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Mitigating Delivery Delays with Virtual Commissioning

Satyam Patel and Ivan Cambronero

Agenda

- Who we are?
- Project Overview
- Emulation Challenges
- Modelling Challenges
- Emulation benefits
- Conclusion

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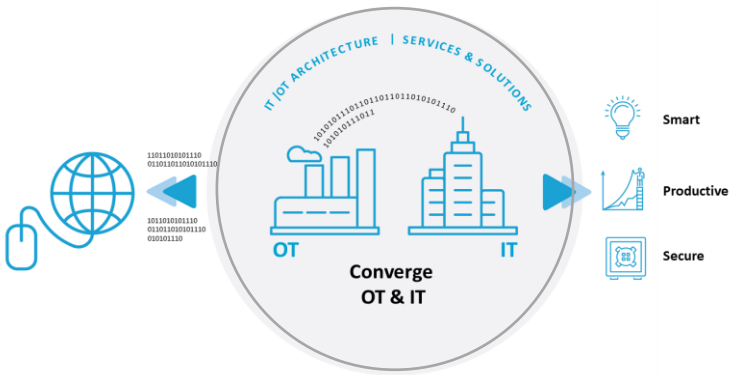
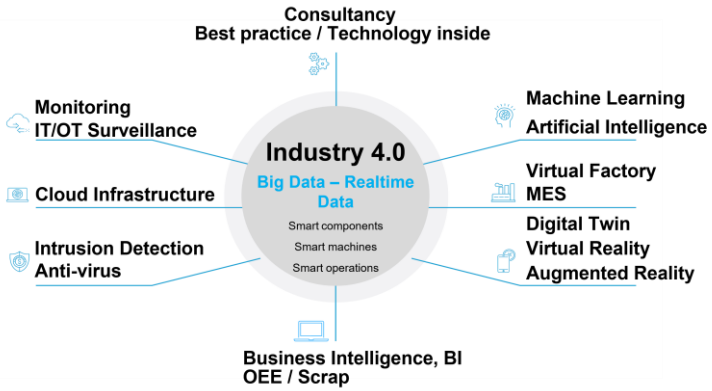
ProjectBinder - Company Overview





ProjectBinder is a company specialized in project management, Compliance and SME competences within all project phases as **implementation partner** for our customers. Our key focus is IT, automation, and network establishment primary within the GMP oriented industries.

In this aspect securing alignment of the OT and IT infrastructure strategy is often the cause of delays and added costs.

Here ProjectBinder provides a solution for IT & OT Convergence in the Industry 4.0

Geographical structure

Selected clients

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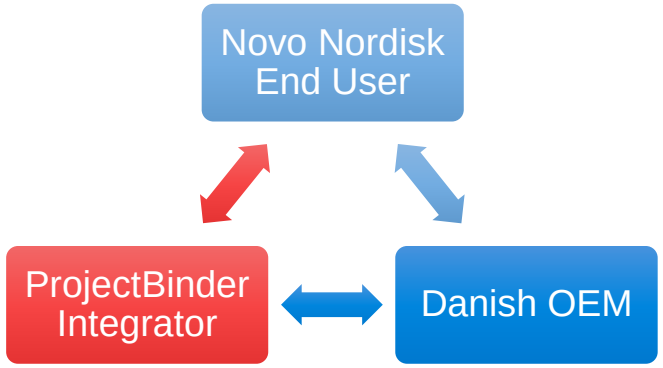
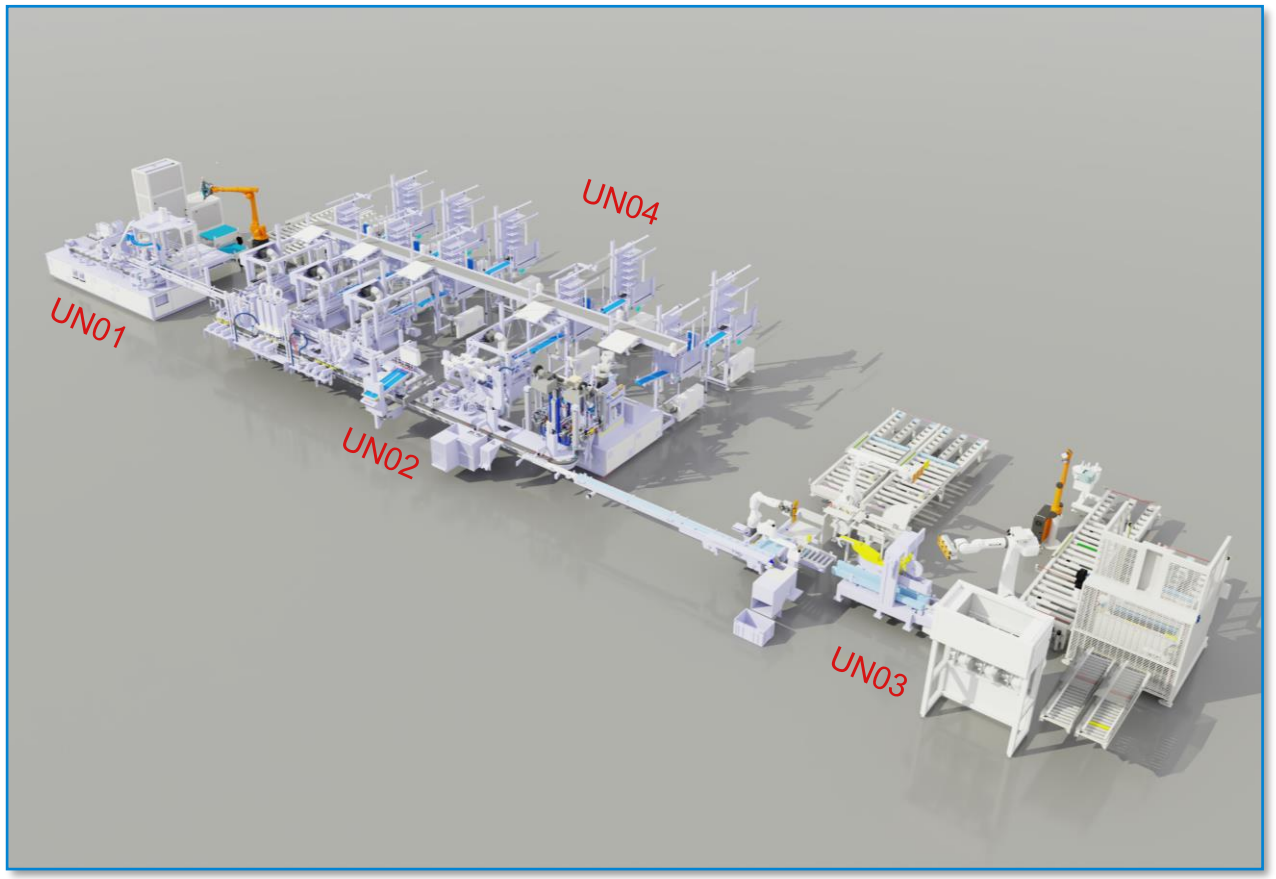
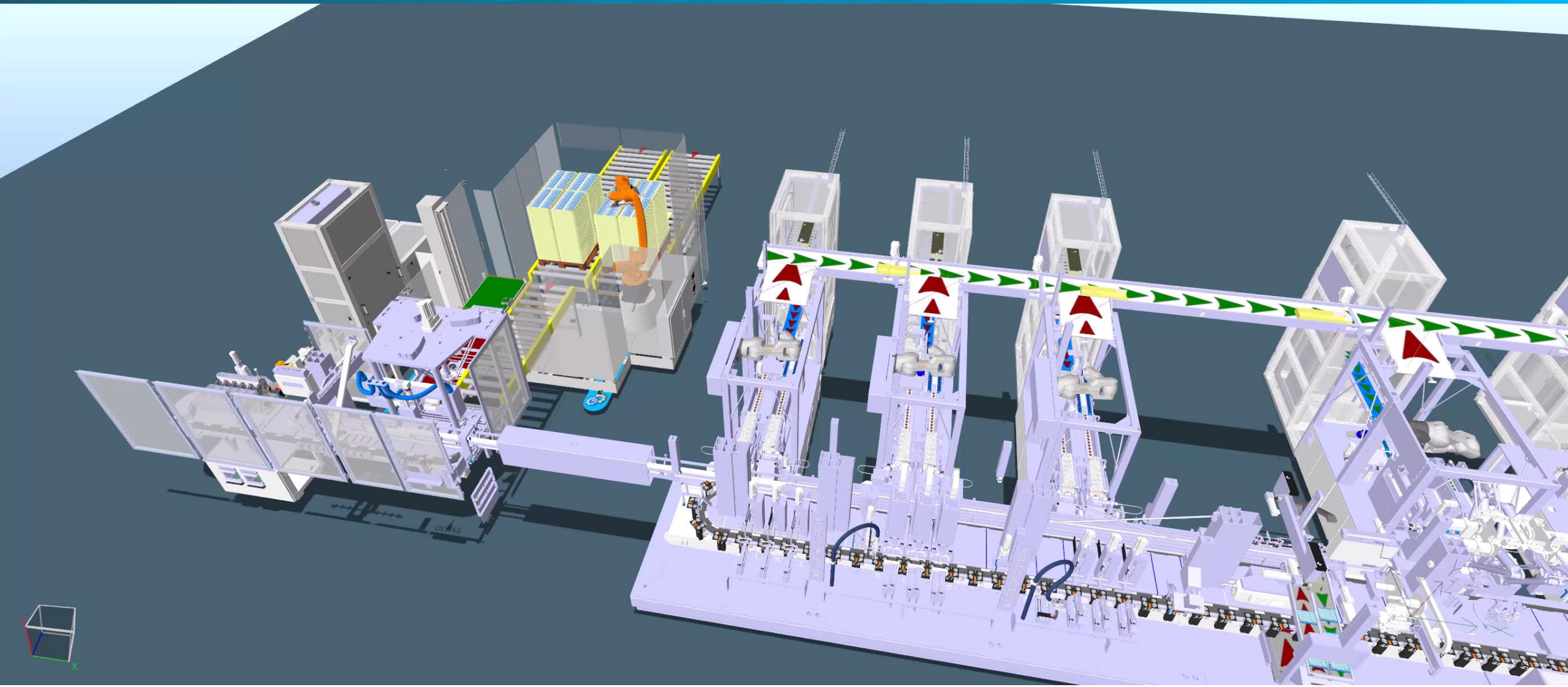
Project Overview

- This project is a **complete emulation of a packaging line** to support:
  - The Design
  - The Manufacturing
  - The Commissioning
- The aim of the project is to Emulate the complete line without any hardware-in-the-loop
- Project involves many suppliers: Siemens, Beckhoff, Kuka, Cognex, Festo
- Complex CITM model with over 4000 joints

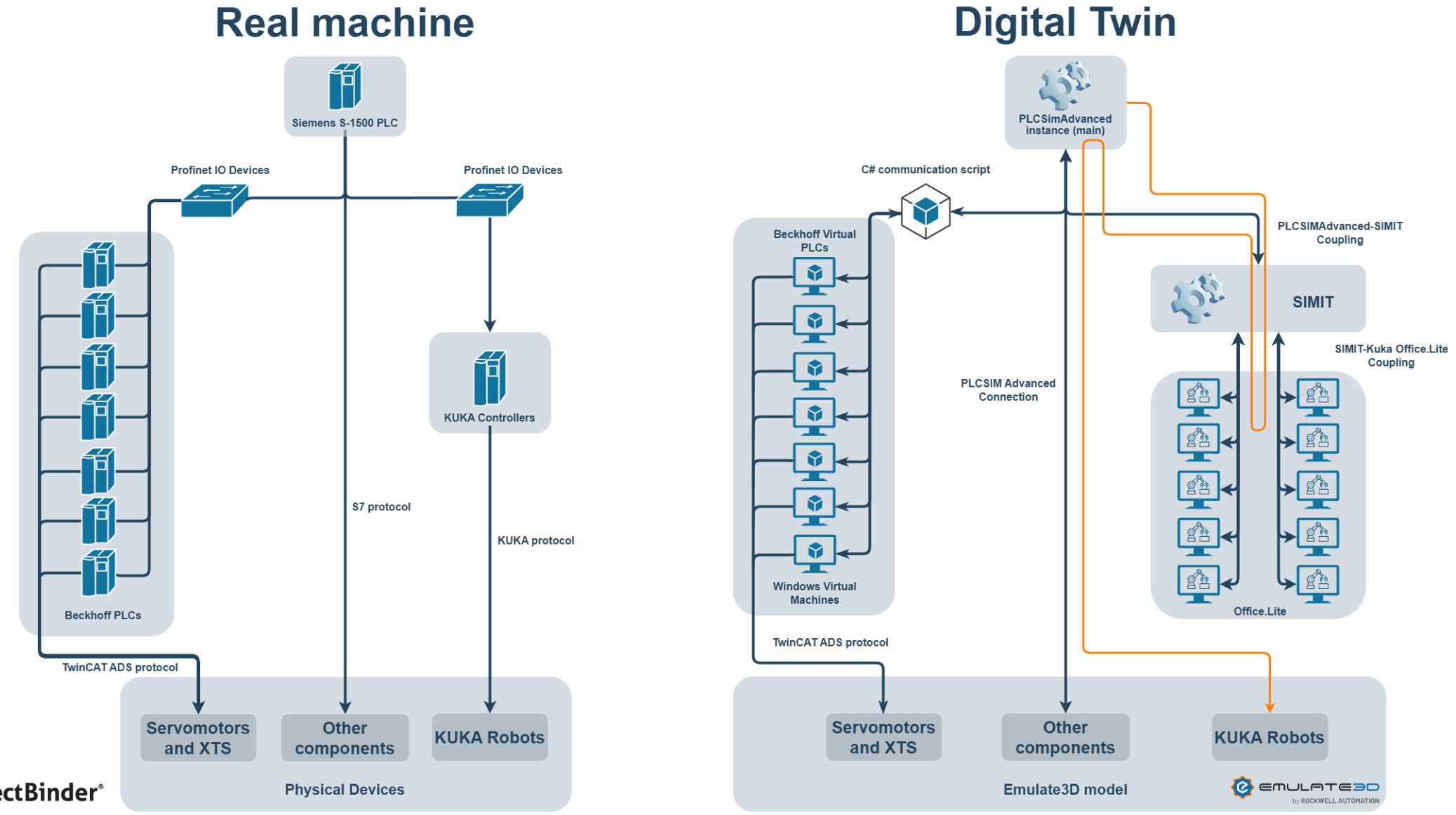




Packaging Line



Architecture Comparison



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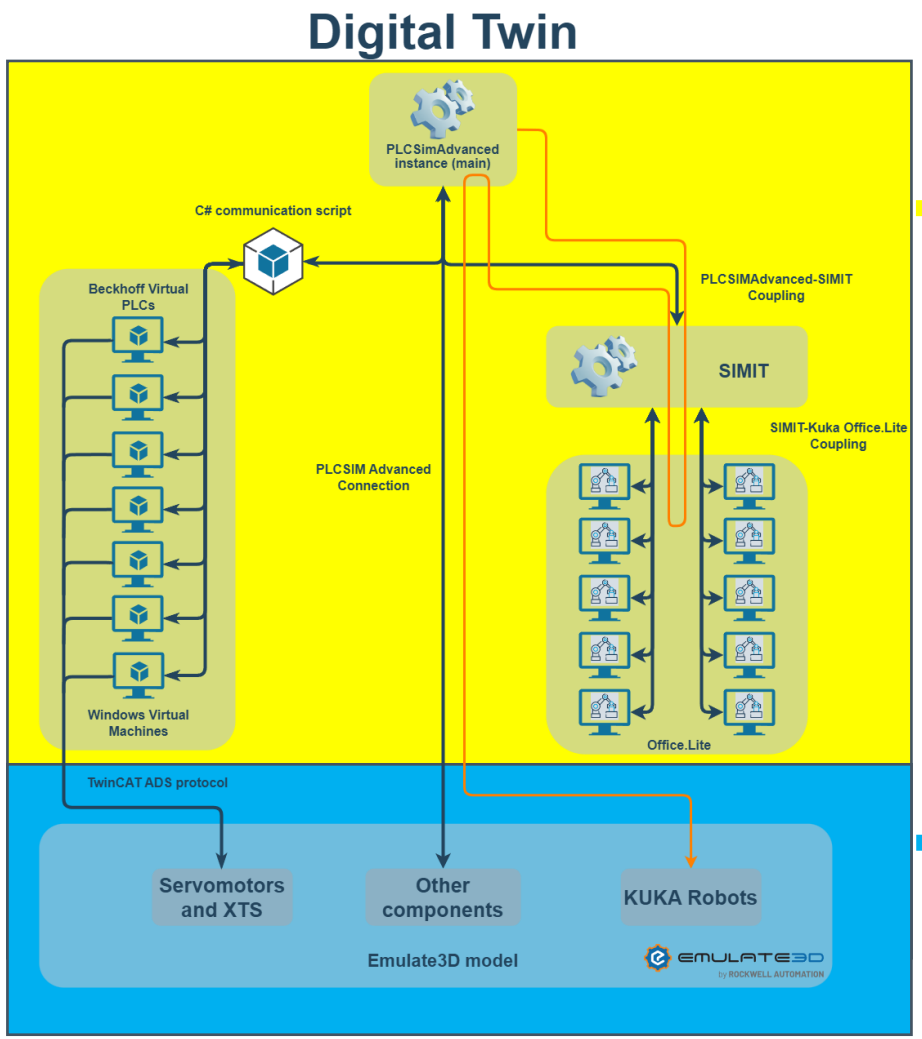
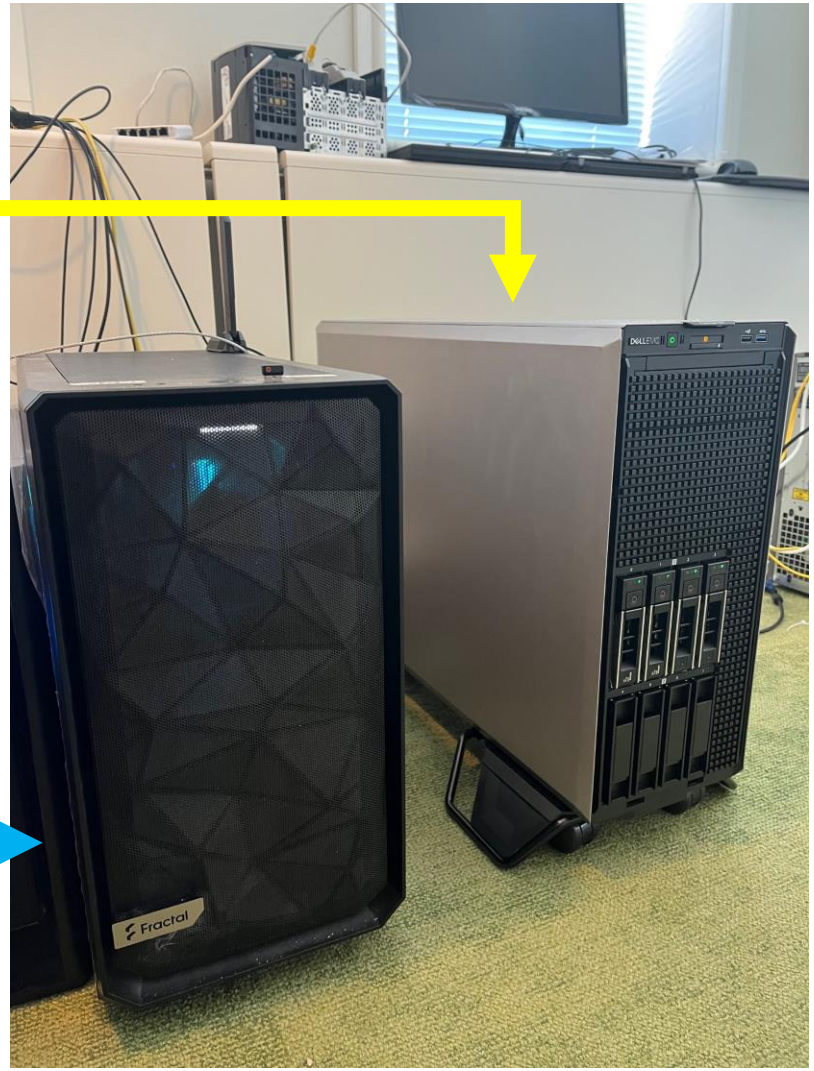
Hardware





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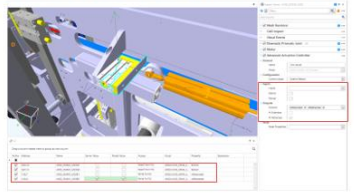
PLCs and Emulation

Siemens S7-1500 PLC

SIEMENS

- Virtual PLC – PLCSIM Advanced
- Master PLC for all 4 Uns
- Controls the majority of the machine minus the motion servos
- Sends commands to Beckhoff Motion PLCs



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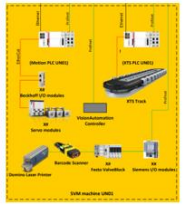
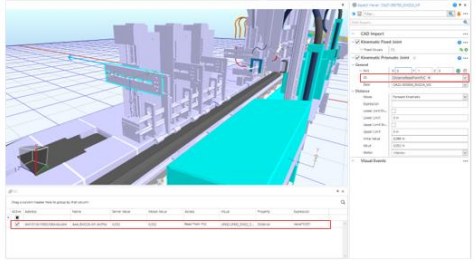
Beckhoff Motion PLCs

- Virtual PLC – TwinCAT
- Controlling fast and/or precise movements
- Modelled as Virtual Axis in Emulate3D





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Siemens – Beckhoff Communication

- ProjectBinder Custom Software
- Siemens – S7.Net library
- Beckhoff – TwinCat.ads library

- Continuous
- Read/Write to the absolute addresses of the PLCs
  - Json file defines mapping between the PLCs
  - Just like if it was real communication between PLCs

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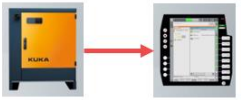
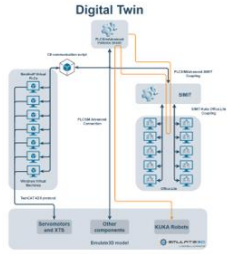
Kuka

KUKA

- Virtual Controller - Kuka Office.Lite
- 1 Virtual Controller per robot
- SIMIT-Kuka Office.Lite Coupling



- Siemens sends job, speed, torque etc.
- Robot moves in the VC
  - Sends back joint positions



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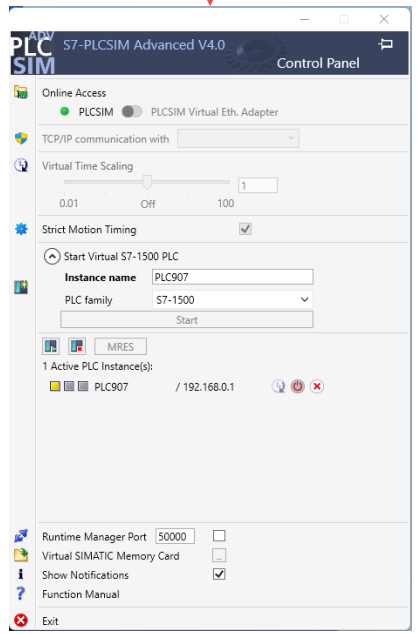

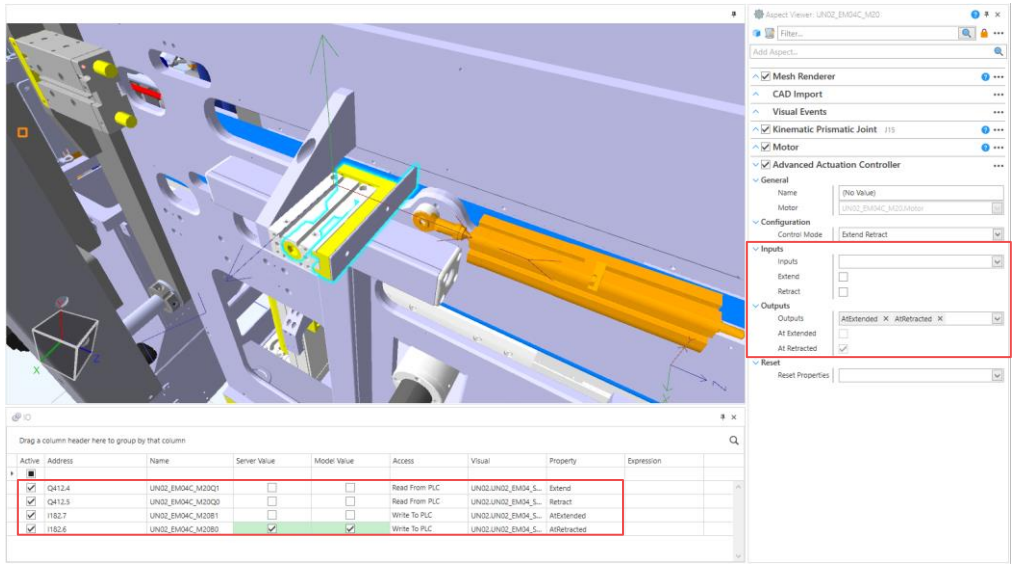

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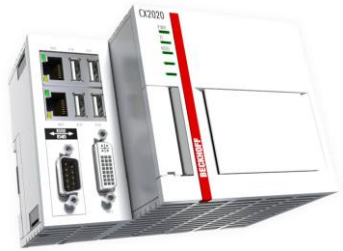

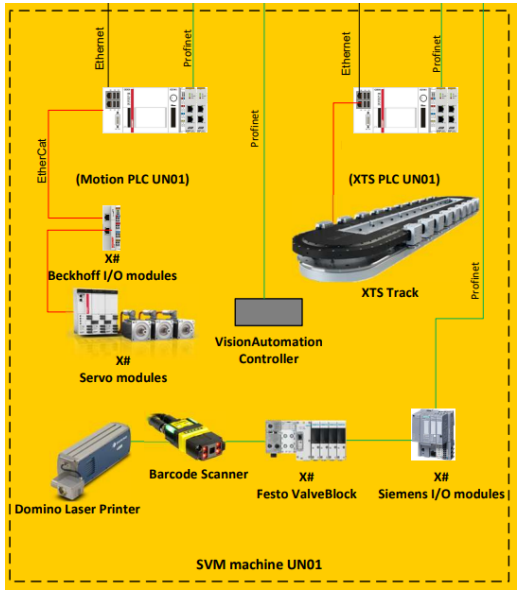

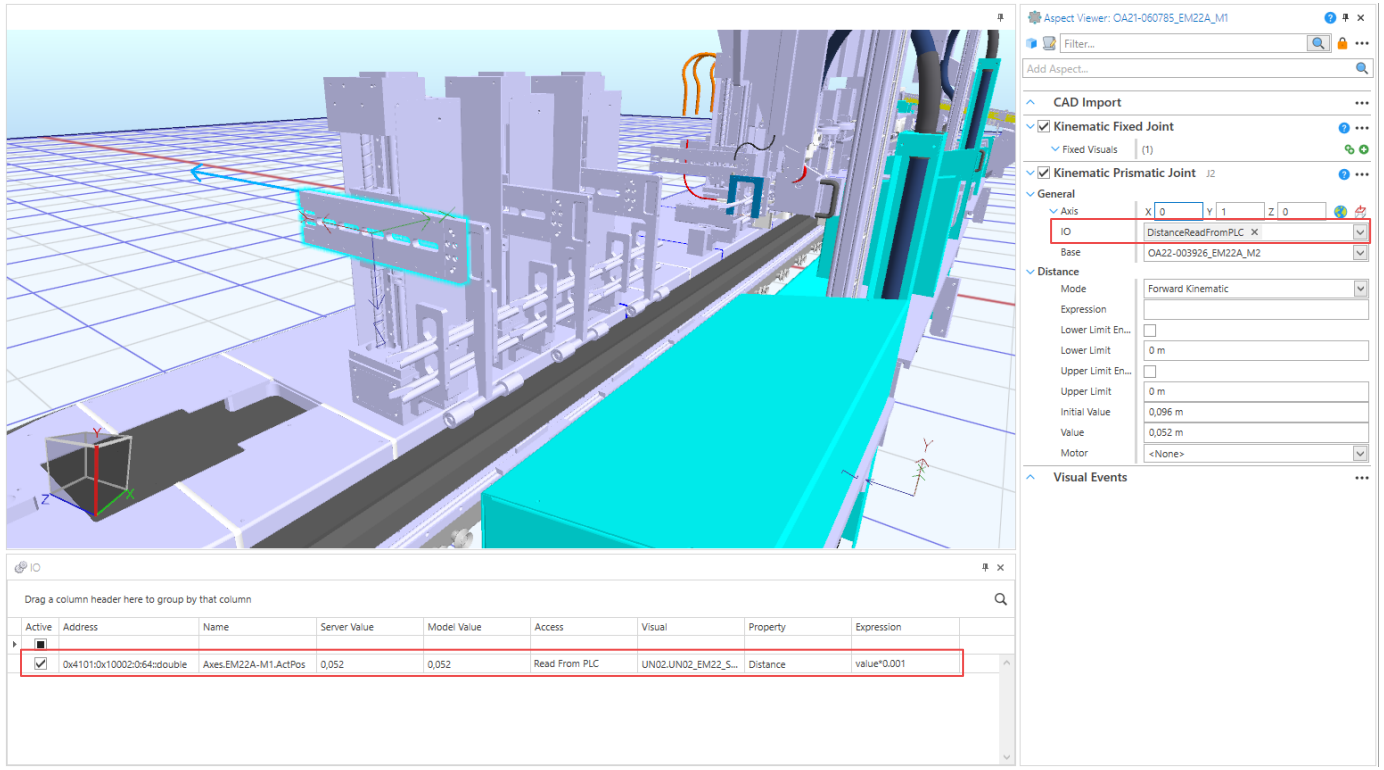

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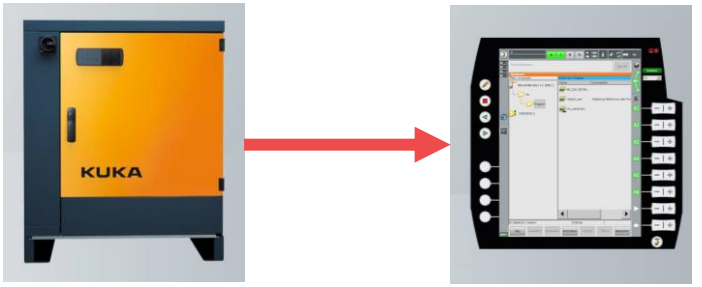
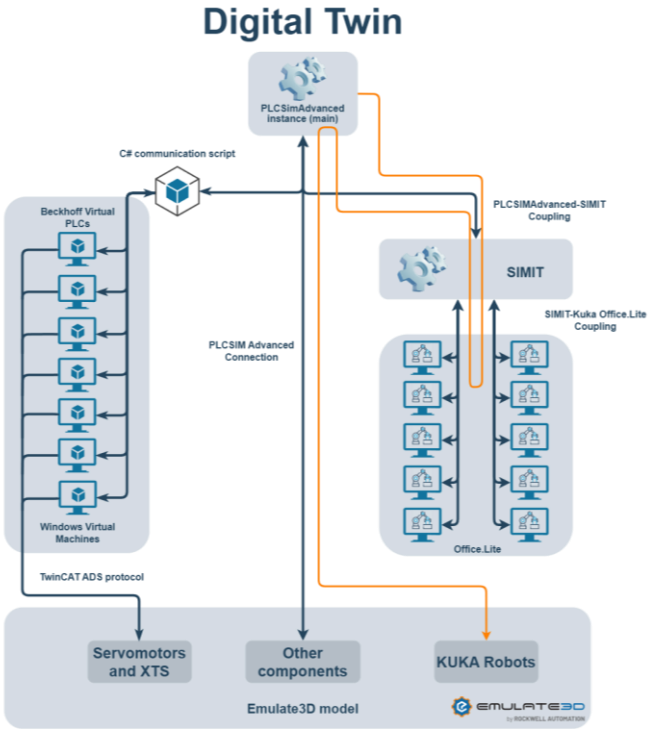


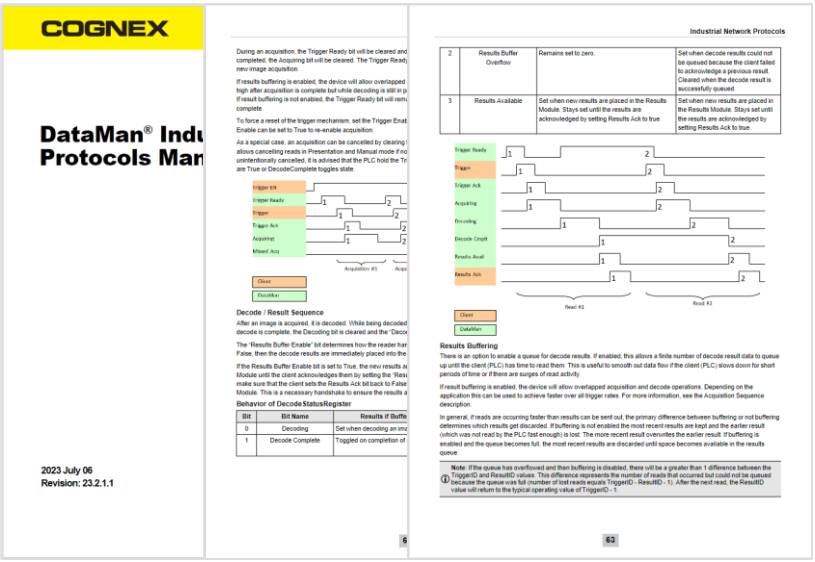


Cognex DataMan

COGNEX

Device modelled in C# with the help of

- DataMan Protocol Manual
- PLC code



- FailSequence programmed to test PLC
  bad, good, good, bad, bad, good, bad, bad, bad

in	"uCmCognexDataM...	
acquisitionSts	Struct	
triggerReady	Bool	
triggerAck	Bool	
acquiring	Bool	
missedAck	Bool	
reserved_4	Bool	
reserved_5	Bool	
reserved_6	Bool	
reserved_7	Bool	
triggerID_H	Byte	
triggerID_L	Byte	
resultSts	Struct	
softEventSts	Struct	
resultData	Struct	
resultID	Word	
resultCode	Word	
resultExtended	Word	
resultLength	Word	
resultData	Array[0..63] of Byte	
out	"uCmCognexDataM...	

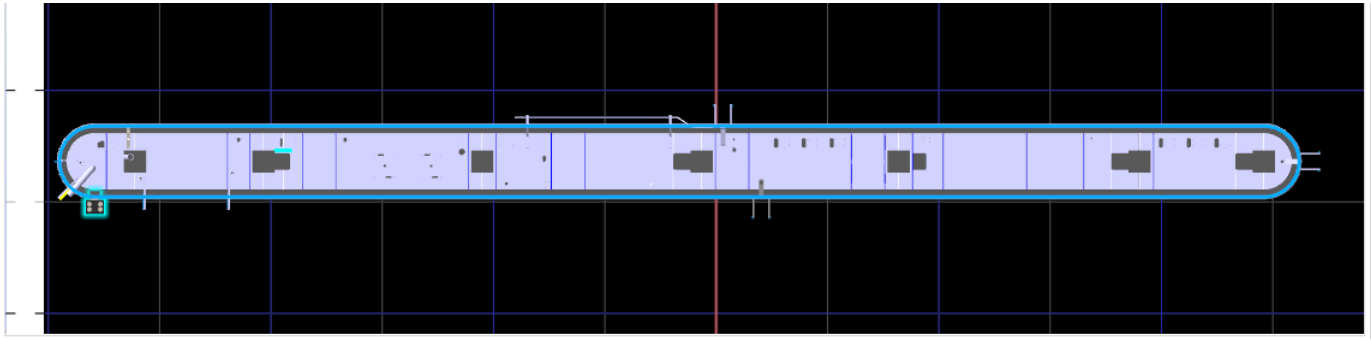
IO

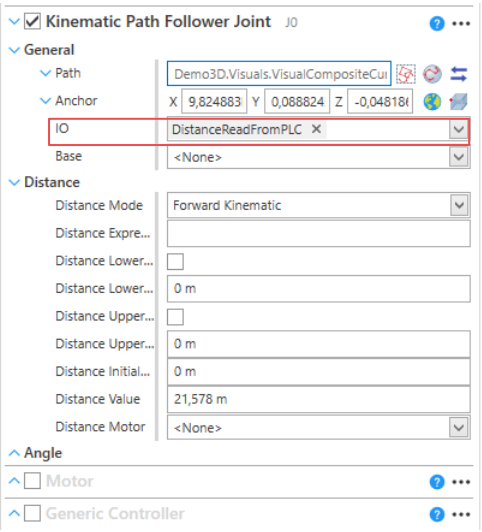
Drag a column header here to group by that column

Active	Address	Name	Server Value	Model Value	Access	Visual	Property
■							
☑	Q6004.6	UN01_EM03C-B1Co...	☐	☐	Read From PLC	BarcodeReader_UN0...	executeDmcc
☑	I6006.6	UN01_EM03C-B1Co...	☐	☐	Write To PLC	BarcodeReader_UN0...	executeDmccAck
☑	Q6002.1	UN01_EM03C-B1Co...	☐	☐	Read From PLC	BarcodeReader_UN0...	resultAck
☑	I6004.3	UN01_EM03C-B1Co...	☑	☑	Write To PLC	BarcodeReader_UN0...	resultAvailable
☑	IW6010	UN01_EM03C-B1Co...	1	1	Write To PLC	BarcodeReader_UN0...	resultCode
☑	P#I6016.0 BYTE 64	UN01_EM03C-B1Co...	SByte[64]	SByte[64]	Write To PLC	BarcodeReader_UN0...	resultData
☑	IW6008	UN01_EM03C-B1Co...	0	0	Write To PLC	BarcodeReader_UN0...	resultID
☑	IW6014	UN01_EM03C-B1Co...	0	0	Write To PLC	BarcodeReader_UN0...	resultLength
☑	Q6000.1	UN01_EM03C-B1Co...	☐	☐	Read From PLC	BarcodeReader_UN0...	trigger
☑	I6000.1	UN01_EM03C-B1Co...	☐	☐	Write To PLC	BarcodeReader_UN0...	triggerAck
☑	Q6000.0	UN01_EM03C-B1Co...	☑	☑	Read From PLC	BarcodeReader_UN0...	triggerEnable
☑	IB6001	UN01_EM03C-B1Co...	0	0	Write To PLC	BarcodeReader_UN0...	triggerID
☑	I6000.0	UN01_EM03C-B1Co...	☑	☑	Write To PLC	BarcodeReader_UN0...	triggerReady
☑	P#Q6010.0 BYTE 64	UN01_EM03C-B1Co...	SByte[64]	SByte[64]	Read From PLC	BarcodeReader_UN0...	userData
☑	QW6008	UN01_EM03C-B1Co...	0	0	Read From PLC	BarcodeReader_UN0...	userDataLength

Modelling the Beckhoff XTS

- XTS is a modular Linear Transport System
- Modelled with CITM Path Follower
- Controlled by Virtual Axis
  - Axes.Mover Axis1ActPosModulo



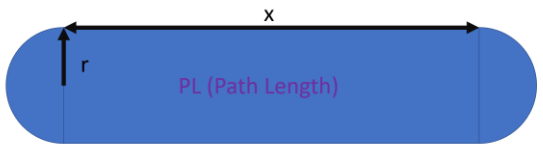


IO

Drag a column header here to group by that column

Active	Address	Name	Server Value	Model Value	Access	Visual	Property	Expression
☐								
☑	0x4101:0x10003:0:64::double	Axes.Mover Axis 1.ActP...	21,578001953125	21,578001953125	Read From PLC	UN02.UN02_EM03_S...	Distance	value*0.001
☐		__Tag__UN02.UN02_EM...		0	Read From PLC	UN02.UN02_EM03_S...	StatusCode	

$$r = \frac{PL - 2x}{2\pi}$$



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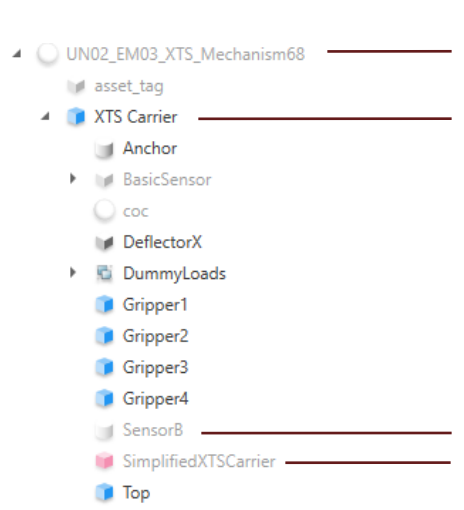
Modelling the Beckhoff XTS

- Each XTS modelled as a separate Mechanism
- Asset tagged
- Defeatured
  - From 43,820 faces to 844 faces
    98% faces removed
    2.6 million faces removed

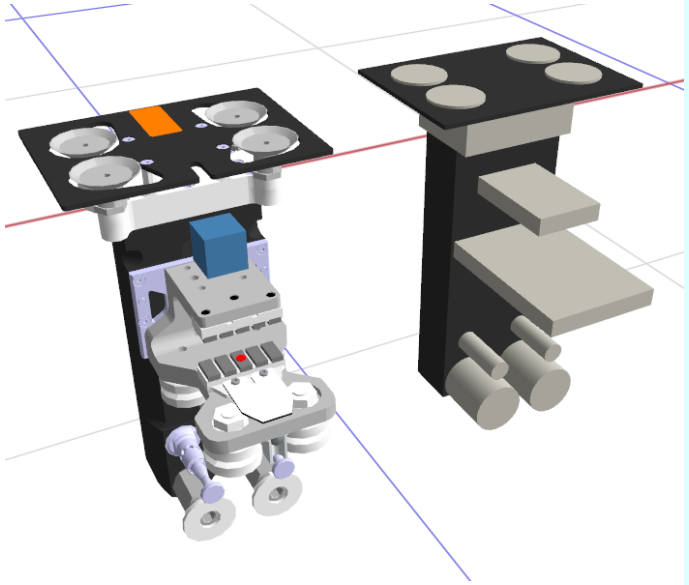


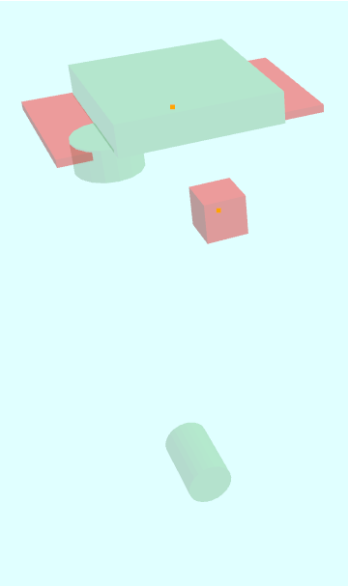
Mechanism Aspect

Path Follow Joint

Script

Core Visual CAD





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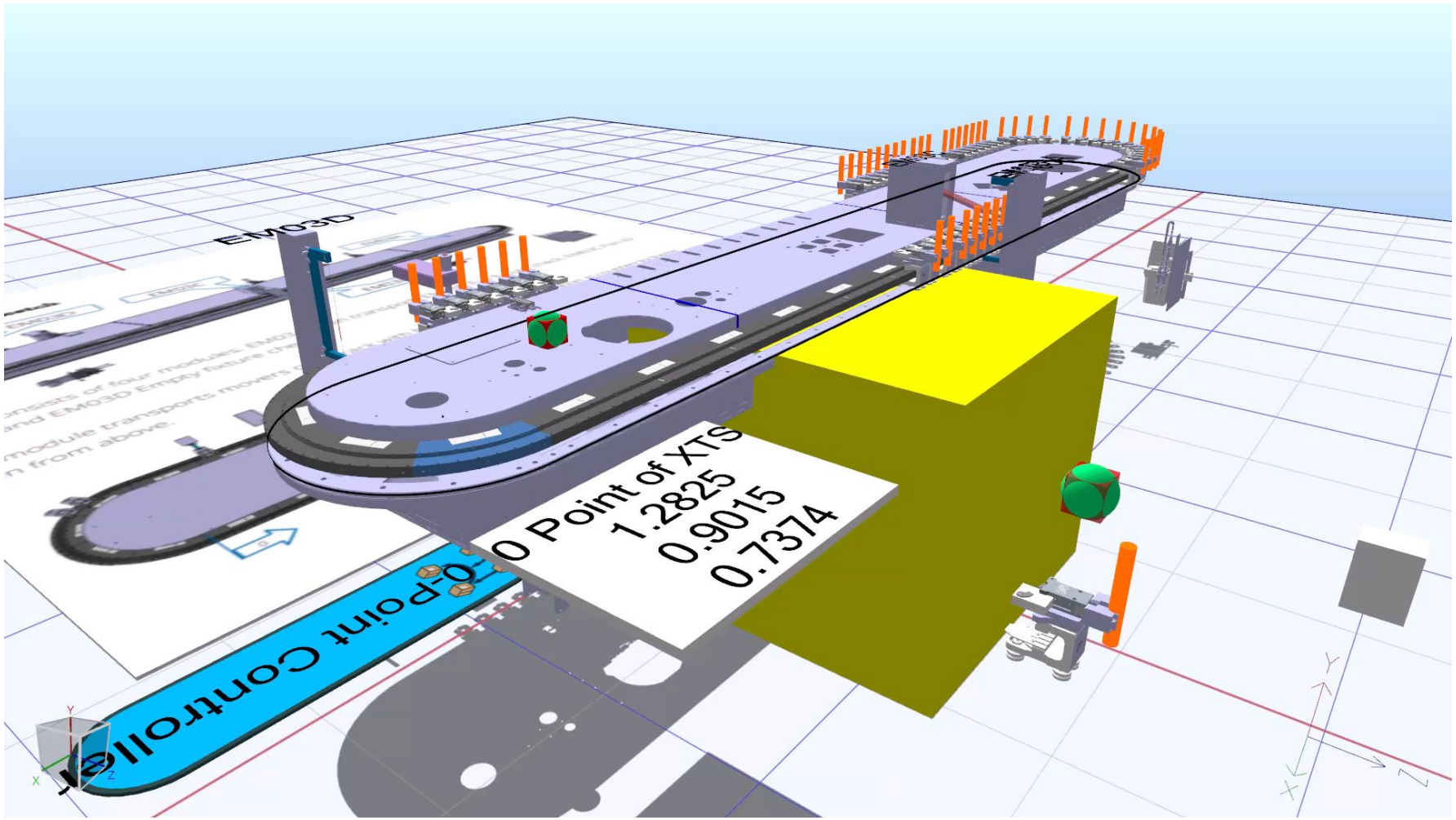
Emulating the XTS for the first time



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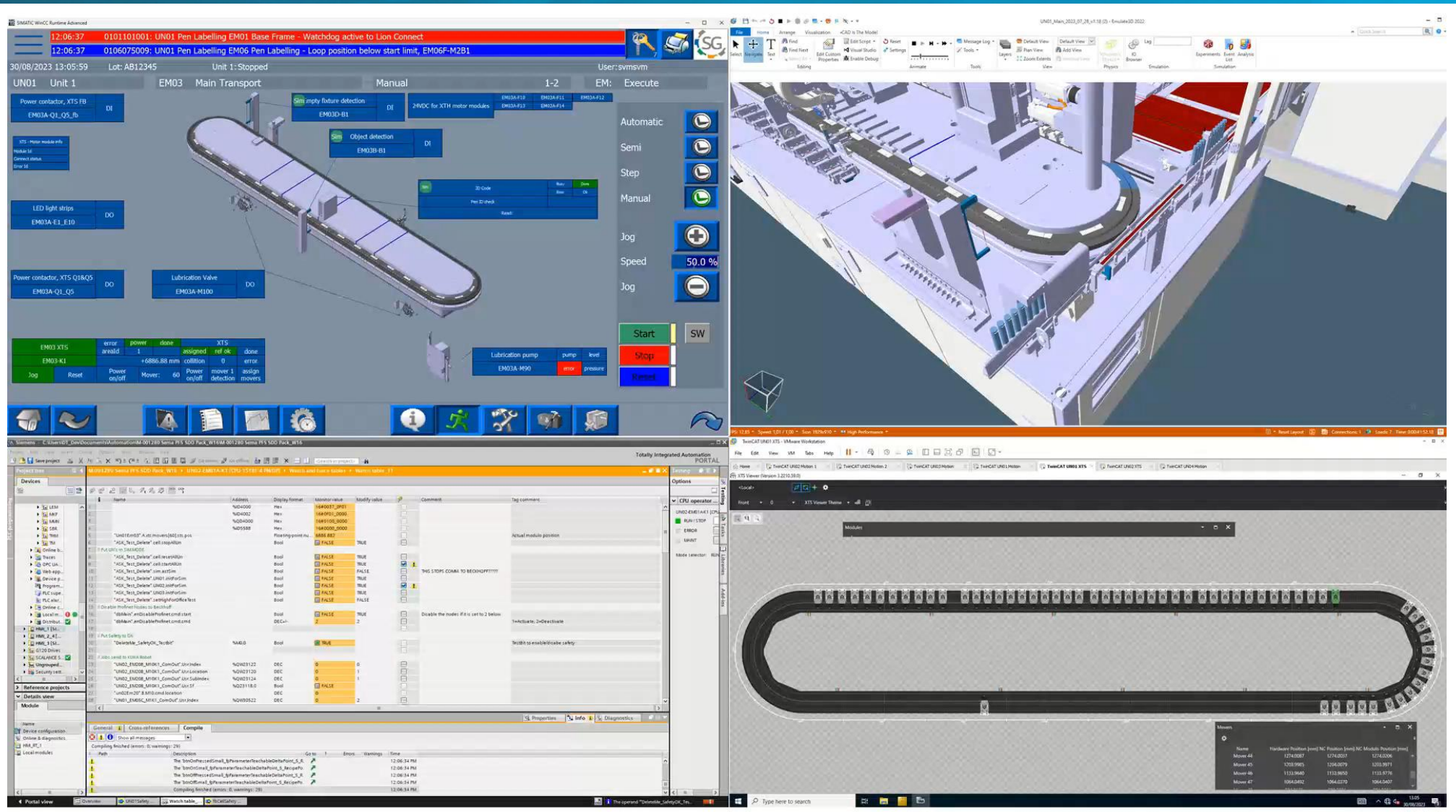
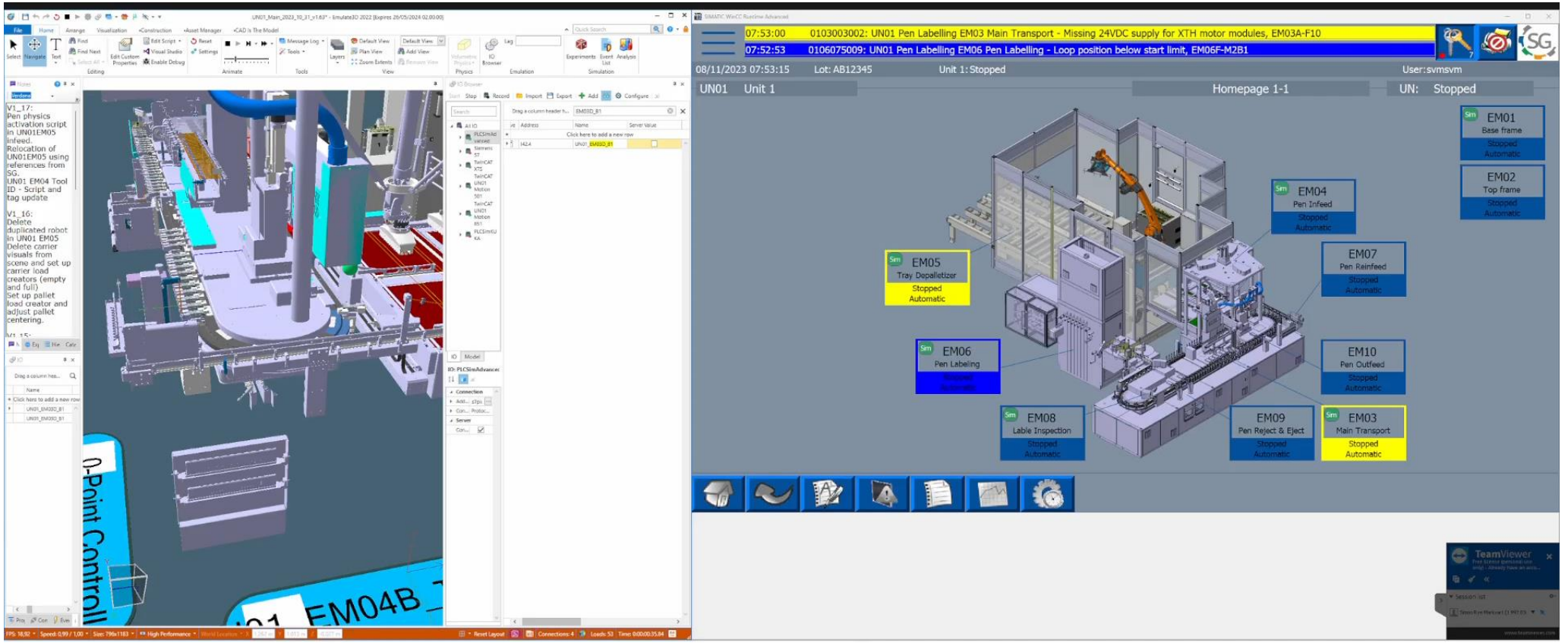
Using the Digital Twin



Virtual Commissioning Test Example - Deviation

16.03.11	UN01 Intended use	Check of Empty fixture. (Always low)Stop the machine. On UN01_EM03D_B1 remove the communications cable to always have a low signal.Cabinet A3 K5.7 DIN 5 I42.4Reset the machine. Verify that the machine cannot enter production when the signal is always low.Reattach the communication cable after test.	The module cannot produce products while the signal is always low. Event ID TBD is shown.



Benefits of using a Digital Twin - Emulation

The main benefits in this case are **finding bugs and fixing the machine's control code.**

Robot path optimisation in UN01 EM10.
PPU cycle time reduction of 25%, from 3,36s to 2,82s.

- Possibility of visualisation of robot sequence.
- Collision detection
- Fine-tuning of the path.
- Mechanical redesign.

HMI Malfunctioning.

- Teach points are not updating correctly from HMI input. This could have caused a PPU crash.

Pen infeed through UN02 EM12-13-14 (combined modules testing).

- Implementation time on real machines was significantly reduced.
- It saved at least one PPU crash.

EM22 malfunctioning

- Forgotten tags in PLC code.
- Faulty mechanical flows on the CAD.
- Offset of one piston.

Benefits of using a Digital Twin - PreFAT

PreFAT testing process using the Digital Twin – Statistics

30% of all TP tests are viable on the Digital Twin.

12% of all TP tests are done on the Digital Twin.

30% of the tested points show deviations with intended behaviour.

Test Plan ID	Test Plan Title	Test points	Tests done with DT	Deviations found
TP016	UN01 FMEA Intended Use	74	37	10
TP016	UN02 FMEA Intended Use	222	122	38
TP016	UN04 FMEA Intended Use	15	10	0

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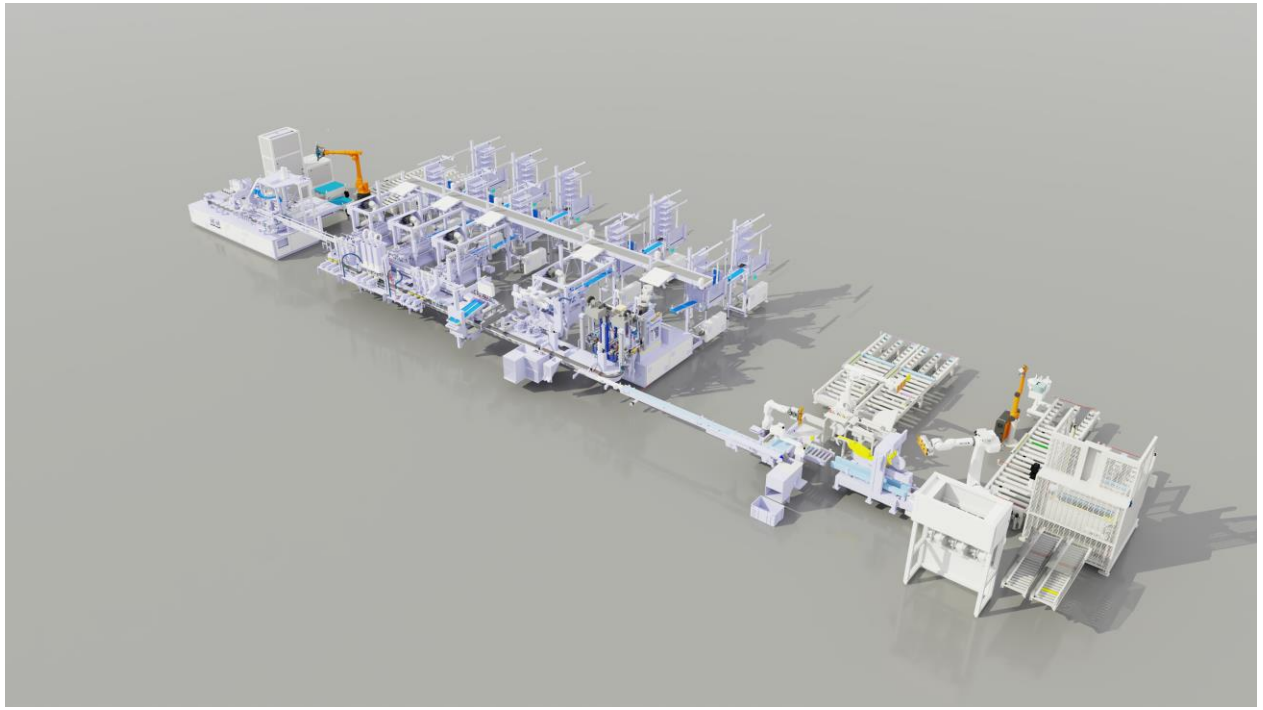
Conclusion

Digital Twin proved helpful at different stages of the project.

All the features shown could be extended and used more in-depth in future projects.

More options to unlock:

- Design optimisation and throughput analyses (early stages).
- Operator training using AR/VR.
- Emulating the second line



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