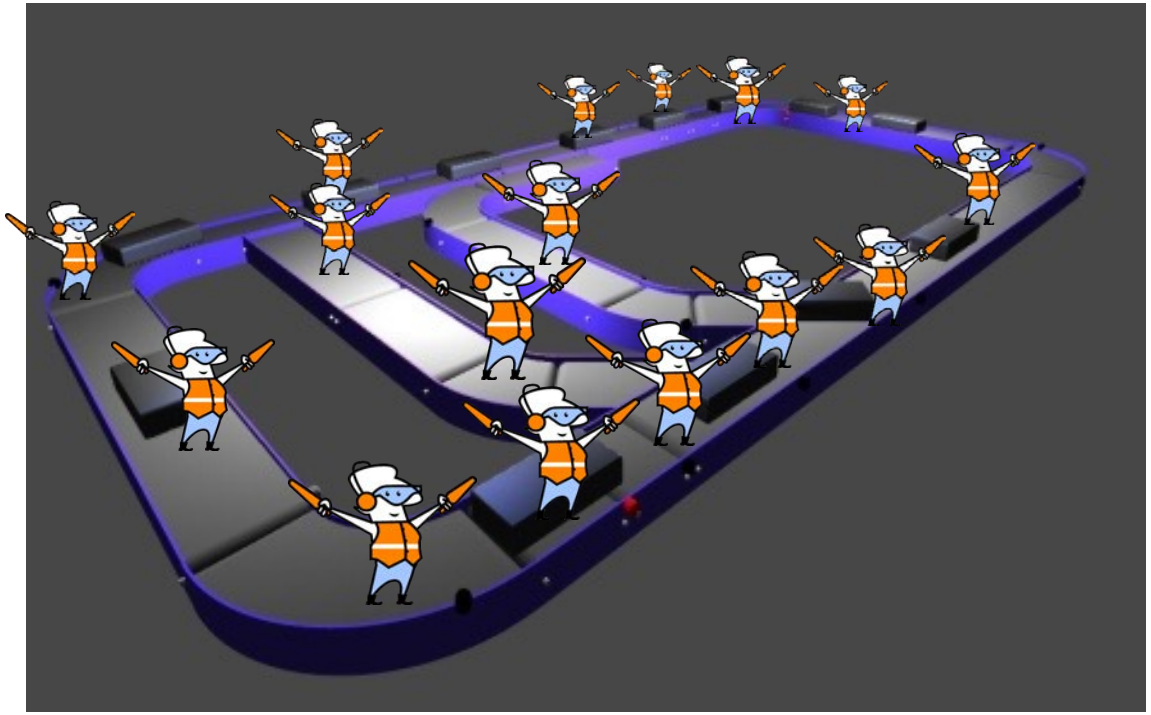
Airport Baggage Handling Systems





IoT ready

Decentralised Multi-agent Control



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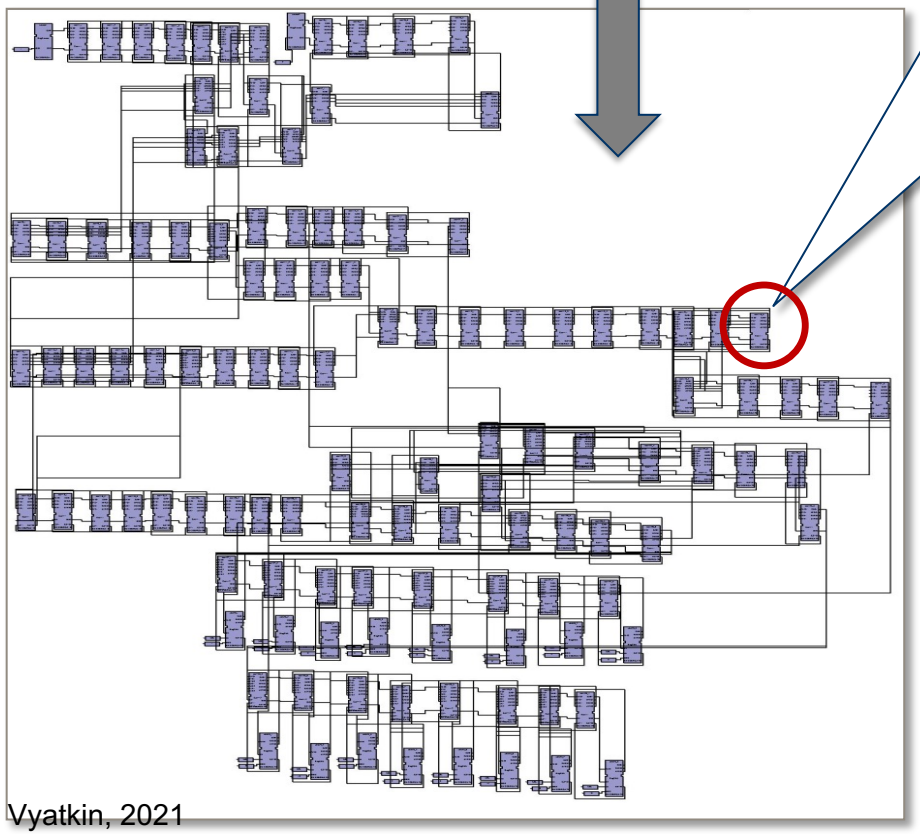
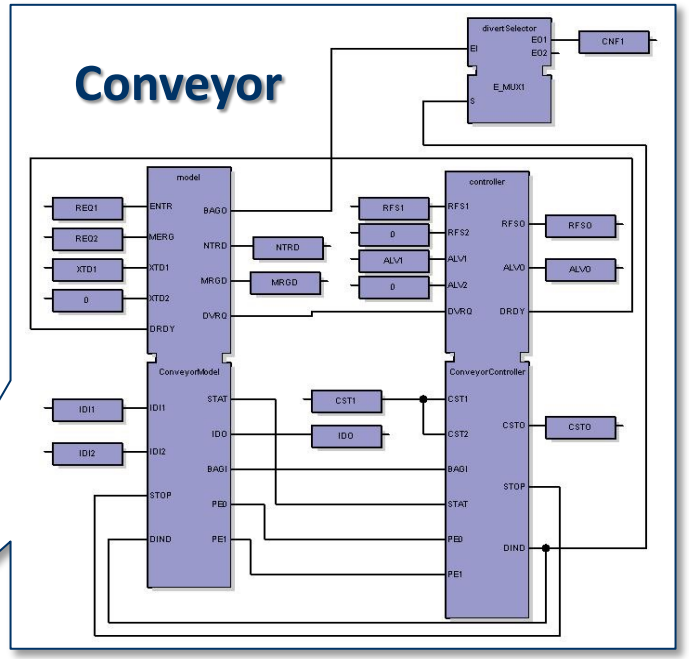
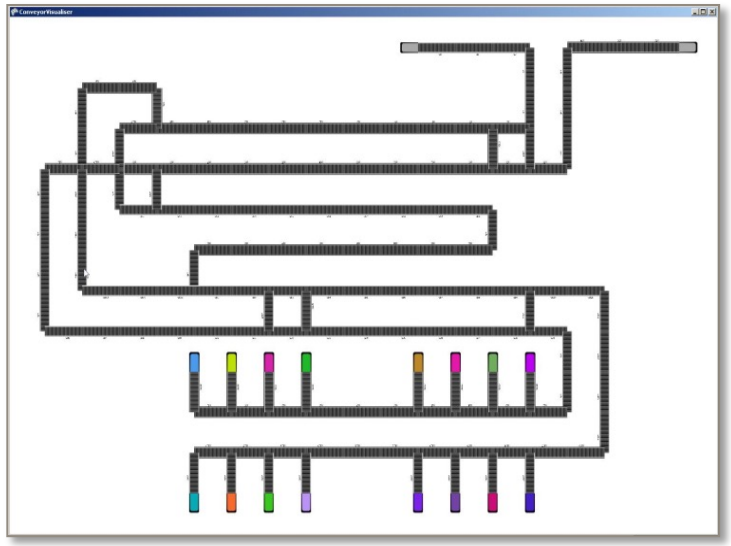
Airport Baggage Handling Systems





The system is composed of exactly same software components!



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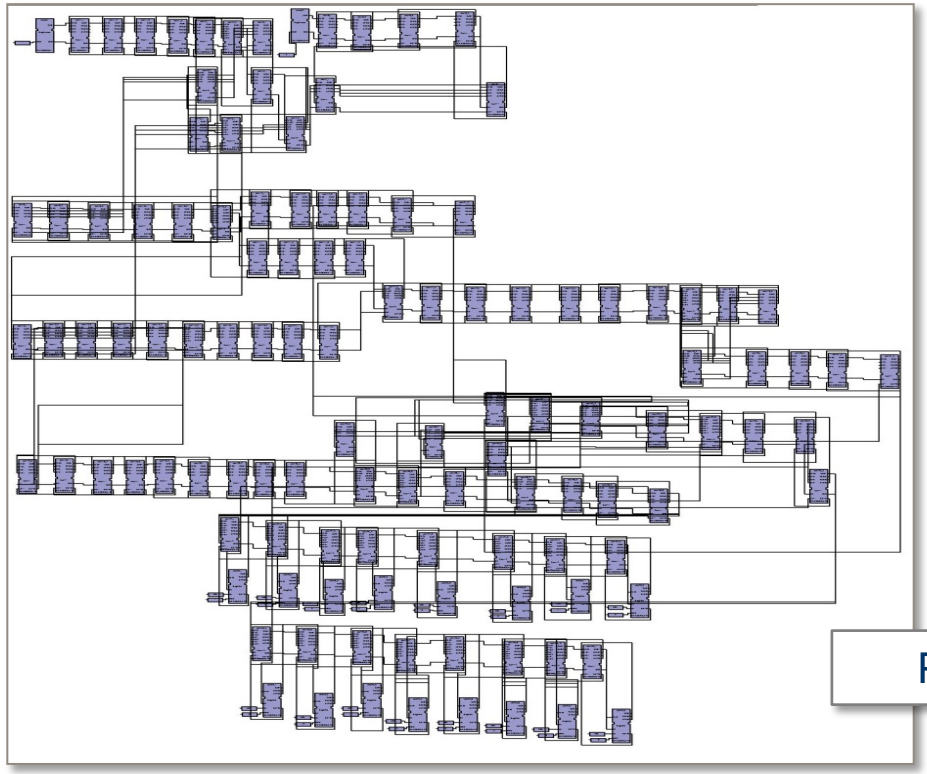
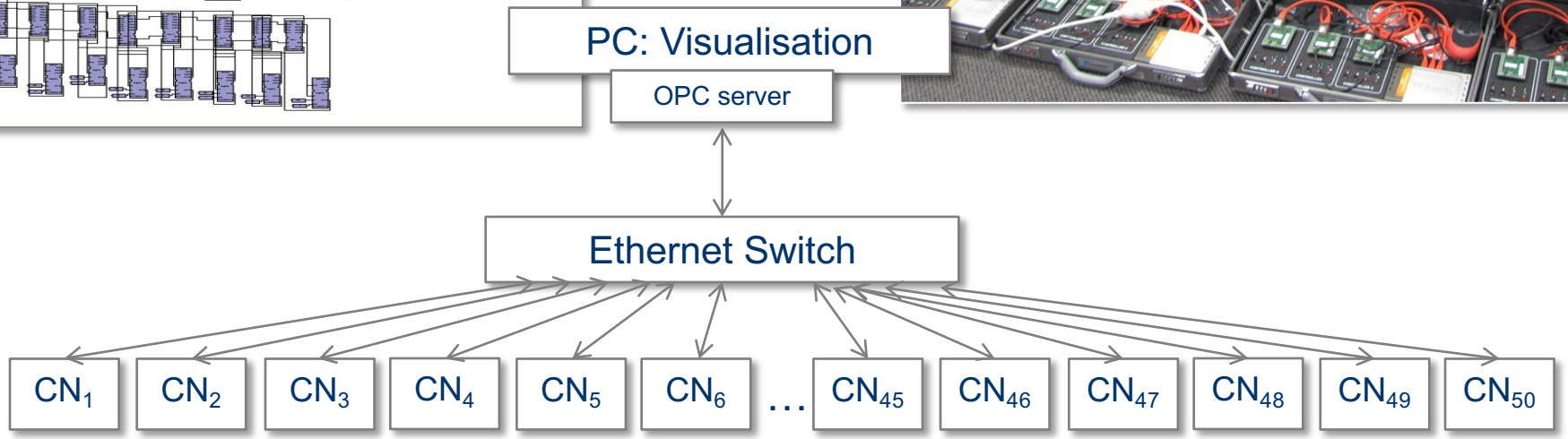
Distributed IEC 61499 Testbed with 50+ Nodes





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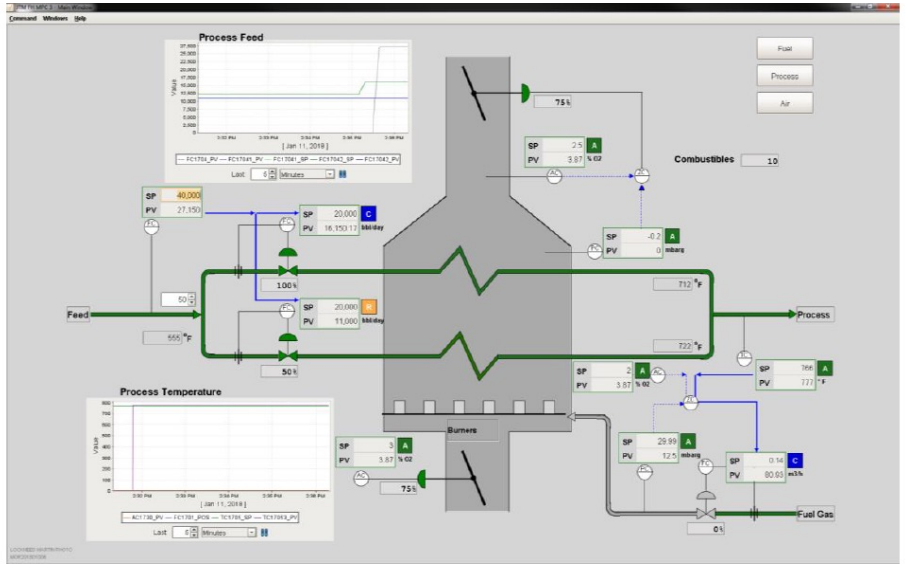
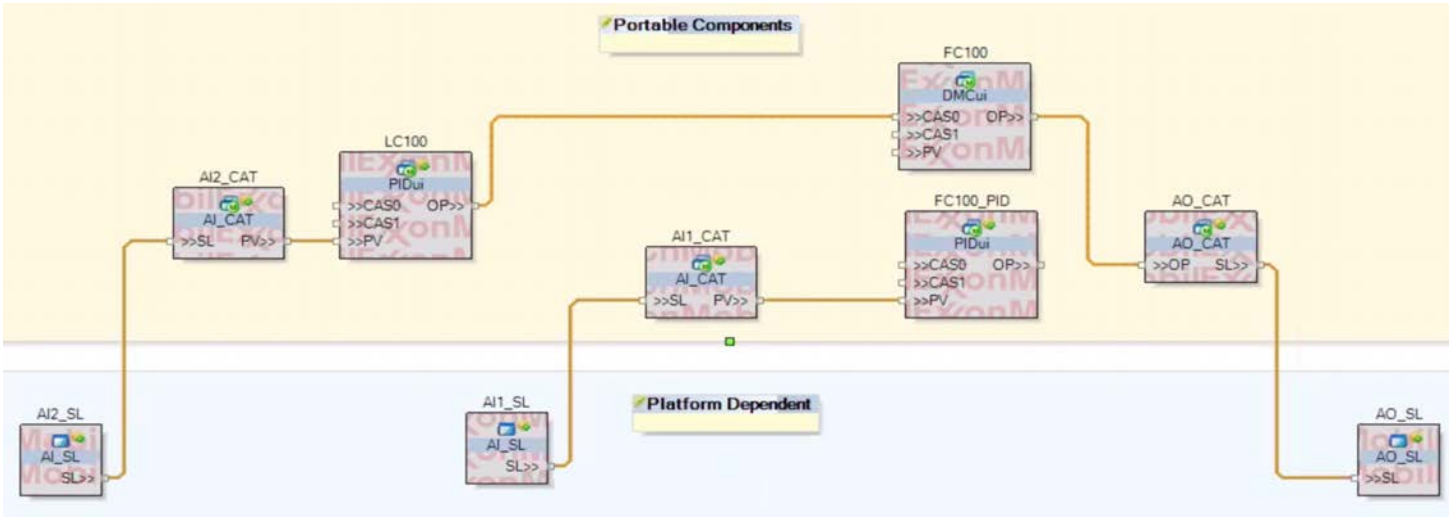
Yan J., and Vyatkin V., "Distributed Execution and Cyber-Physical Design of Baggage Handling Automation with IEC 61499", *9th International IEEE Conference on Industrial Informatics*, (INDIN'11), July, 2011, Lisbon, Portugal

ExxonMobil OPAF testbed

Realised using more than 200 HW/SW based controllers





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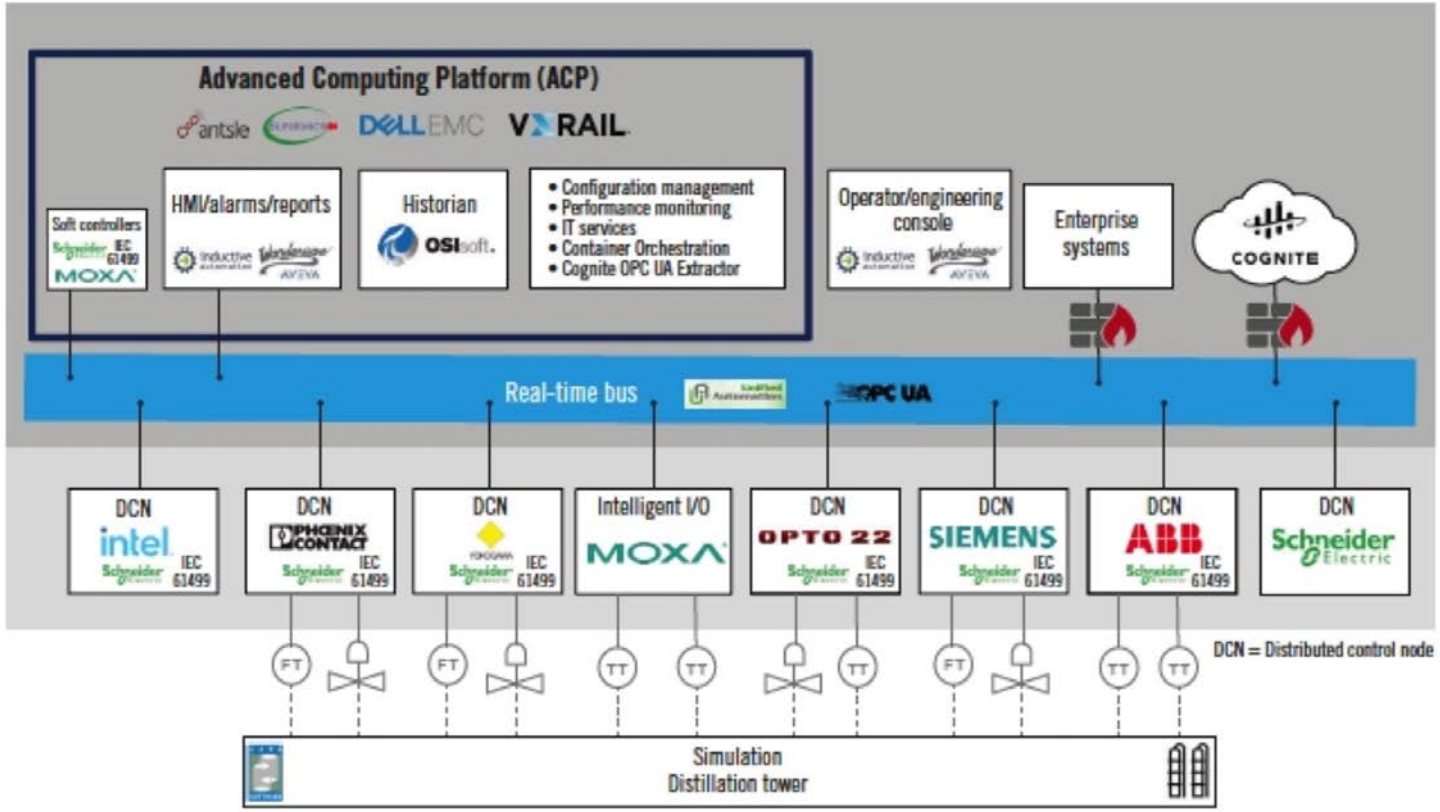
ExxonMobil OPAF testbed



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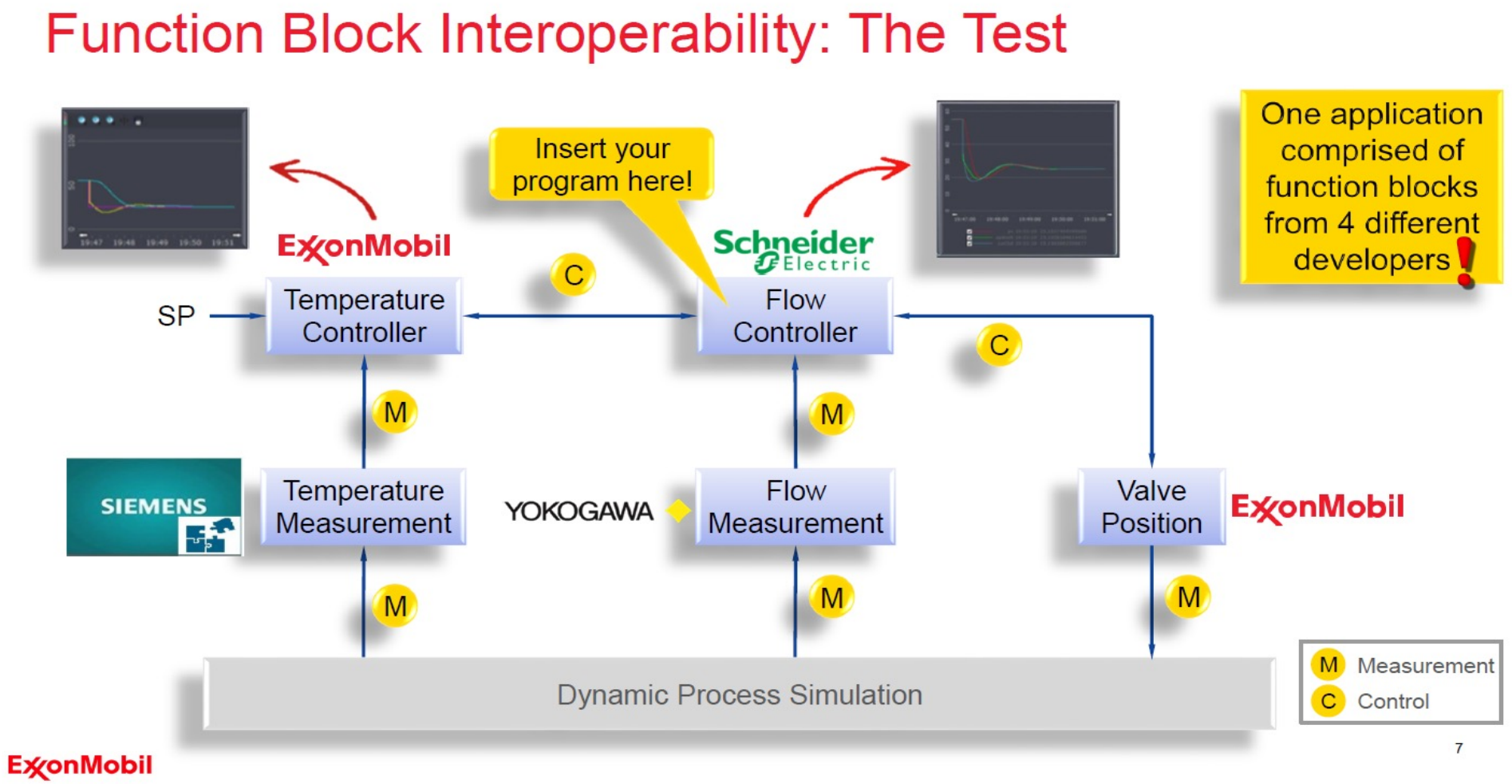
Semantic-level Interoperability



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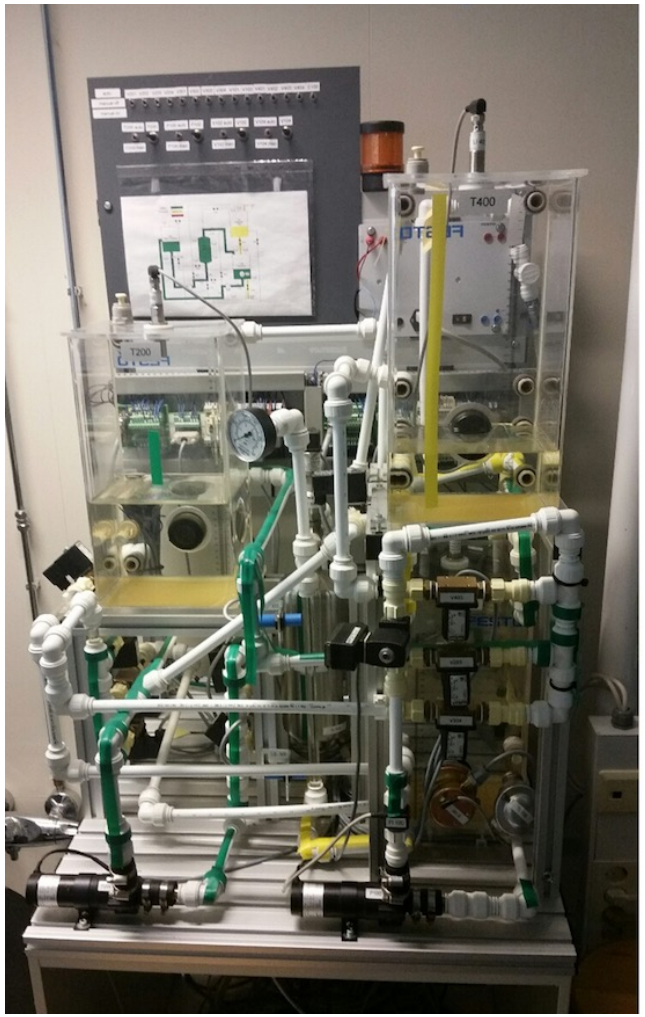
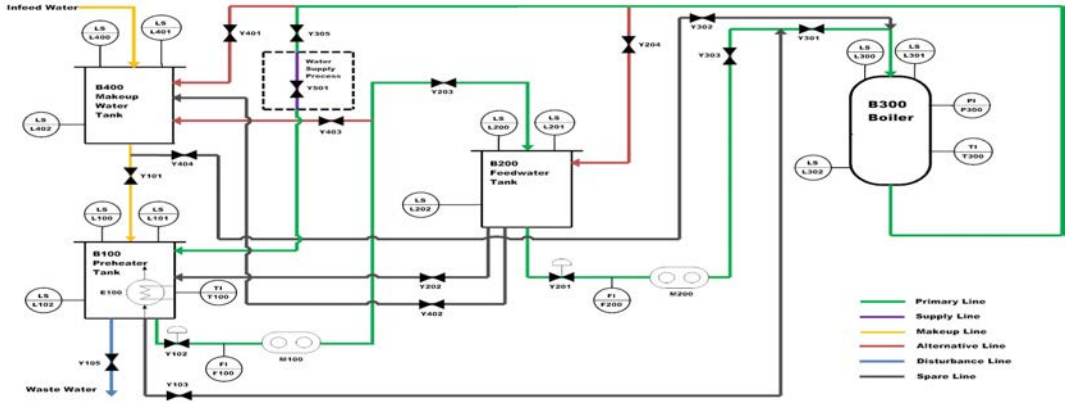
Picture courtesy S. Bitar, ExxonMobile

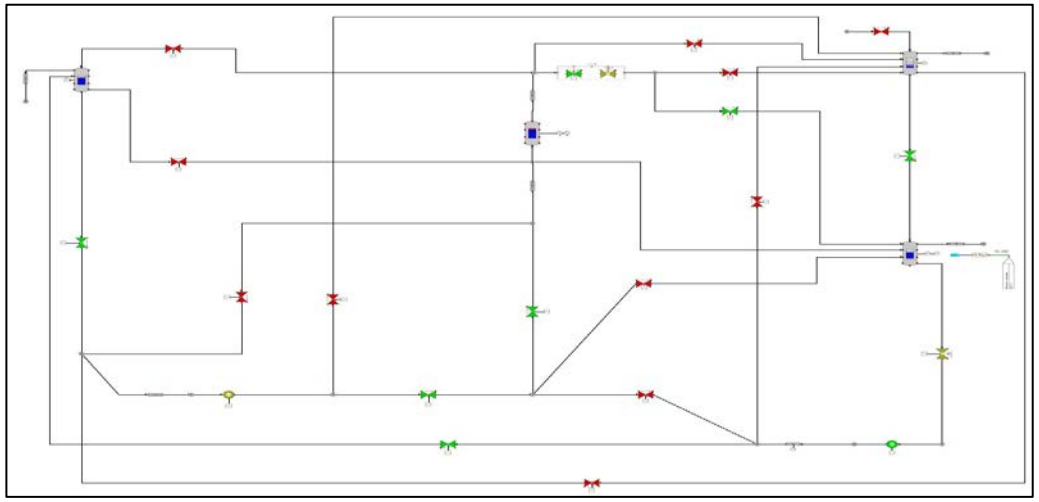
Aalto University OPAF–inspired Testbed

Water process laboratory system





APROS Simulation Model



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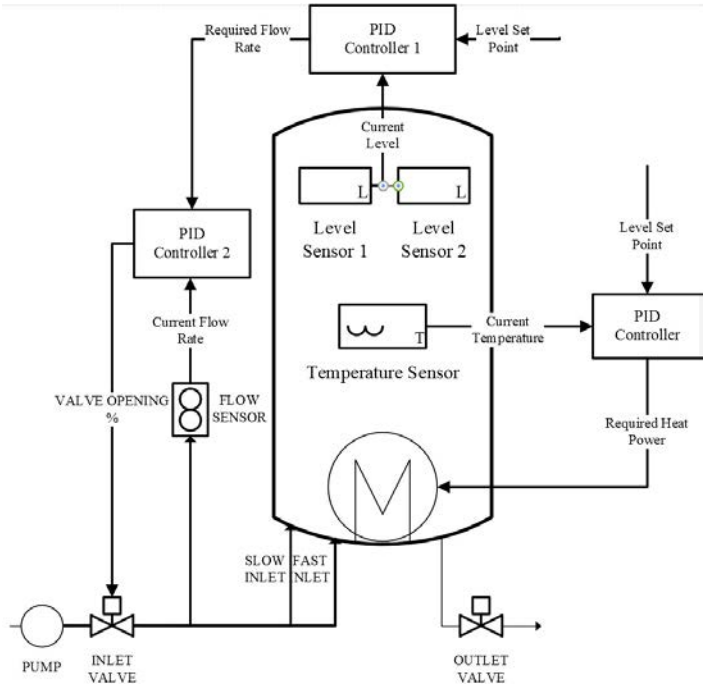
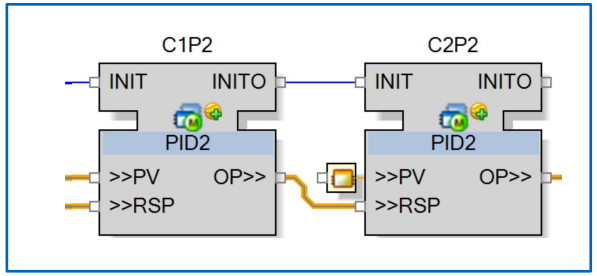
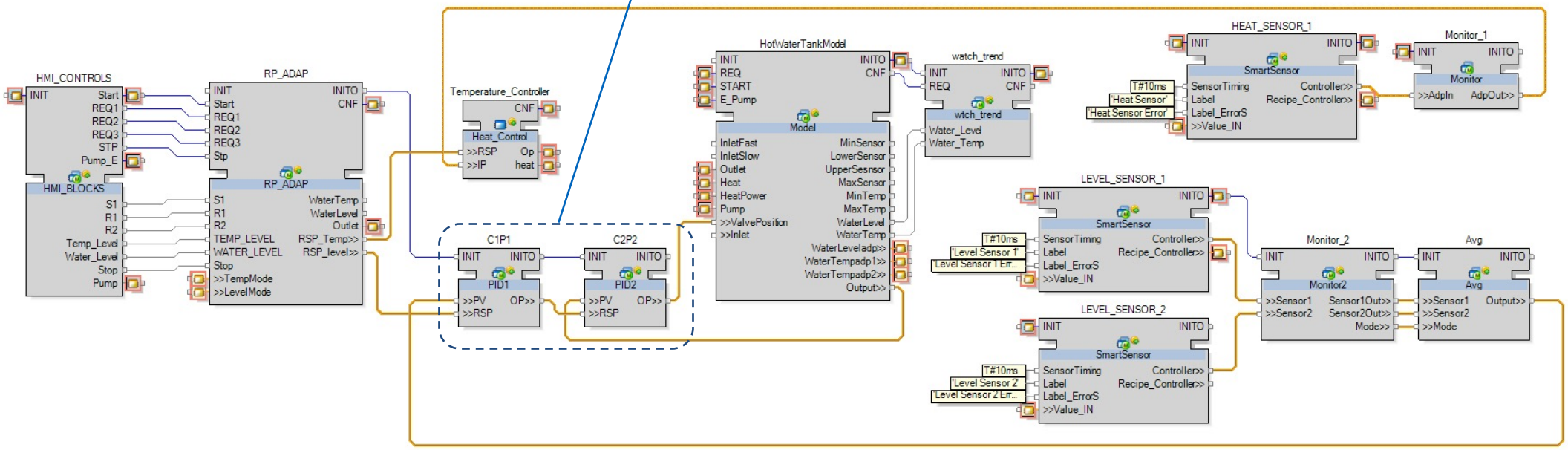
Modern automation of a batch process:

Integration of different PIDs







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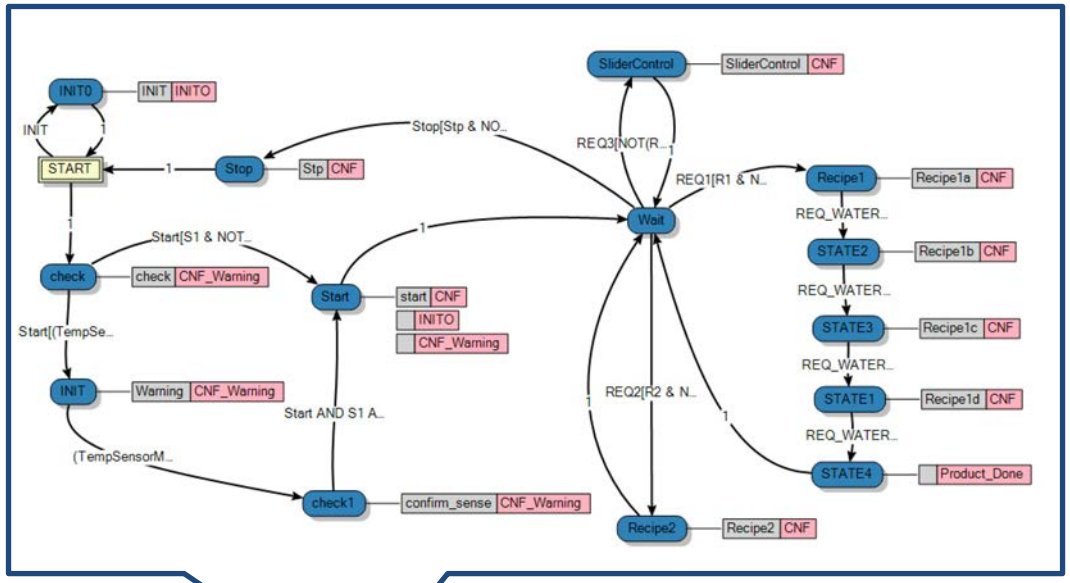
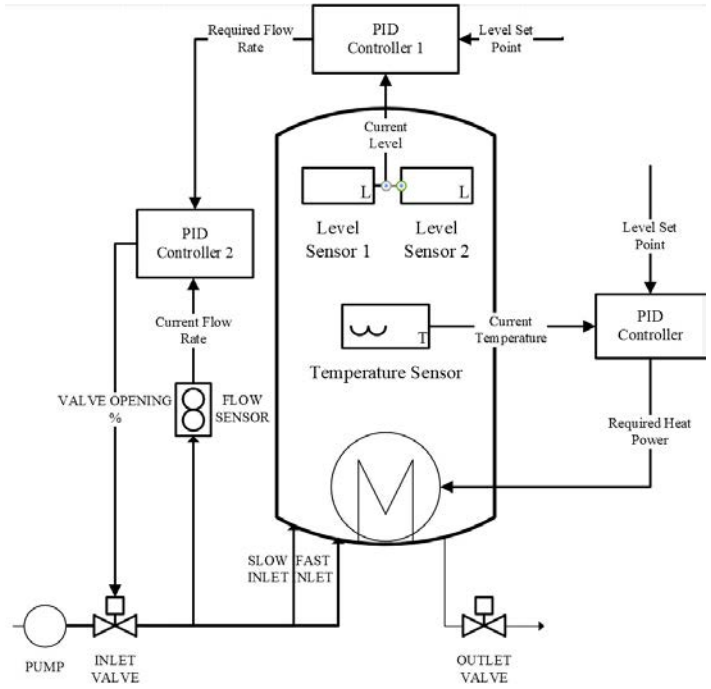
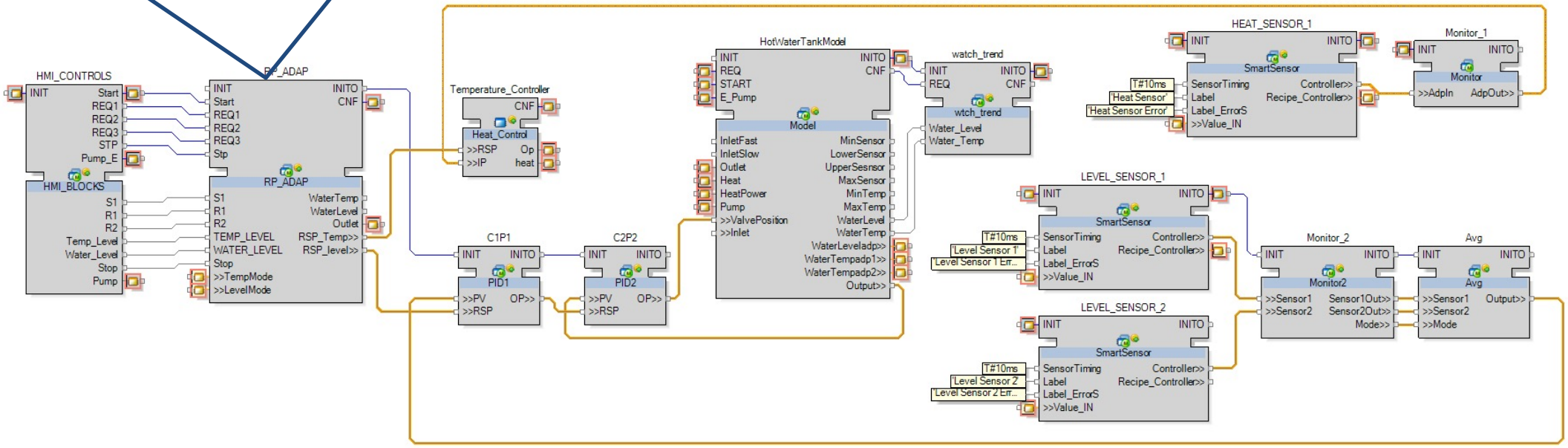
Modern automation of a batch process:

Recipe controller







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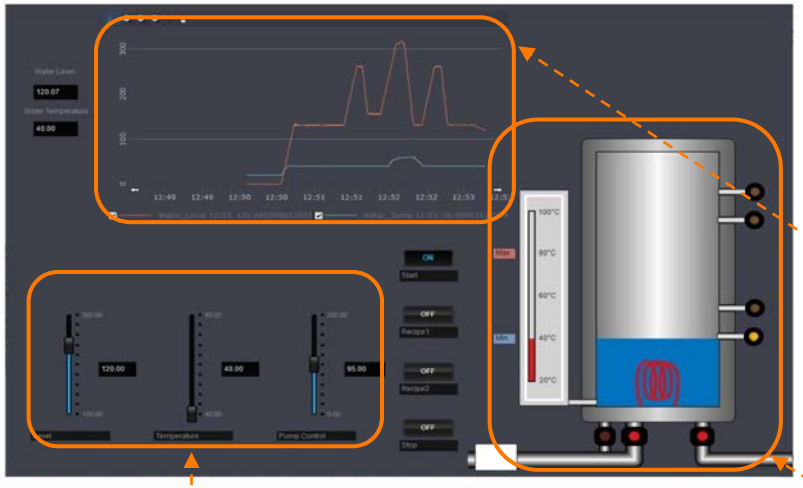
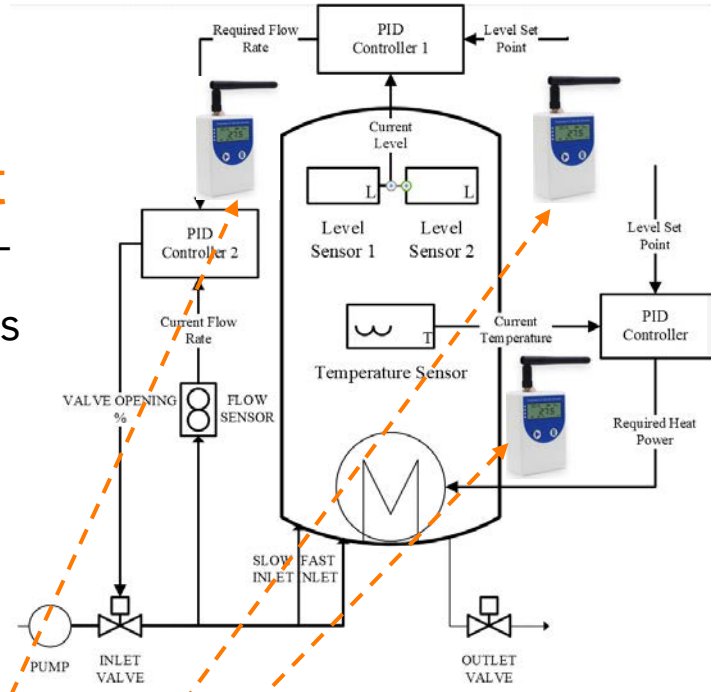
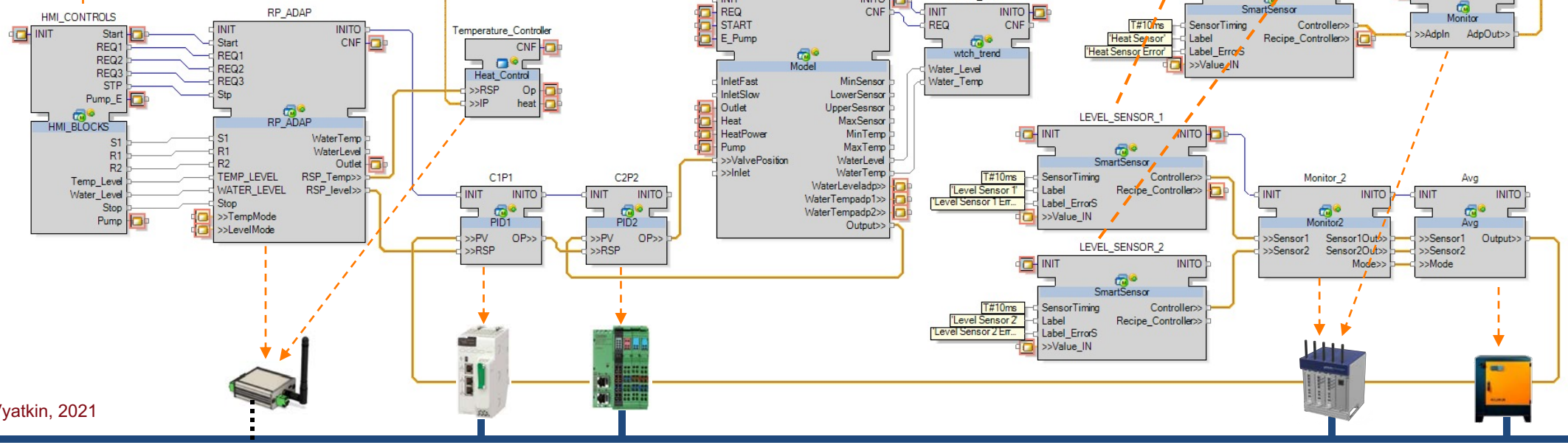
Modern automation of a batch process:



Heterogeneous deployment

One application combines OT, IT, IoT and Digital Twin functionalities, and is deployed seamlessly to a distributed heterogeneous network of communicating devices.





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Flexible Assembly Model

With layout changeable during the operation

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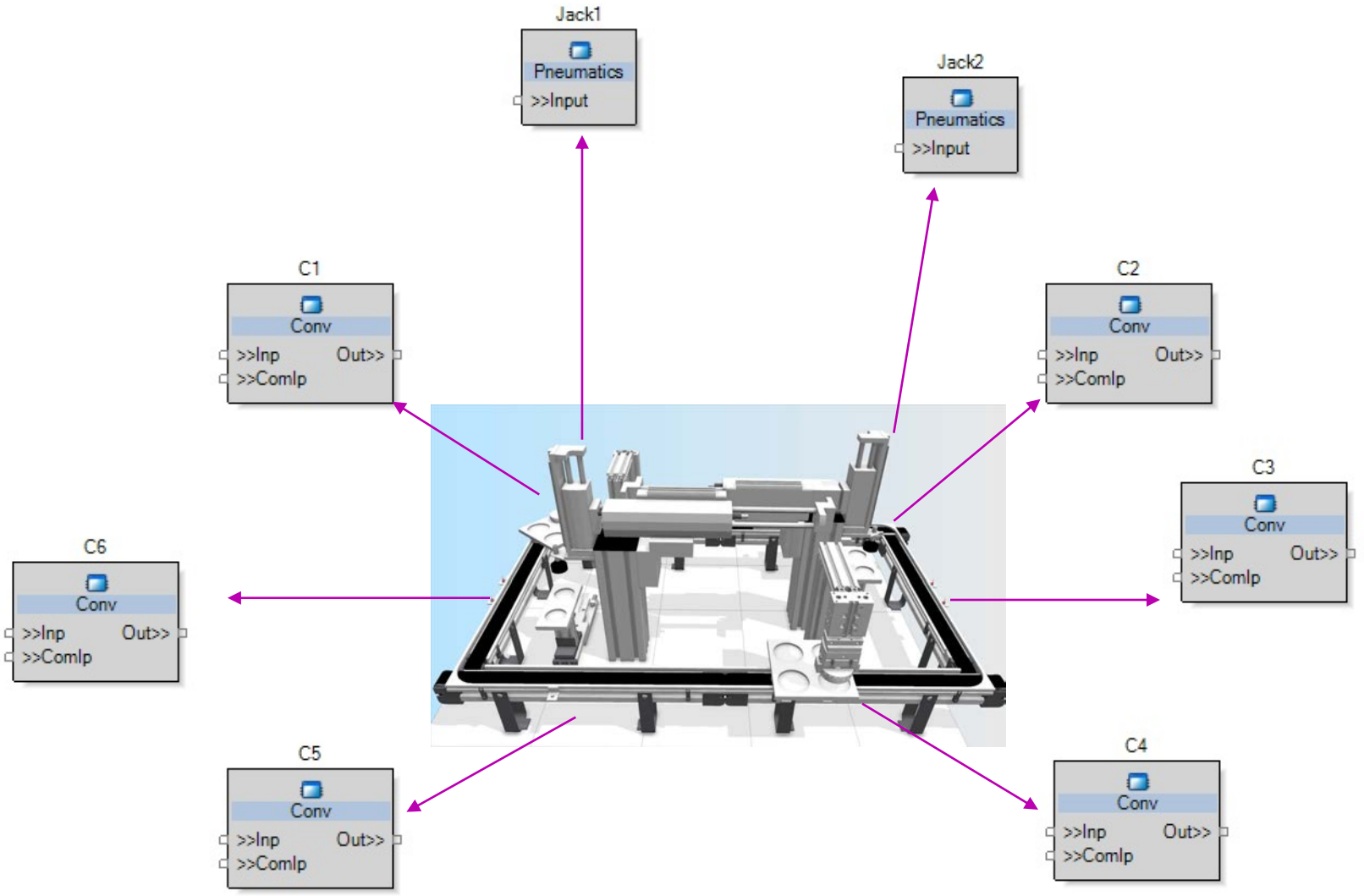
Programming with Function Blocks



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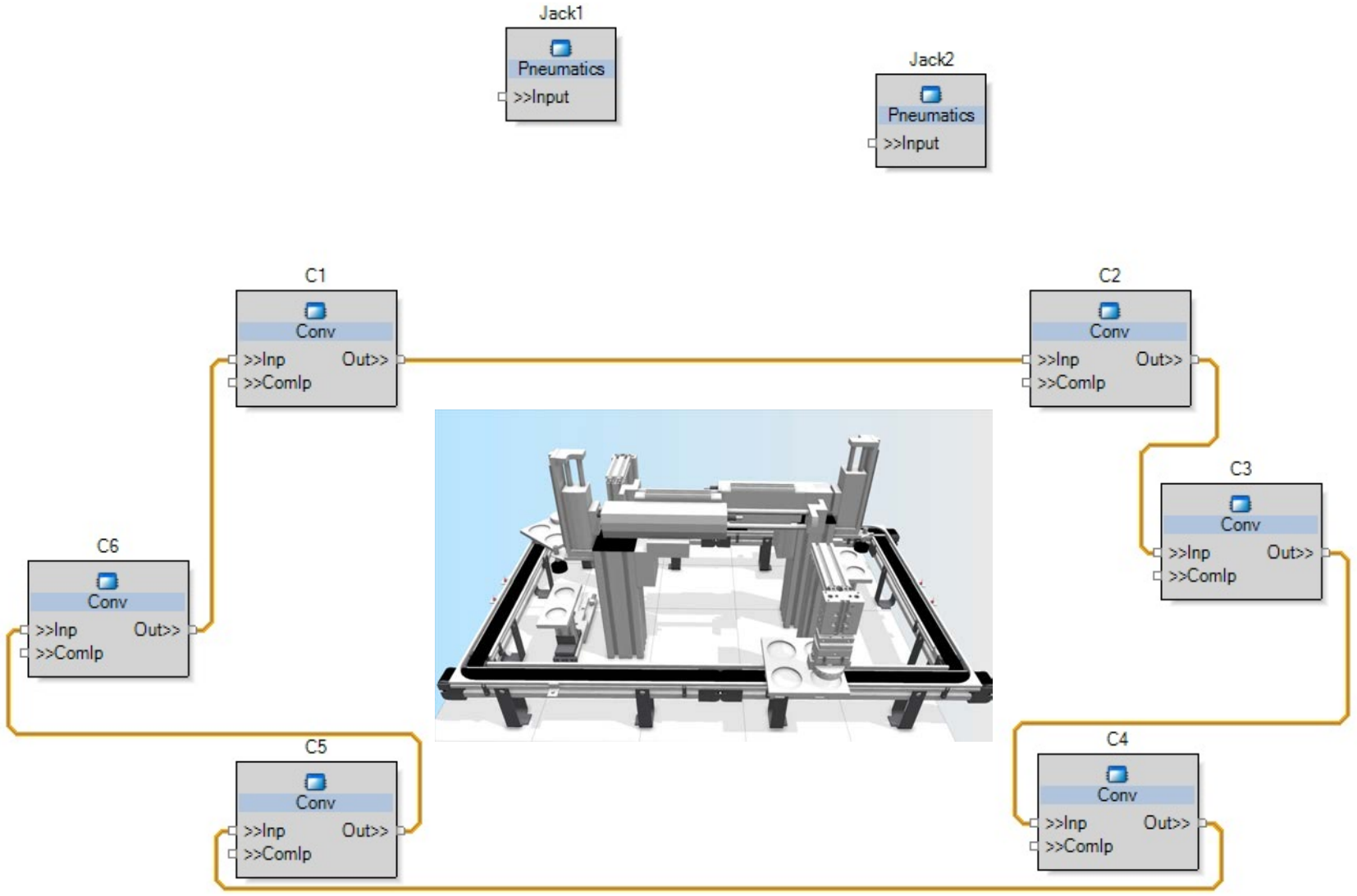
Programming with Function Blocks



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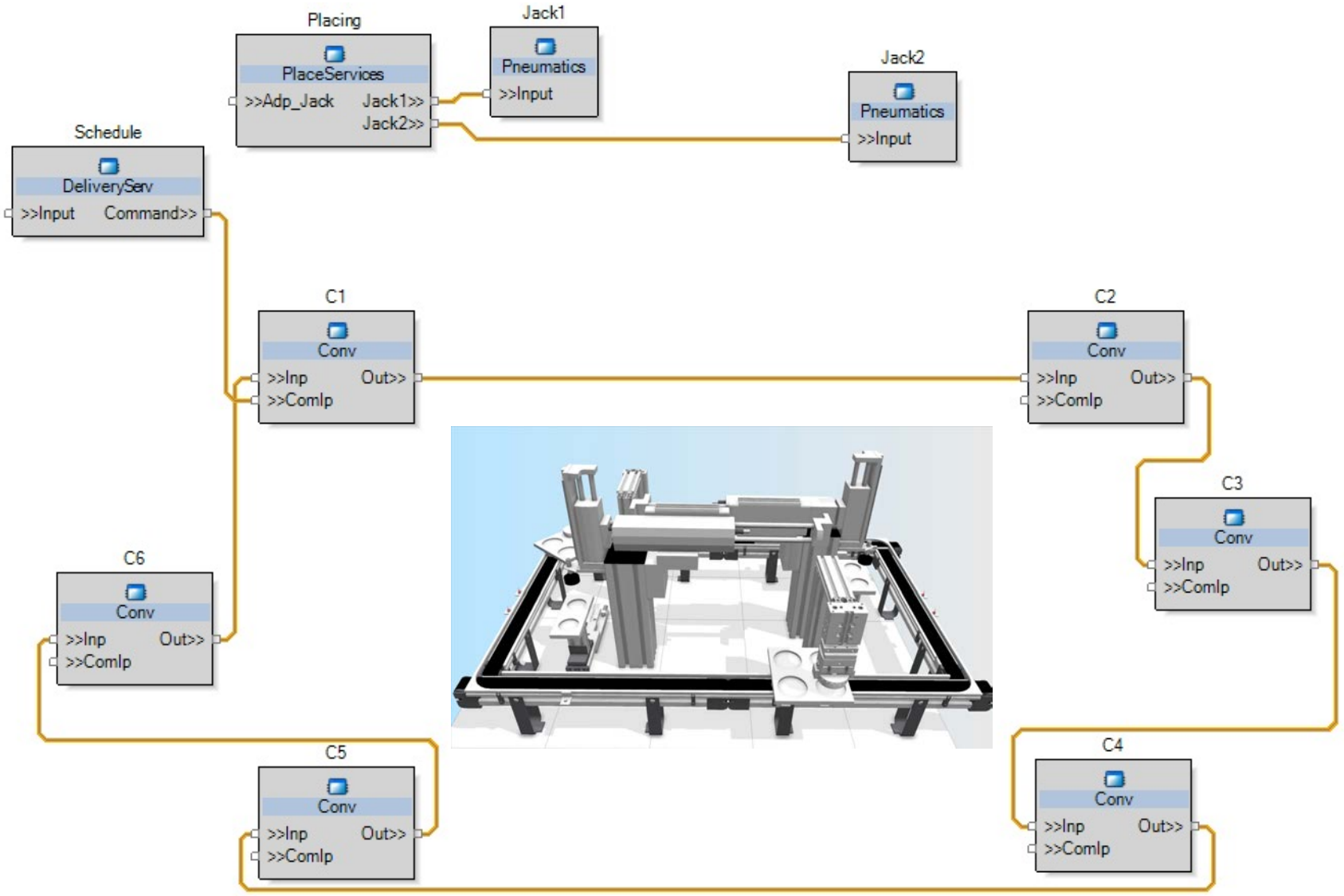
Programming with Function Blocks



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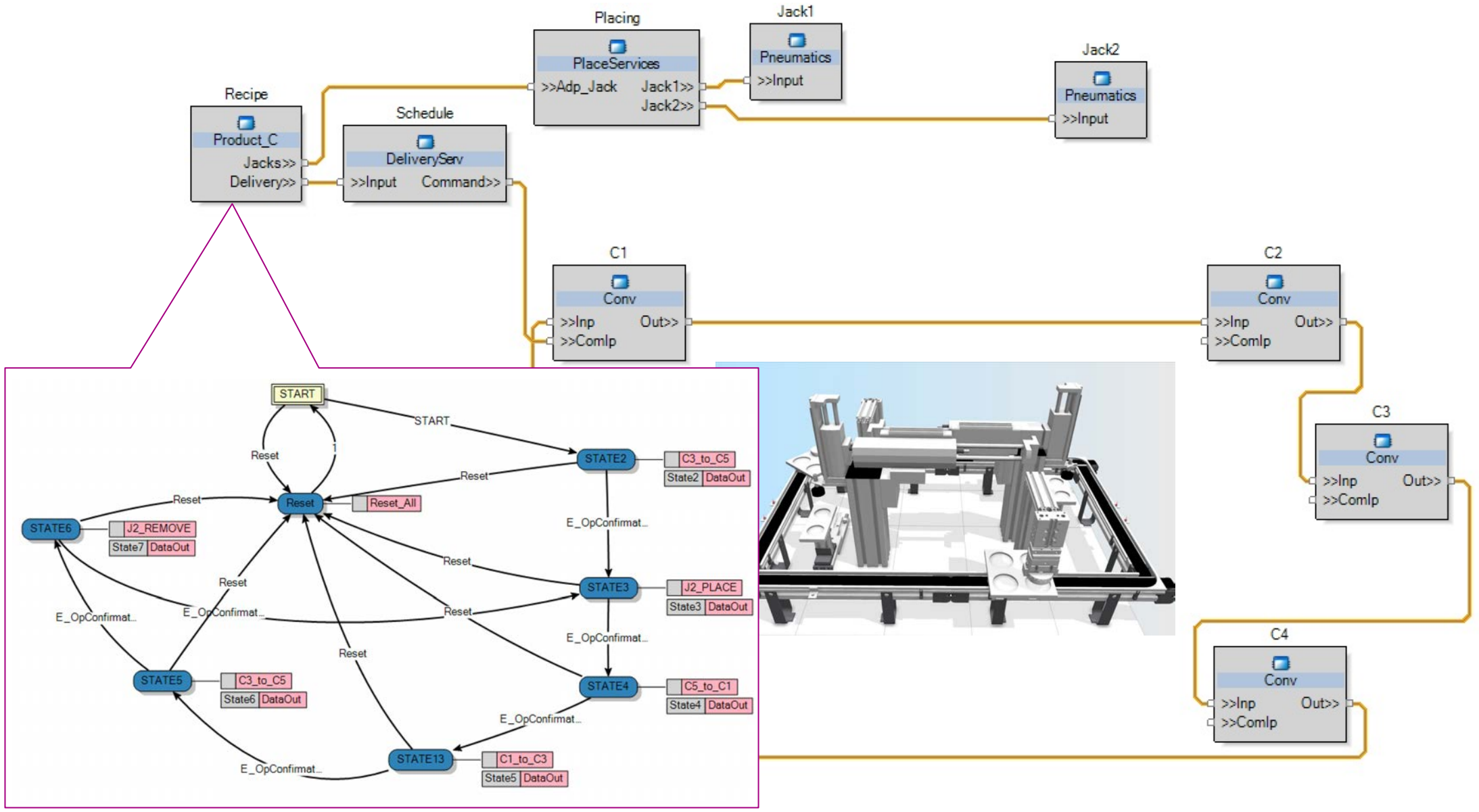
Programming with Function Blocks



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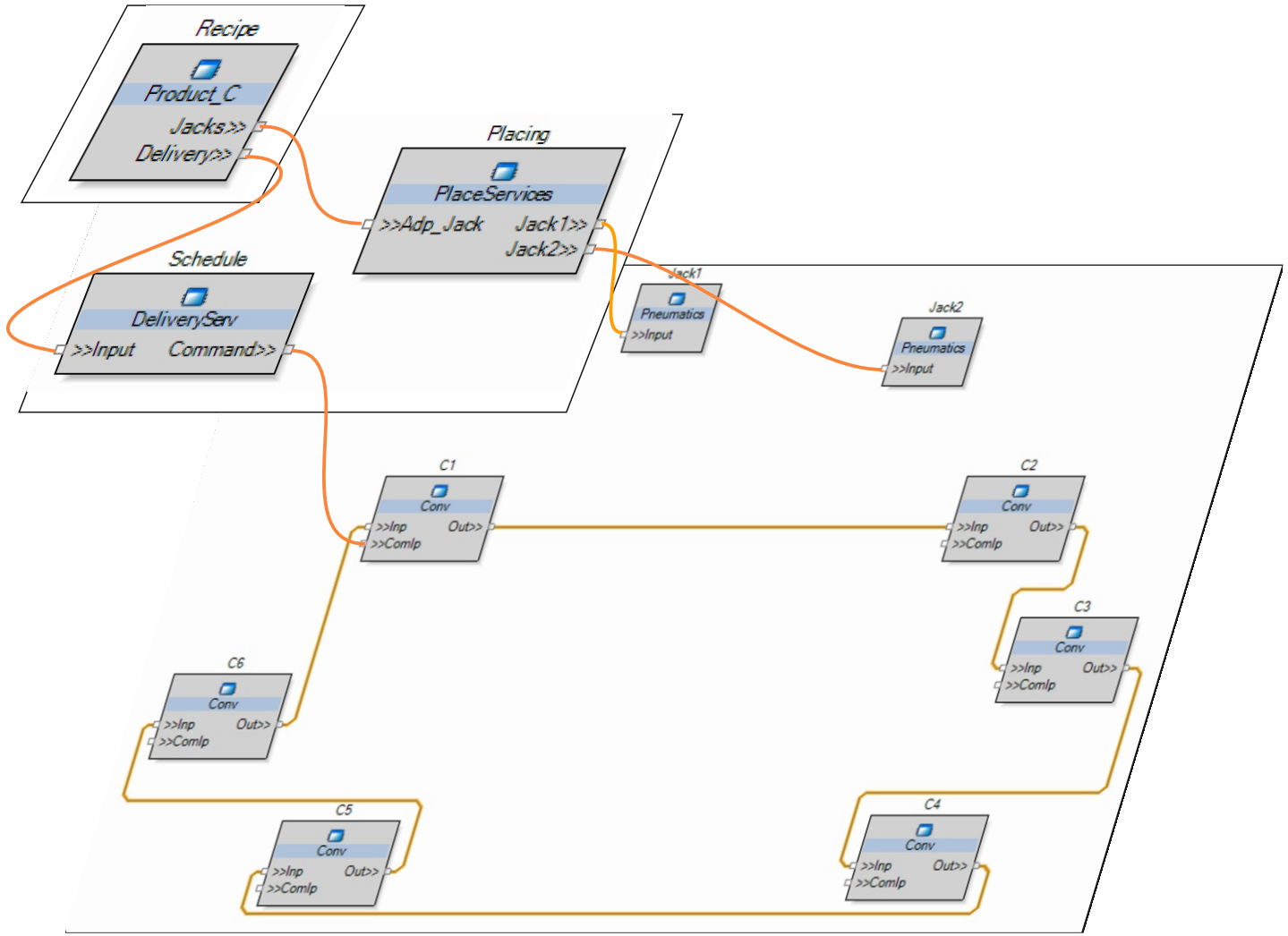
Layered services architecture

Product description layer

Planning services layer

Execution services layer



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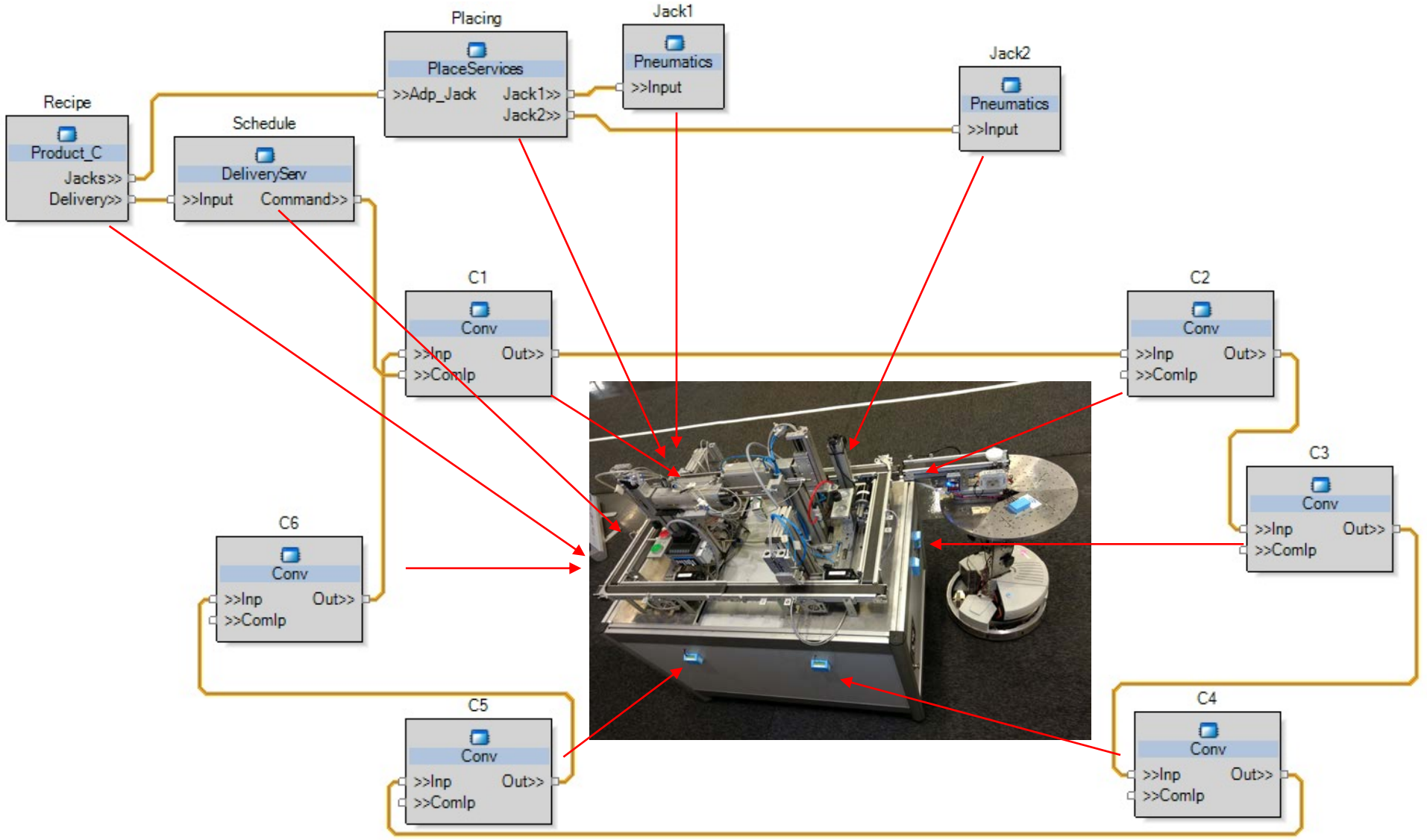
Distributed deployment magic



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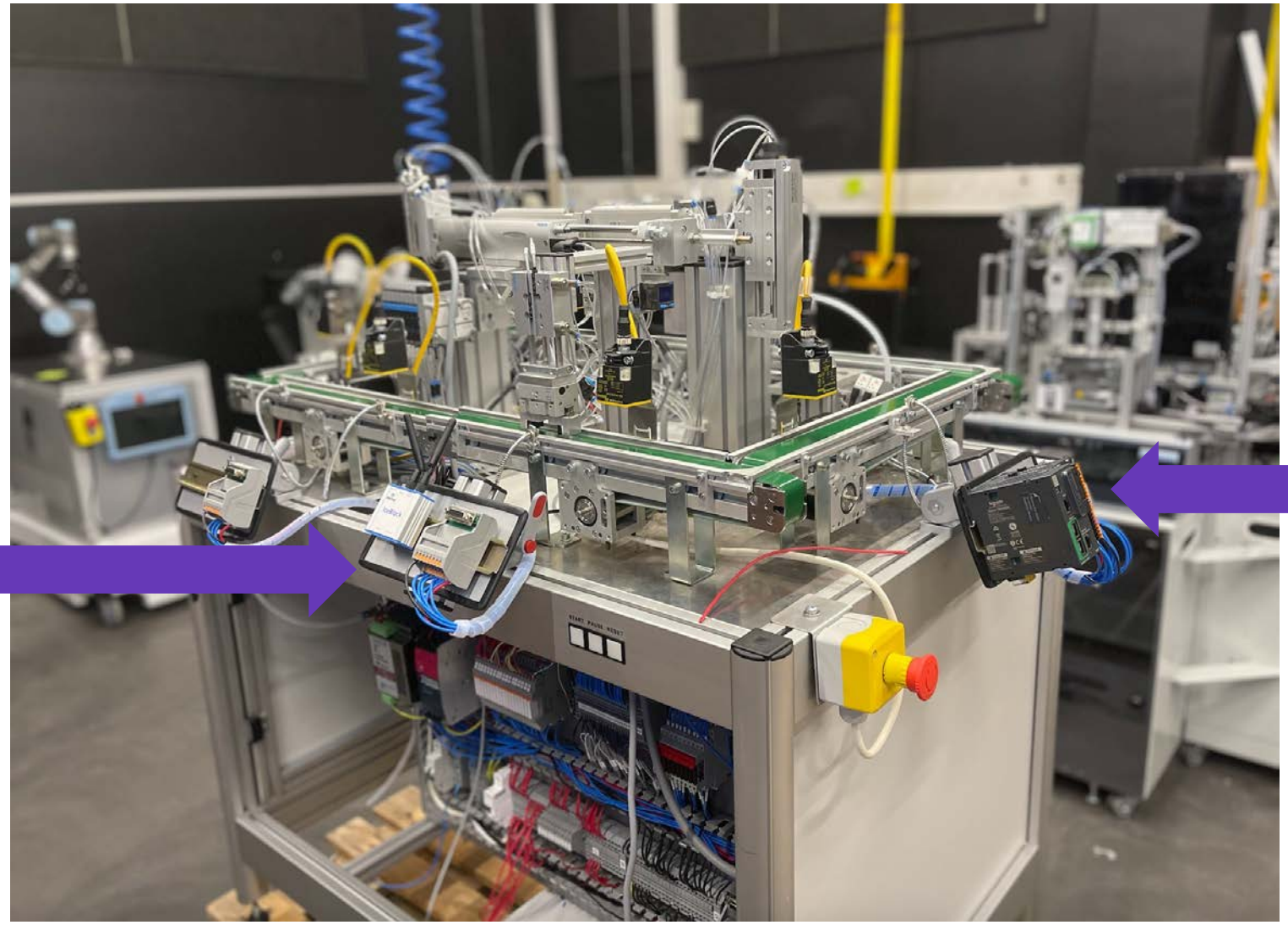
Deployment to Heterogeneous System



Flexbridge
Iceblock nanoPLC

Schneider Electric
Modicon 251

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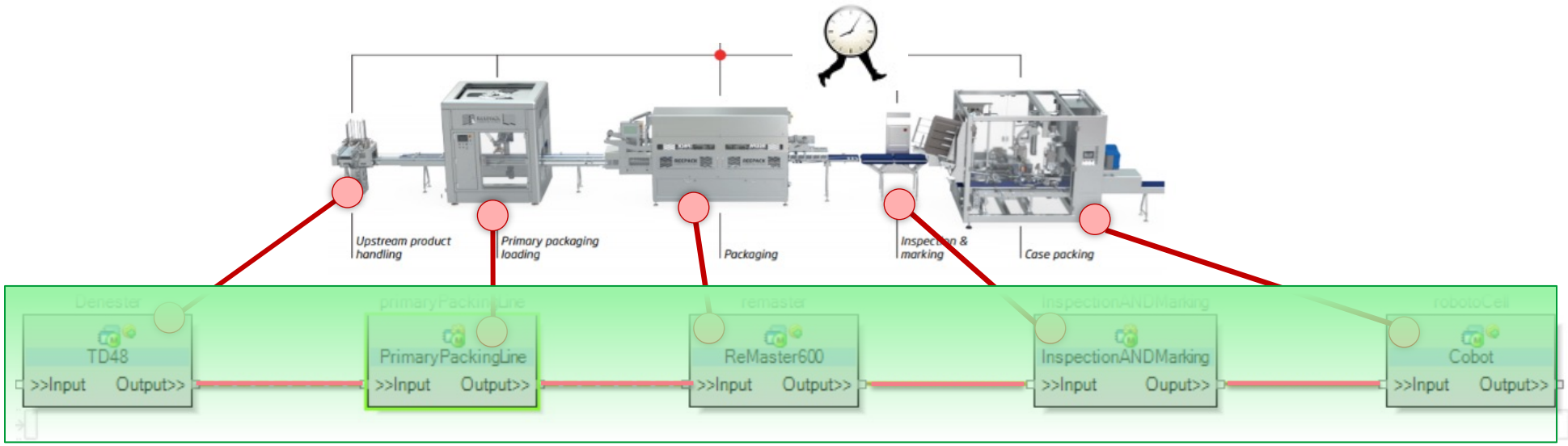
Enabler of the "Plug & Produce"

- Use a **graphical design language,** without additional programming.
  - Use **single line Engineering** to plug together
  - Allow a **non-automation specialists to plug together** black-box software components
  - Engineering gains of **three to four times**



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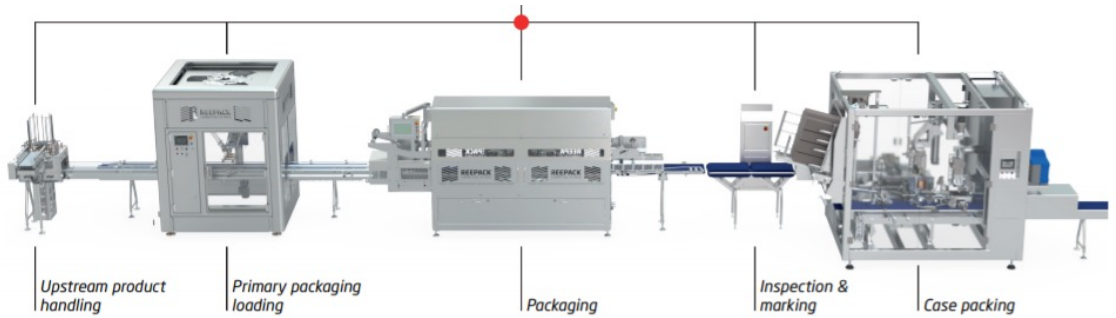
Slide courtesy A.Fritz, NxtControl

Hardware Abstraction

- **Separating** the SW application from the system HW model
- **Independently** of the underlying control devices

- **Distributed and centralized** architectures
- **Scalable** from small footprint HW to virtualisation



From field devices, controllers, to edge computers

- Hardware is Software
- Automatic I/O mapping
- Automatic distributed communication
- Automatic HMI connections

Benefits:

- portable applications **across multi-vendor hardware platforms**
- enables **separation of lifecycles** for physical and digital domain

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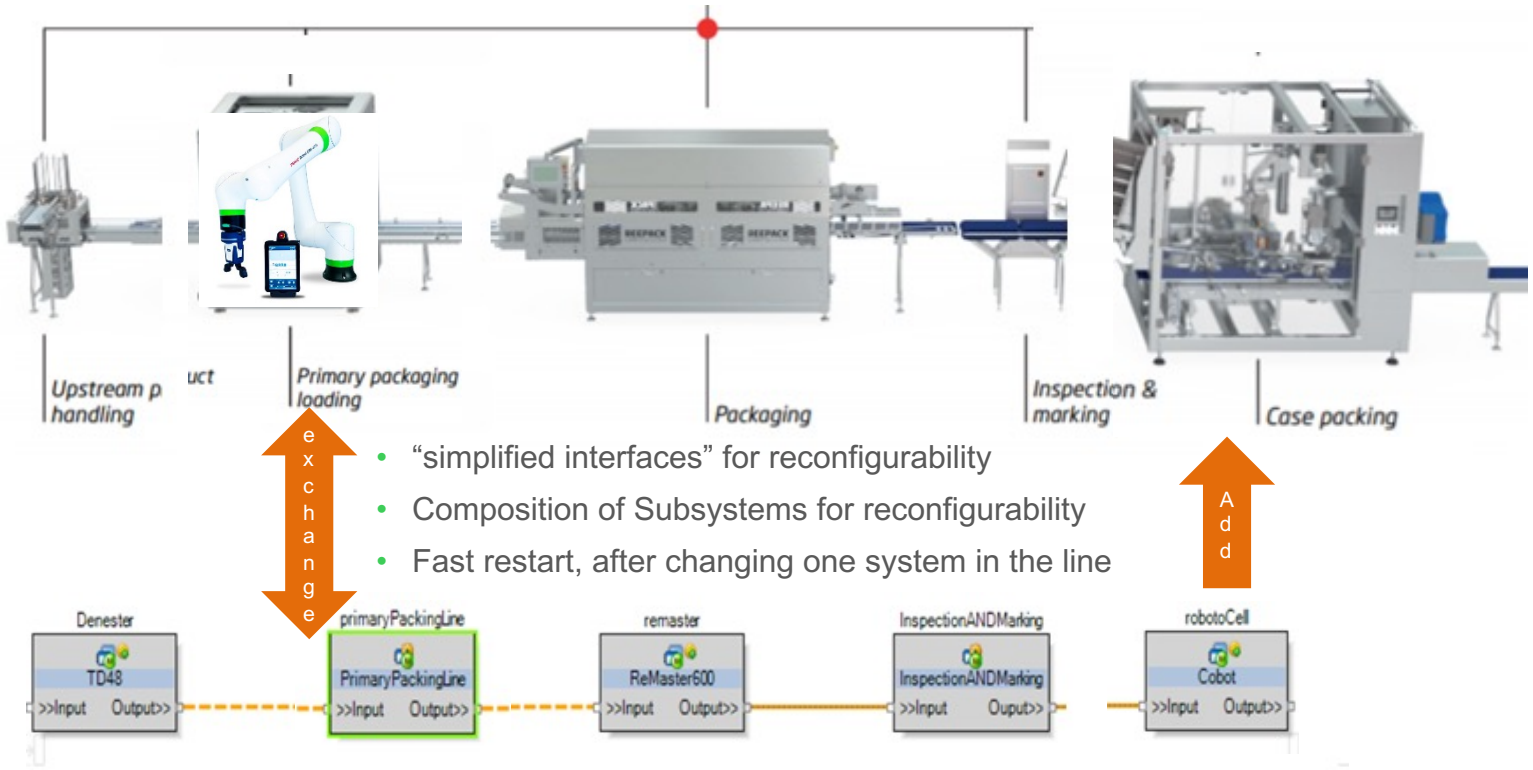
Slide courtesy A.Fritz, NxtControl

Reconfigurability



- "simplified interfaces" for reconfigurability
- Composition of Subsystems for reconfigurability
- Fast restart, after changing one system in the line

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Slide courtesy A.Fritz, NxtControl

Book on IEC 61499

- Teaching IEC 61499 to around 200 students every year
- 20 years+ research experience with IEC 61499
- Member of OPAF and upcoming user organisation
- Participate in dozens related research projects
- Authored a book on IEC 61499 published in 4 editions

Vyatkin, V. "IEC 61499 Function Blocks for Embedded and Distributed Control Systems Design", Instrumentation Society of America, 2016, **Third Edition, ISBN: 978-1-936007-93-6**

Vyatkin, V. "IEC 61499 Function Blocks Für Den Entwurf Von Eingebetteten Und Verteilten Systemen", Instrumentation Society of America, 2014 (in German), **Third Edition, ISBN: 978-0-876640-44-9**

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Thank you for your attention!

Always happy to further discuss the IEC 61499 technology!

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