



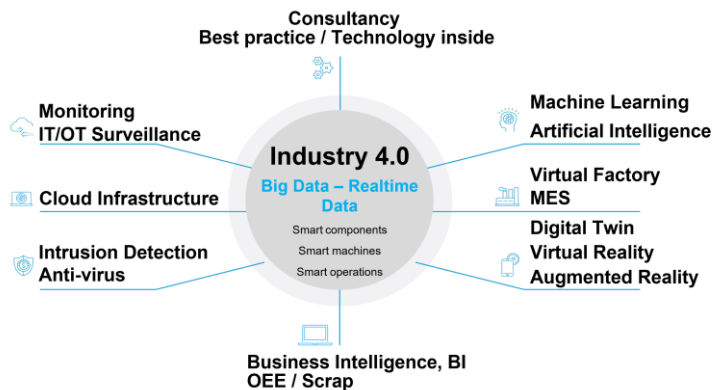
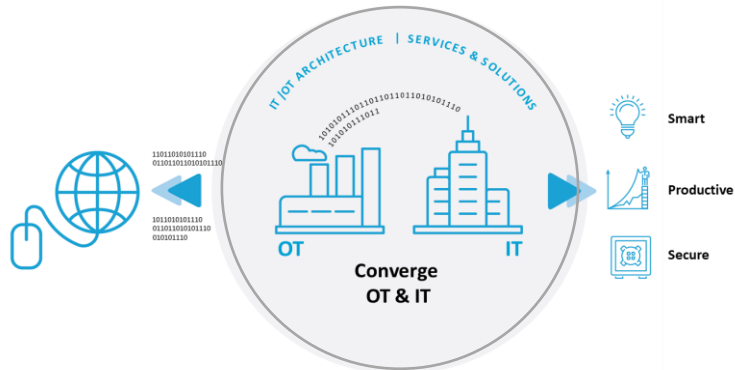
Mitigating Delivery Delays with Virtual Commissioning

Satyam Patel and Ivan Cambroner

Agenda

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

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

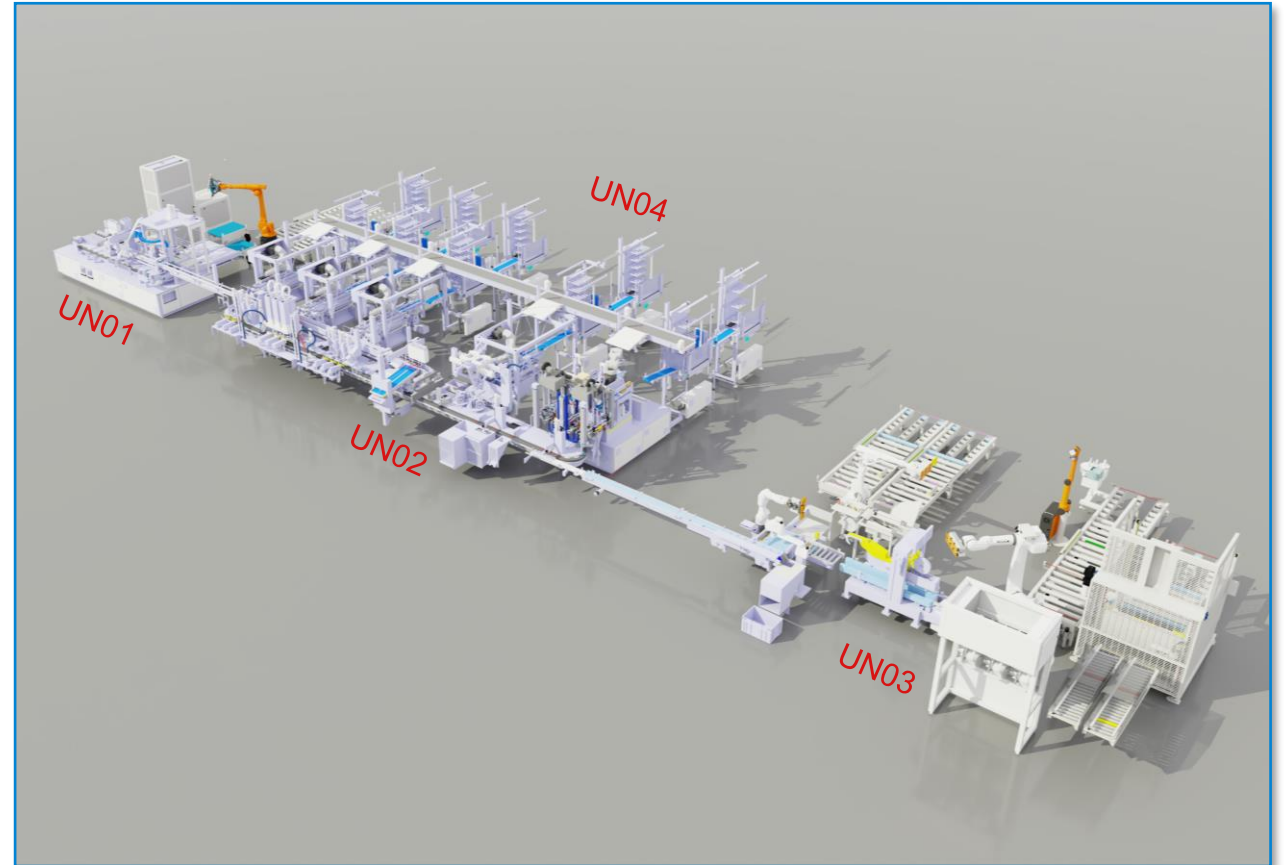
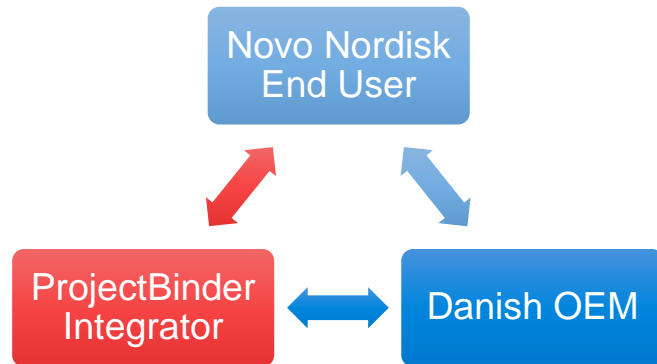


Selected clients

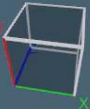
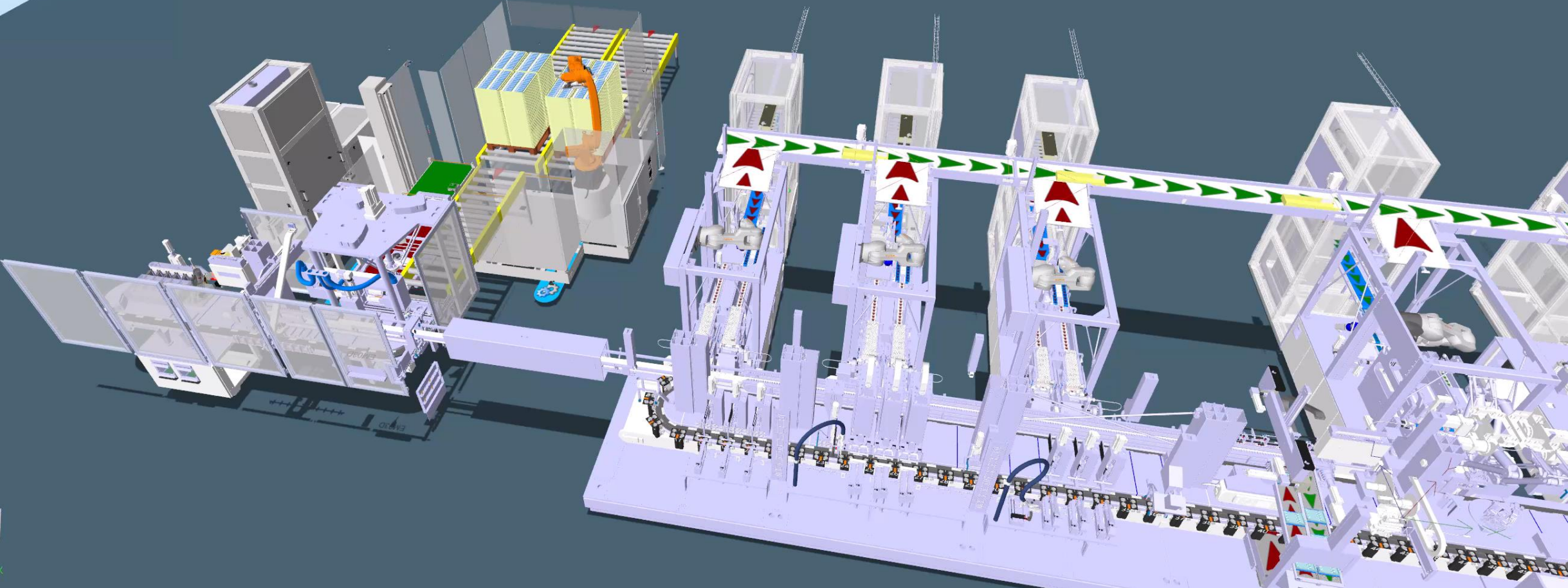


Project Overview

- 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

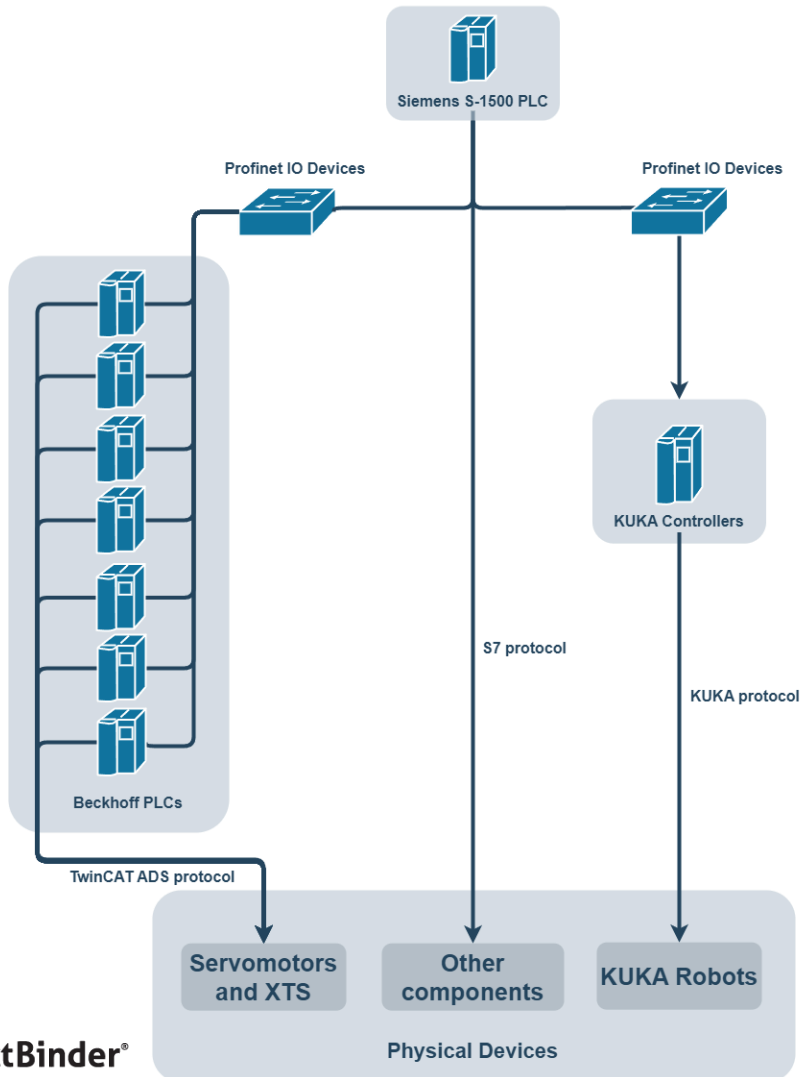


Packaging Line

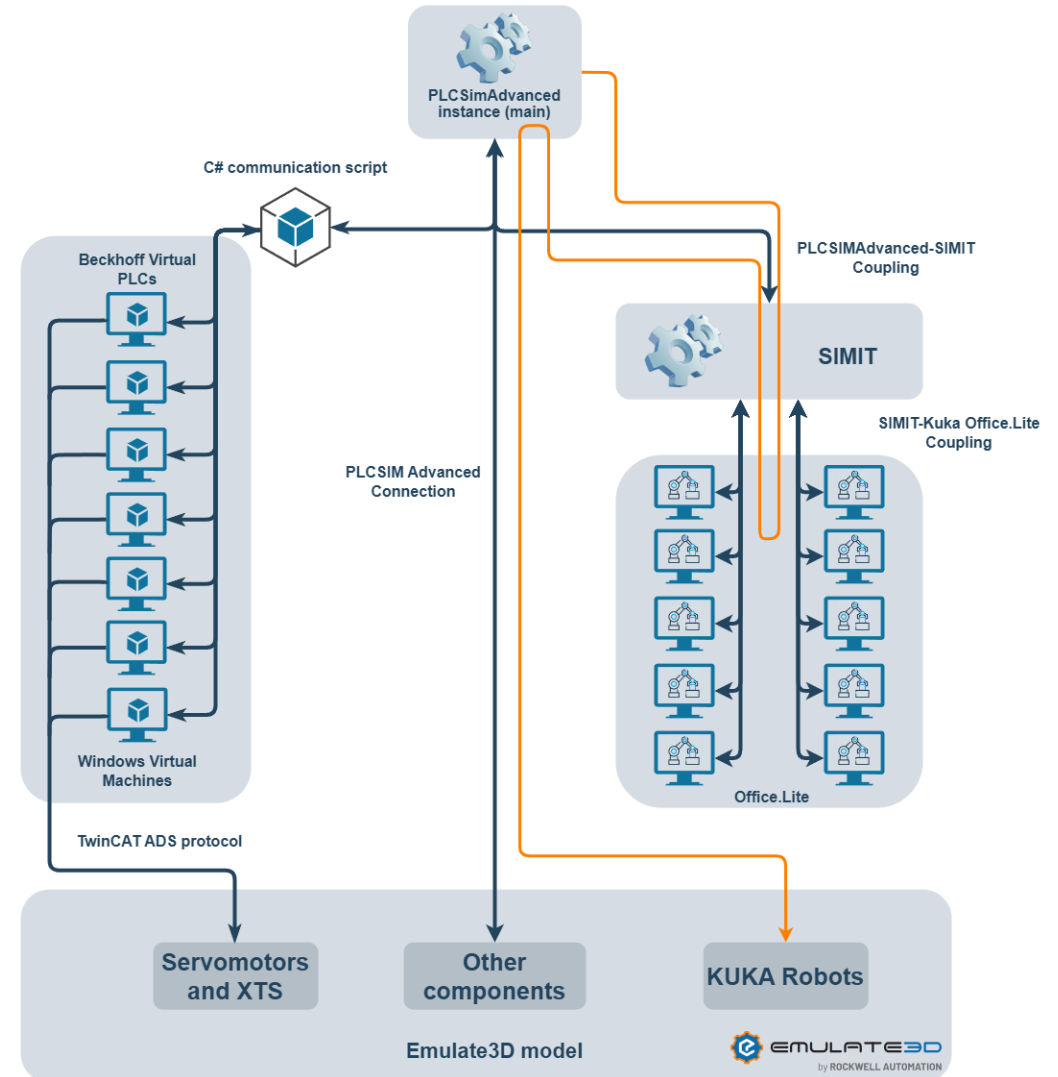


Architecture Comparison

Real machine

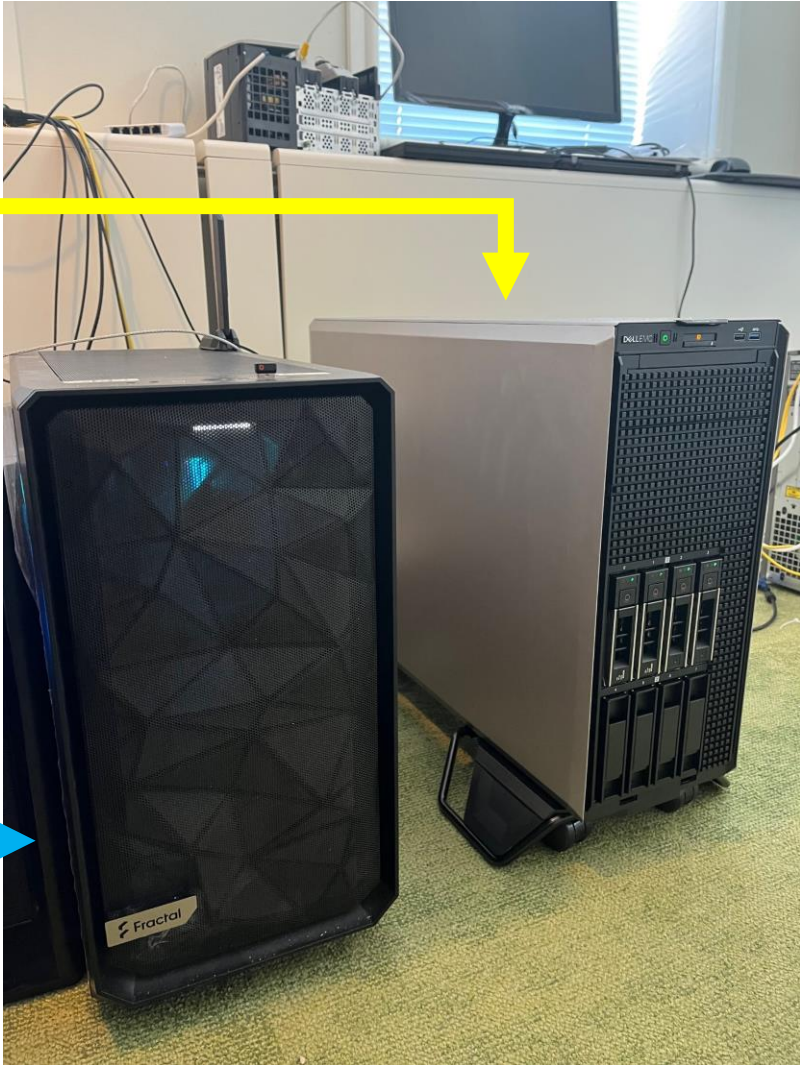
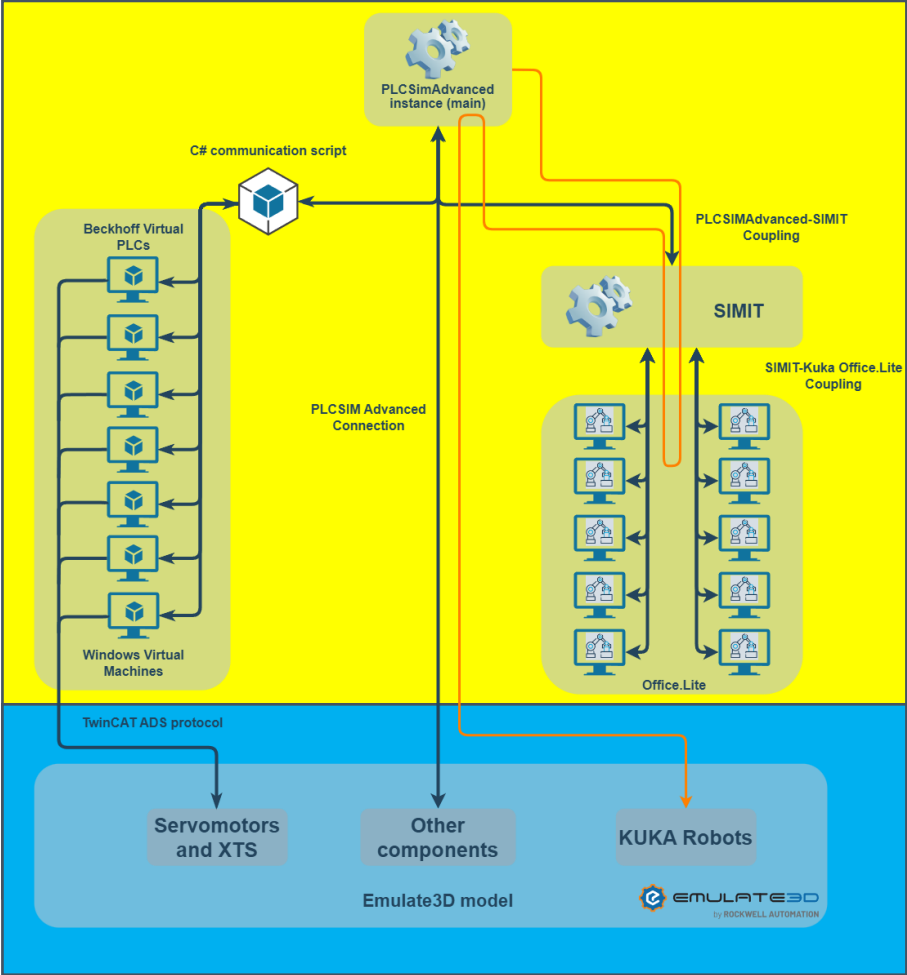


Digital Twin



Hardware

Digital Twin

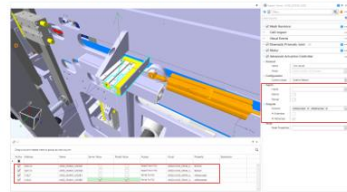


PLCs and Emulation

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

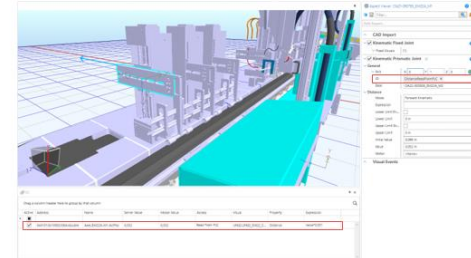
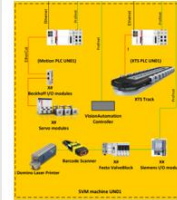


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Beckhoff Motion PLCs

- 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



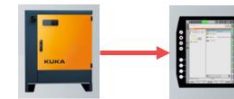
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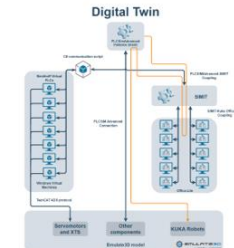
Kuka

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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- Virtual PLC – PLCSIM Advanced
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- Controls the majority of the machine minus the motion servos
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Aspect Viewer: UN02_EMO4C_M00

Mesh Renderer
CAD Import
Visual Events
Kinematic Prismatic Joint: 115
Motor
Advanced Actuation Controller

General
Name: [No Value]
Motor: UN02_EMO4C_M001A001

Configuration
Control Mode: Extend Retract

Inputs
Extend:
Retract:

Outputs
AllExtended: AllRetracted:
At Extended:
At Retracted:

Reset
Reset Properties:

Active	Address	Name	Server Value	Motor Value	Access	Visual	Property	Expression
<input checked="" type="checkbox"/>	Q412.4	UN02_EMO4C_M001	<input type="checkbox"/>	<input type="checkbox"/>	Read From PLC	UN02.UN02_EMO4_S_	Extend	
<input checked="" type="checkbox"/>	Q412.5	UN02_EMO4C_M002	<input type="checkbox"/>	<input type="checkbox"/>	Read From PLC	UN02.UN02_EMO4_S_	Retract	
<input checked="" type="checkbox"/>	I182.7	UN02_EMO4C_M001	<input type="checkbox"/>	<input type="checkbox"/>	Write To PLC	UN02.UN02_EMO4_S_	AllExtended	
<input checked="" type="checkbox"/>	I182.6	UN02_EMO4C_M002	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Write To PLC	UN02.UN02_EMO4_S_	AllRetracted	

Control Panel

Online Access
 PLCSIM PLCSIM Virtual Eth. Adapter

TCP/IP communication with: [Dropdown]

Virtual Time Scaling
0.01 Off 100 1

Strict Motion Timing

Start Virtual S7-1500 PLC
Instance name: PLC907
PLC family: S7-1500
Start

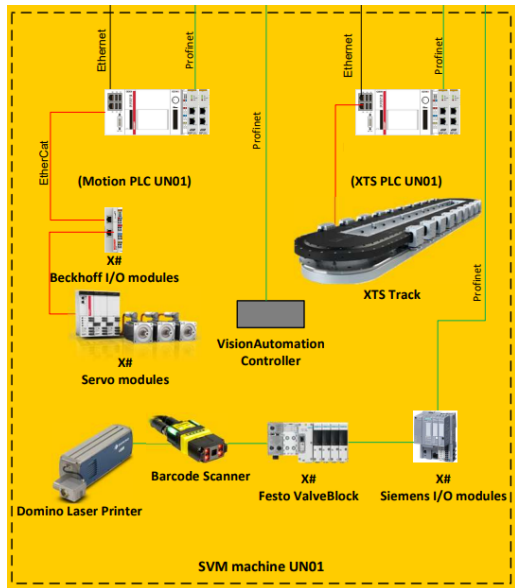
MRES

1 Active PLC Instance(s):
■ PLC907 / 192.168.0.1

Runtime Manager Port: 50000
Virtual SIMATIC Memory Card
Show Notifications
Function Manual
Exit

Beckhoff Motion PLCs

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



A 3D CAD model of a machine structure, likely a robotic arm or conveyor system, rendered in a light blue and grey color scheme. The model is shown in a perspective view on a grid floor. To the right of the model is the TwinCAT software interface, specifically the Aspect Viewer for 'OA21-060785_EM22A_M1'. The interface shows various configuration options for kinematic joints and distance parameters.

Aspect Viewer: OA21-060785_EM22A_M1

Filter...
Add Aspect...

CAD Import

- Kinematic Fixed Joint
 - Fixed Visuals (1)
- Kinematic Prismatic Joint J2

General

Axis: X 0 Y 1 Z 0

IO: DistanceReadFromPLC X

Base: OA22-003926_EM22A_M2

Distance

Mode: Forward Kinematic

Expression: [empty]

Lower Limit En: [checkbox]

Lower Limit: 0 m

Upper Limit En: [checkbox]

Upper Limit: 0 m

Initial Value: 0,096 m

Value: 0,052 m

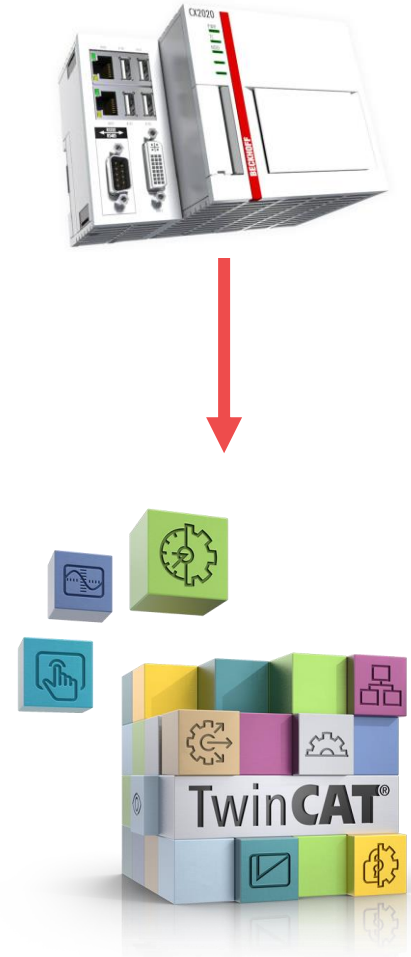
Motor: <None>

Visual Events

IO

Drag a column header here to group by that column

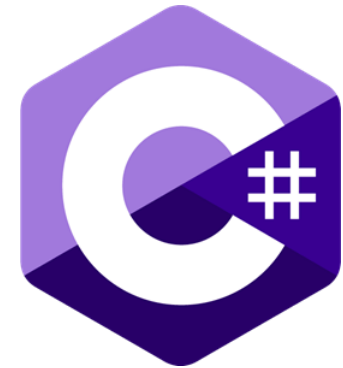
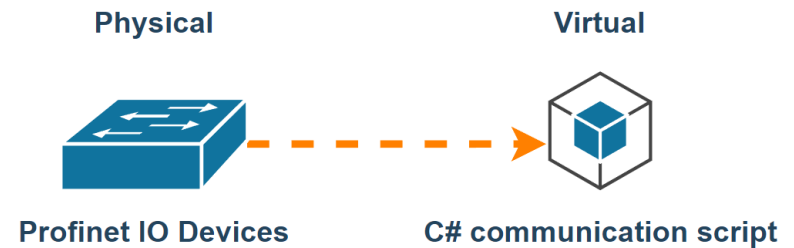
Active	Address	Name	Server Value	Model Value	Access	Visual	Property	Expression
<input checked="" type="checkbox"/>	0x4101:0x10002:0x64:double	AxesEM22A-M1.ActPos	0,052	0,052	Read From PLC	UN02.UN02_EM22_S...	Distance	value*0,001



Siemens – Beckhoff Communication

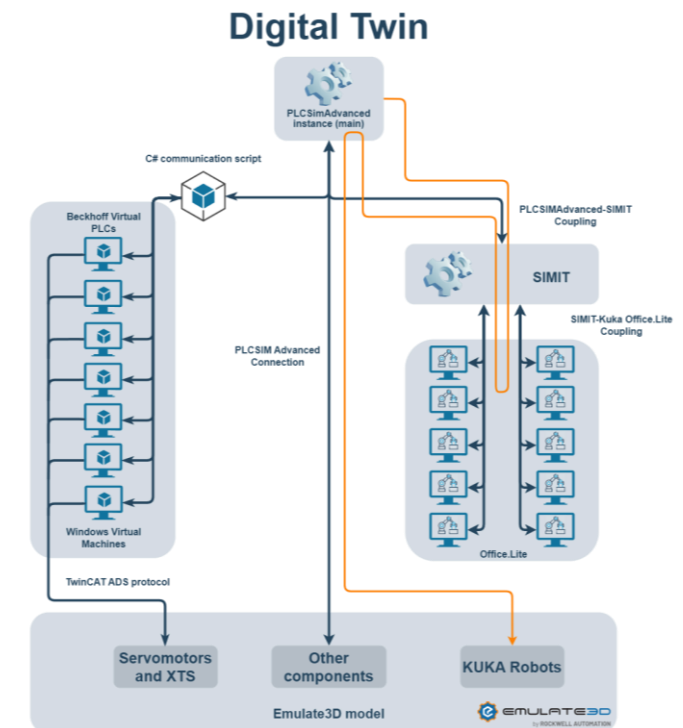
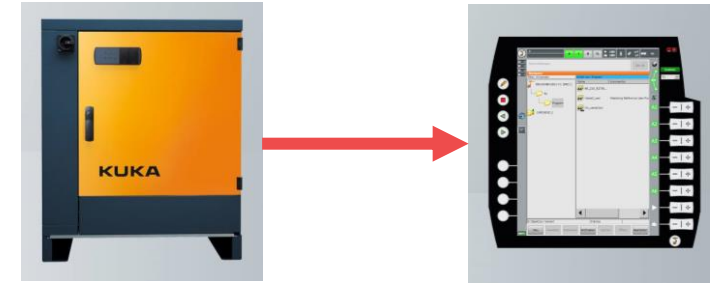
- ProjectBinder Custom Software
- Siemens – S7.Net library
- Beckhoff – TwinCat.ads library

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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

COGNEX

DataMan® Industrial Protocols Manual

During an acquisition, the Trigger Ready bit will be cleared and completed, the Acquiring bit will be cleared. The Trigger Ready, reserved, and Acquiring bits will be cleared. The Trigger Ready bit will be cleared after the acquisition is complete but while decoding is still in progress. If buffering is not enabled, the Trigger Ready bit will not be cleared.

To force a reset of the trigger mechanism, set the Trigger Enable Enable bit to True to enable acquisition.

As a special case, an acquisition can be cancelled by clearing the Trigger Ready bit in Presentation and Manual mode if no sensor data is present. It is advised that the PLC keep the Trigger Ready bit set to True to avoid acquisition.

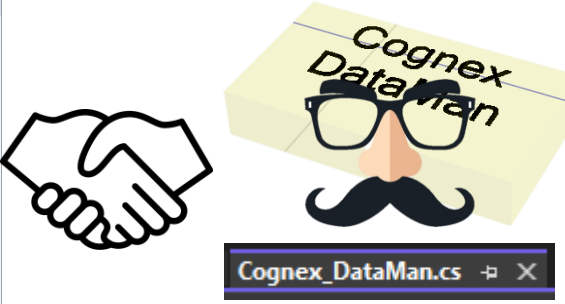
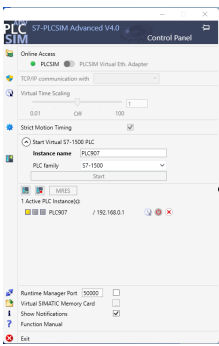
Decode / Result Sequence
After an image is acquired, the decoder will be decoding. While being decoded, the Decoding bit is cleared and the 'Decode Complete' bit is set to True. The 'Decode Complete' bit is set to True when the decoder has finished decoding the image. The 'Decode Complete' bit is set to True when the decoder has finished decoding the image. The 'Decode Complete' bit is set to True when the decoder has finished decoding the image.

Results Buffer
This is an option to enable a queue for decode results. If enabled, this allows a finite number of decode result data to queue up until the client (PLC) has time to read them. This is useful to smooth out data flow if the client (PLC) slows down for short periods of time or if there are surges of read activity.

Results Available
If result buffering is enabled, the device will also developed acquisition and decode operations. Depending on the application this can be used to achieve faster turn on trigger rates. For more information, see the Acquisition Sequence description.

Results Buffering
In general, if reads are occurring faster than results can be sent out, the primary difference between buffering and not buffering determines which results get discarded. If buffering is not enabled the most recent results are kept and the earlier result which was not read by the PLC is lost. If buffering is enabled and the queue becomes full, the most recent results are discarded until space becomes available in the results queue.

Warning
While the queue has overflowed and then buffering is disabled, there will be a greater than 1 difference between the TriggerID and ResultID values. This difference represents the number of reads that occurred but could not be queued. To determine the queue size, the number of reads equals TriggerID - ResultID - 1. After the next read, the ResultID value will return to the typical operating value of TriggerID - 1.

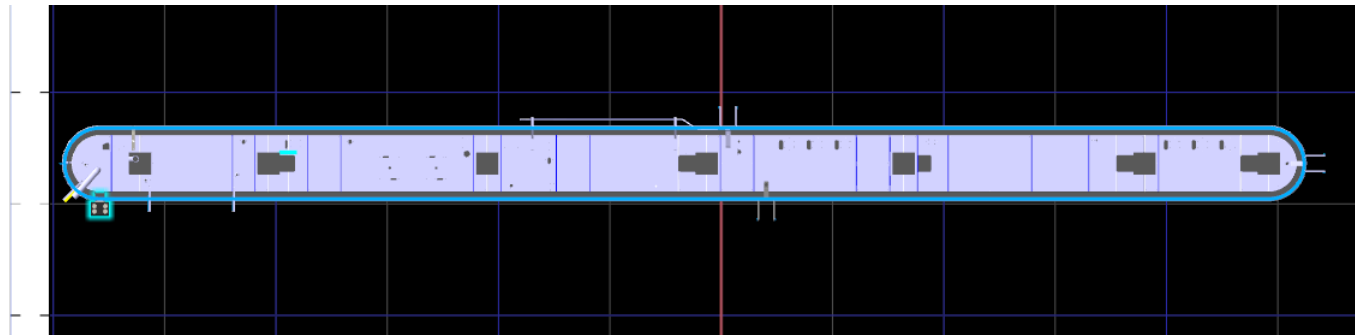


in	*uCmCognexDataM...
acquistionSts	Struct
triggerReady	Bool
triggerAck	Bool
acquiring	Bool
missedAck	Bool
reserved_4	Bool
reserved_5	Bool
reserved_6	Bool
reserved_7	Bool
triggerID_H	Byte
triggerID_L	Byte
resultSts	Struct
softEventSts	Struct
resultData	Struct
resultID	Word
resultCode	Word
resultExtended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

Active	Address	Name	Server Value	Model Value	Access	Visual	Property
<input checked="" type="checkbox"/>	Q6004.6	UN01_EM03C-B1Co...			Read From PLC	BarcodeReader_UND...	executeDmcc
<input checked="" type="checkbox"/>	I6006.6	UN01_EM03C-B1Co...			Write To PLC	BarcodeReader_UND...	executeDmccAck
<input checked="" type="checkbox"/>	Q6002.1	UN01_EM03C-B1Co...			Read From PLC	BarcodeReader_UND...	resultAck
<input checked="" type="checkbox"/>	I6004.3	UN01_EM03C-B1Co...	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Write To PLC	BarcodeReader_UND...	resultAvailable
<input checked="" type="checkbox"/>	IW6010	UN01_EM03C-B1Co...	1	1	Write To PLC	BarcodeReader_UND...	resultID
<input checked="" type="checkbox"/>	P#I6016.0 BYTE 64	UN01_EM03C-B1Co...	SByte[64]	SByte[64]	Write To PLC	BarcodeReader_UND...	resultData
<input checked="" type="checkbox"/>	IW6008	UN01_EM03C-B1Co...	0	0	Write To PLC	BarcodeReader_UND...	resultID
<input checked="" type="checkbox"/>	IW6014	UN01_EM03C-B1Co...	0	0	Write To PLC	BarcodeReader_UND...	resultLength
<input checked="" type="checkbox"/>	Q6000.1	UN01_EM03C-B1Co...			Read From PLC	BarcodeReader_UND...	trigger
<input checked="" type="checkbox"/>	I6000.1	UN01_EM03C-B1Co...			Write To PLC	BarcodeReader_UND...	triggerAck
<input checked="" type="checkbox"/>	Q6000.0	UN01_EM03C-B1Co...	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Read From PLC	BarcodeReader_UND...	triggerEnable
<input checked="" type="checkbox"/>	I60001	UN01_EM03C-B1Co...	0	0	Write To PLC	BarcodeReader_UND...	triggerID
<input checked="" type="checkbox"/>	I6000.0	UN01_EM03C-B1Co...	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Write To PLC	BarcodeReader_UND...	triggerReady
<input checked="" type="checkbox"/>	P#Q6010.0 BYTE 64	UN01_EM03C-B1Co...	SByte[64]	SByte[64]	Read From PLC	BarcodeReader_UND...	userData
<input checked="" type="checkbox"/>	QW6008	UN01_EM03C-B1Co...	0	0	Read From PLC	BarcodeReader_UND...	userDataLength

Modelling the Beckhoff XTS

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



Active	Address	Name	Server Value	Model Value	Access	Visual	Property	Expression
<input checked="" type="checkbox"/>	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
<input type="checkbox"/>		_Tag_UN02.UN02_EM...	0		Read From PLC	UN02.UN02_EM03_S...	StatusCode	

✓ Kinematic Path Follower Joint J0

General

Path Demo3D.Visuals.VisualCompositeCui

Anchor X 9,824883 Y 0,088824 Z -0,048184

IO DistanceReadFromPLC X

Base <None>

Distance

Distance Mode Forward Kinematic

Distance Expre...

Distance Lower... 0 m

Distance Upper... 0 m

Distance Initial... 0 m

Distance Value 21,578 m

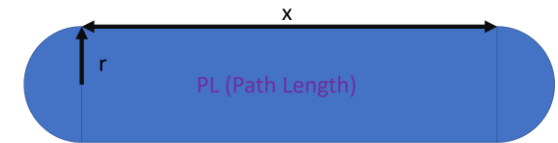
Distance Motor <None>

Angle

Motor

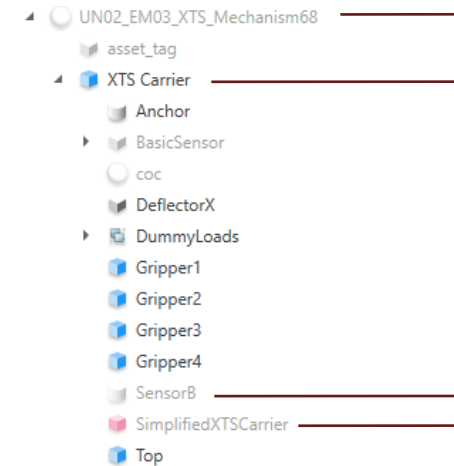
Generic Controller

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



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

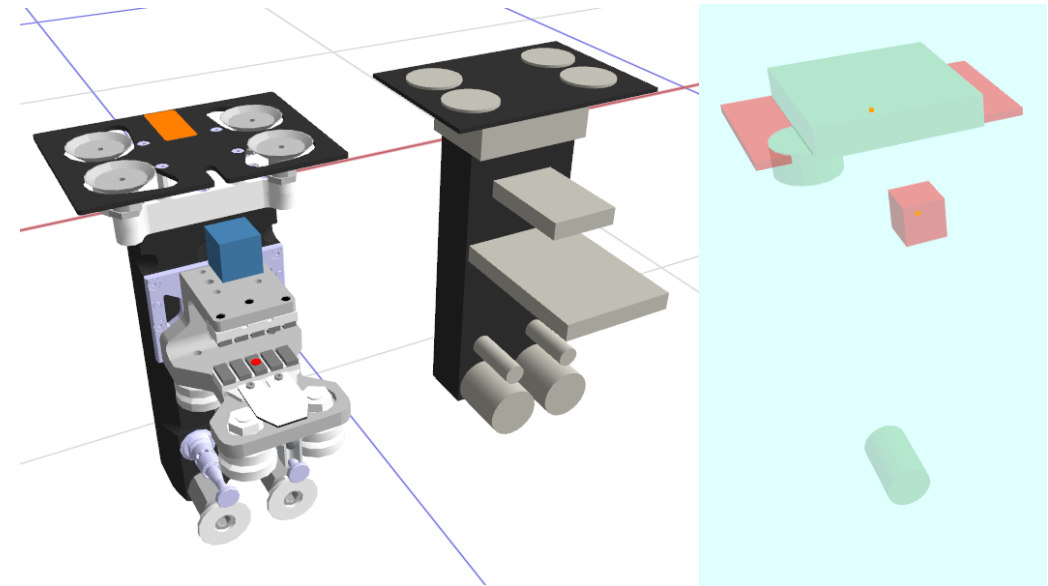


Mechanism Aspect

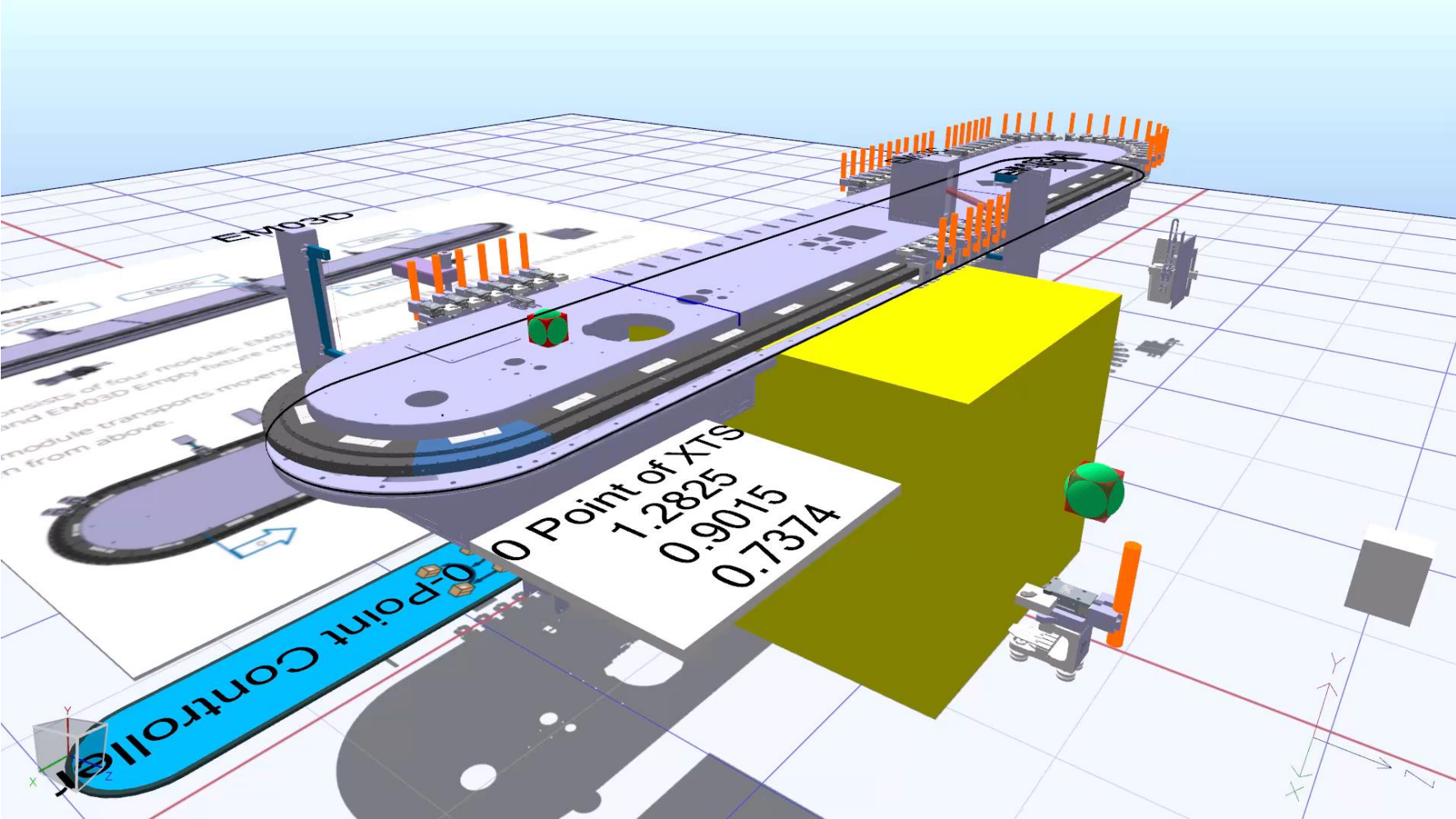
Path Follow Joint

Script

Core Visual CAD



Emulating the XTS for the first time



Using the Digital Twin

The image displays four screenshots of industrial automation software:

- Top-Left:** SIMATIC Manager HMI interface. It shows a 3D model of a transport system with various control buttons (Start, Stop, Jog, Speed) and status indicators. The interface includes a top status bar with timestamps and error messages, and a central control panel with buttons for 'Automatic', 'Semi', 'Step', 'Manual', 'Jog', and 'Speed'.
- Top-Right:** A 3D CAD model of a machine, likely a transport system, showing its internal components and structure. The model is rendered in a light blue and white color scheme.
- Bottom-Left:** SIMATIC Manager LAD editor. It shows a ladder logic program with various logic elements and a table of variables. The table includes columns for 'Name', 'Address', 'Display format', 'Monitor value', 'Modify value', and 'Comment'.

Name	Address	Display format	Monitor value	Modify value	Comment	Tag comment
UN01_0000	max	%d	12000	12000		
UN01_0001	max	%d	12000	12000		
UN01_0002	max	%d	12000	12000		
UN01_0003	max	%d	12000	12000		
UN01_0004	max	%d	12000	12000		
UN01_0005	max	%d	12000	12000		
UN01_0006	max	%d	12000	12000		
UN01_0007	max	%d	12000	12000		
UN01_0008	max	%d	12000	12000		
UN01_0009	max	%d	12000	12000		
UN01_0010	max	%d	12000	12000		
UN01_0011	max	%d	12000	12000		
UN01_0012	max	%d	12000	12000		
UN01_0013	max	%d	12000	12000		
UN01_0014	max	%d	12000	12000		
UN01_0015	max	%d	12000	12000		
UN01_0016	max	%d	12000	12000		
UN01_0017	max	%d	12000	12000		
UN01_0018	max	%d	12000	12000		
UN01_0019	max	%d	12000	12000		
UN01_0020	max	%d	12000	12000		
UN01_0021	max	%d	12000	12000		
UN01_0022	max	%d	12000	12000		
- Bottom-Right:** SIMATIC Manager HMI operator interface. It shows a 2D top-down view of the transport system with various control buttons and a status bar. The interface includes a top status bar with timestamps and error messages, and a central control panel with buttons for 'Start', 'Stop', 'Jog', and 'Speed'.

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.
----------	-------------------	---	--

The screenshot displays a virtual commissioning environment. On the left, a 3D CAD model of a machine is shown with various components highlighted. The right side features a control panel with a status bar at the top showing the time (07:53:00) and a message: "0103003002: UN01 Pen Labelling EM03 Main Transport - Missing 24VDC supply for XTH motor modules, EM03A-F10". Below this, another message reads: "07:52:53 0106075009: UN01 Pen Labelling EM06 Pen Labelling - Loop position below start limit, EM06F-M2B1". The control panel includes a "Unit 1: Stopped" indicator and a "Homepage 1-1" button. A central 3D model of the machine is surrounded by several modules, each with a status indicator: EM01 (Base frame, Stopped Automatic), EM02 (Top frame, Stopped Automatic), EM03 (Main Transport, Stopped Automatic), EM04 (Pen Infeed, Stopped Automatic), EM05 (Tray Depalletizer, Stopped Automatic), EM06 (Pen Labelling, Stopped Automatic), EM07 (Pen Reinfed, Stopped Automatic), EM08 (Lable Inspection, Stopped Automatic), EM09 (Pen Reject & Eject, Stopped Automatic), and EM10 (Pen Outfeed, Stopped Automatic). A "TeamViewer" window is visible in the bottom right corner.

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

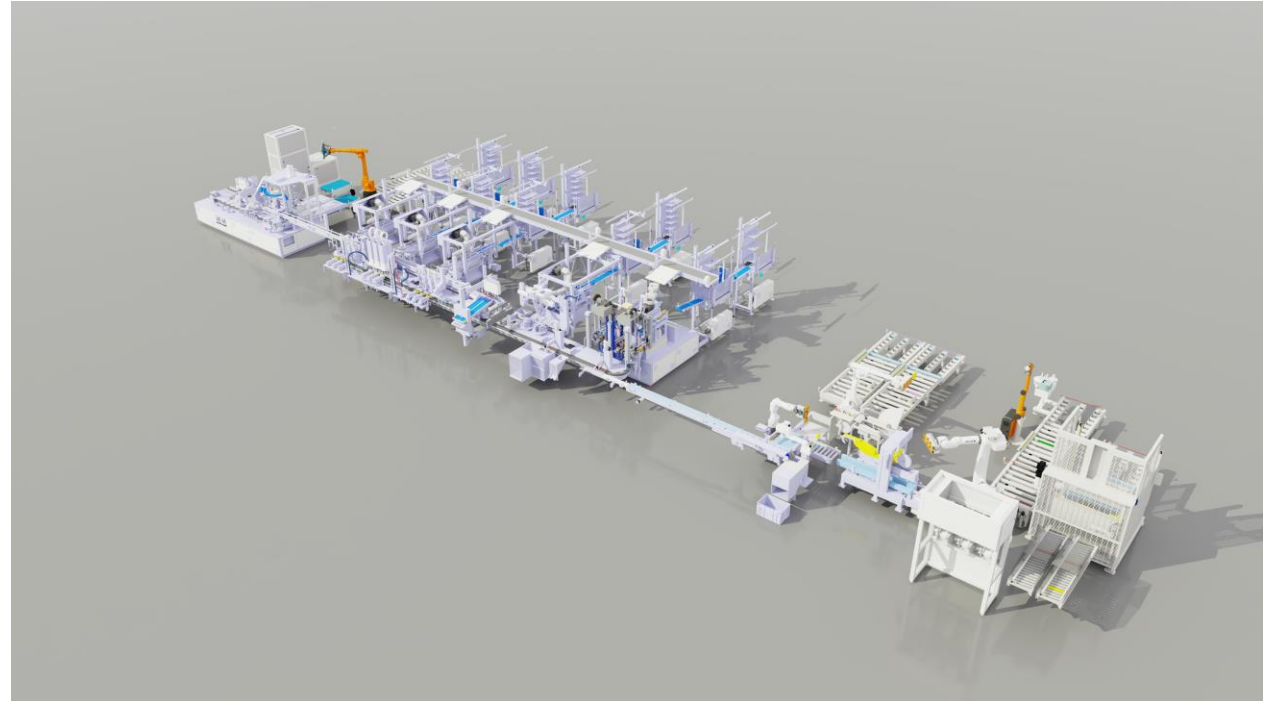
Conclusion

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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