

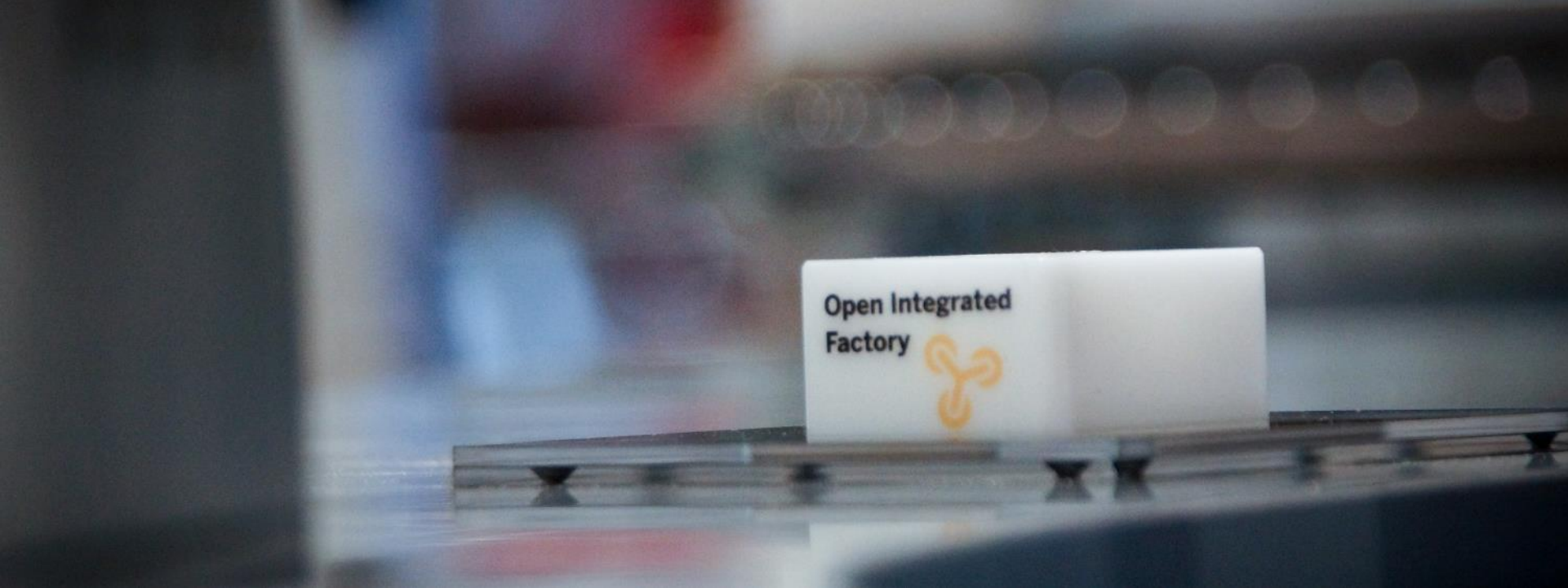
Manufacturing Execution in combination with Autonomous Agents based on SAP and OPC UA

Ruediger Fritz, SAP

October 11th 2017

PUBLIC





OPEN INTEGRATED FACTORY – GENERATION 2017

PUBLIC



Open Integrated Factory

Generation 2017

Industrie 4.0 | LIVE and REAL

<https://www.youtube.com/watch?v=7AAfLkaNKEc>

Smart Products



Open Integrated Factory

Generation 2017



April 24 – 28, 2017
Hannover, Germany



Embedded Software to Automation Process

Make-to-Order Process

Digital Manufacturing Insights



Machine Learning Process



PROCESSES

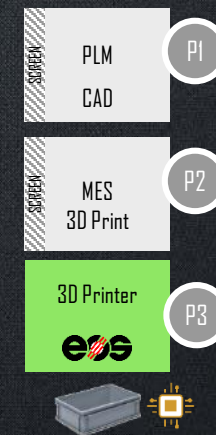
>> Make-to-Order

>> Engineer-to-order

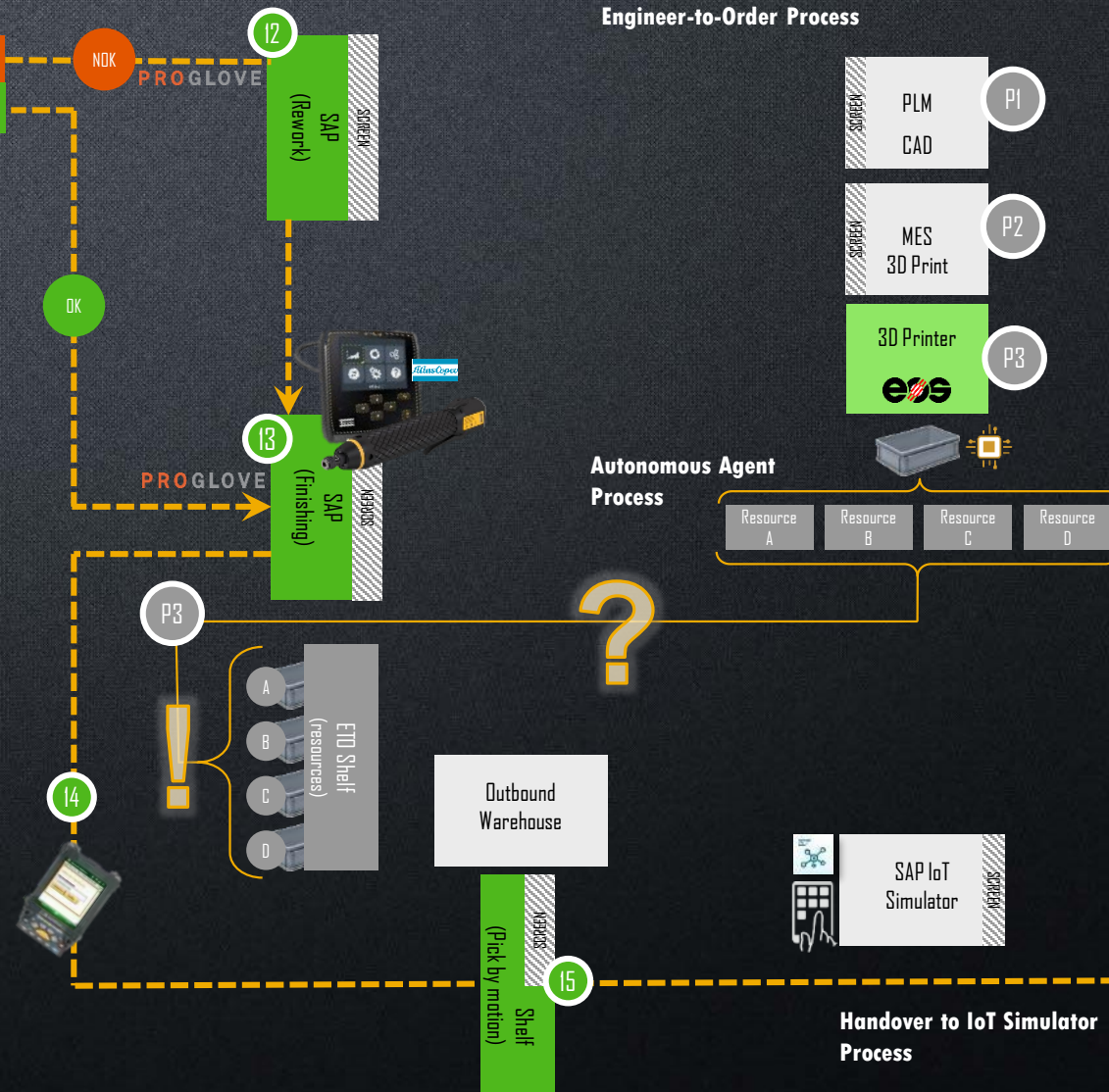


Overall: IT/OT Convergence

Engineer-to-Order Process



Autonomous Agent Process



Handover to IoT Simulator Process



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OPC UA as the standard for each
machine unit

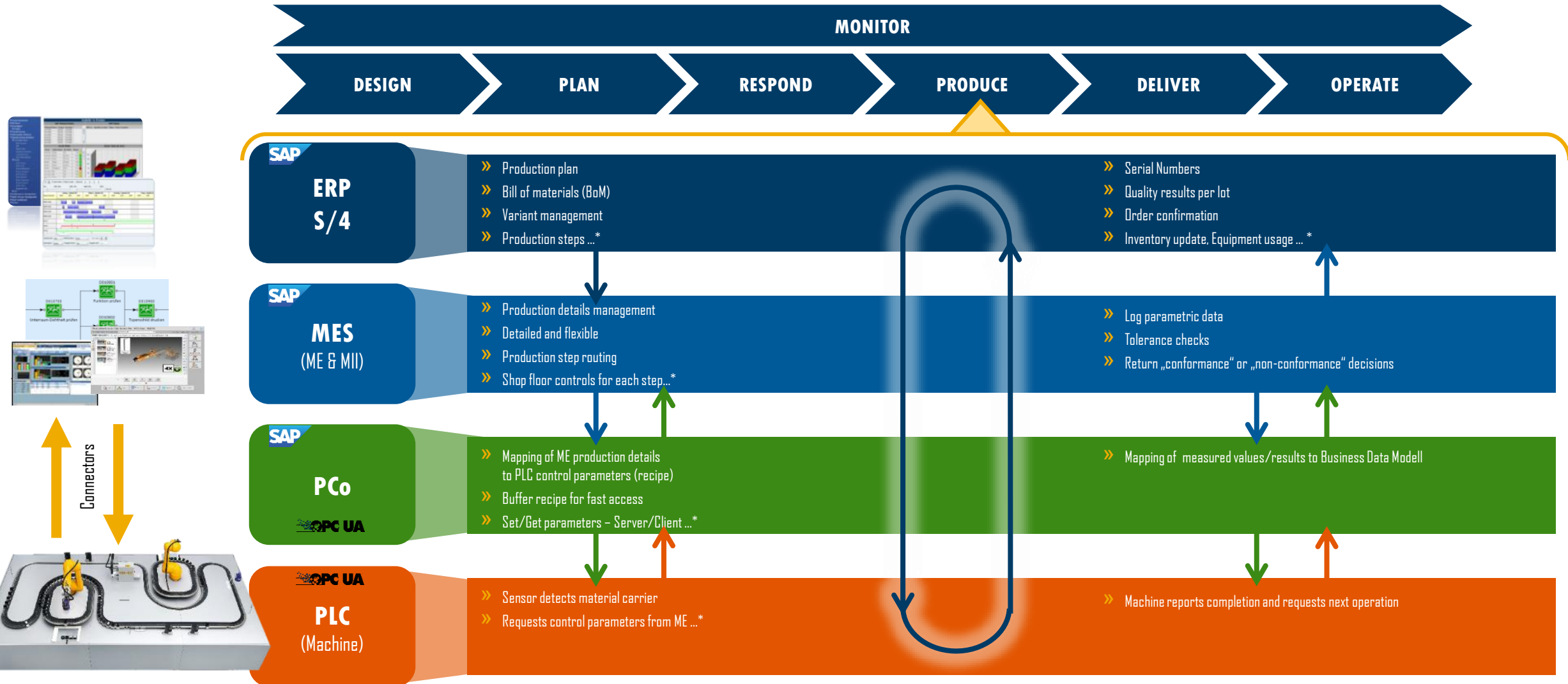
Partner Consortium

Hardware



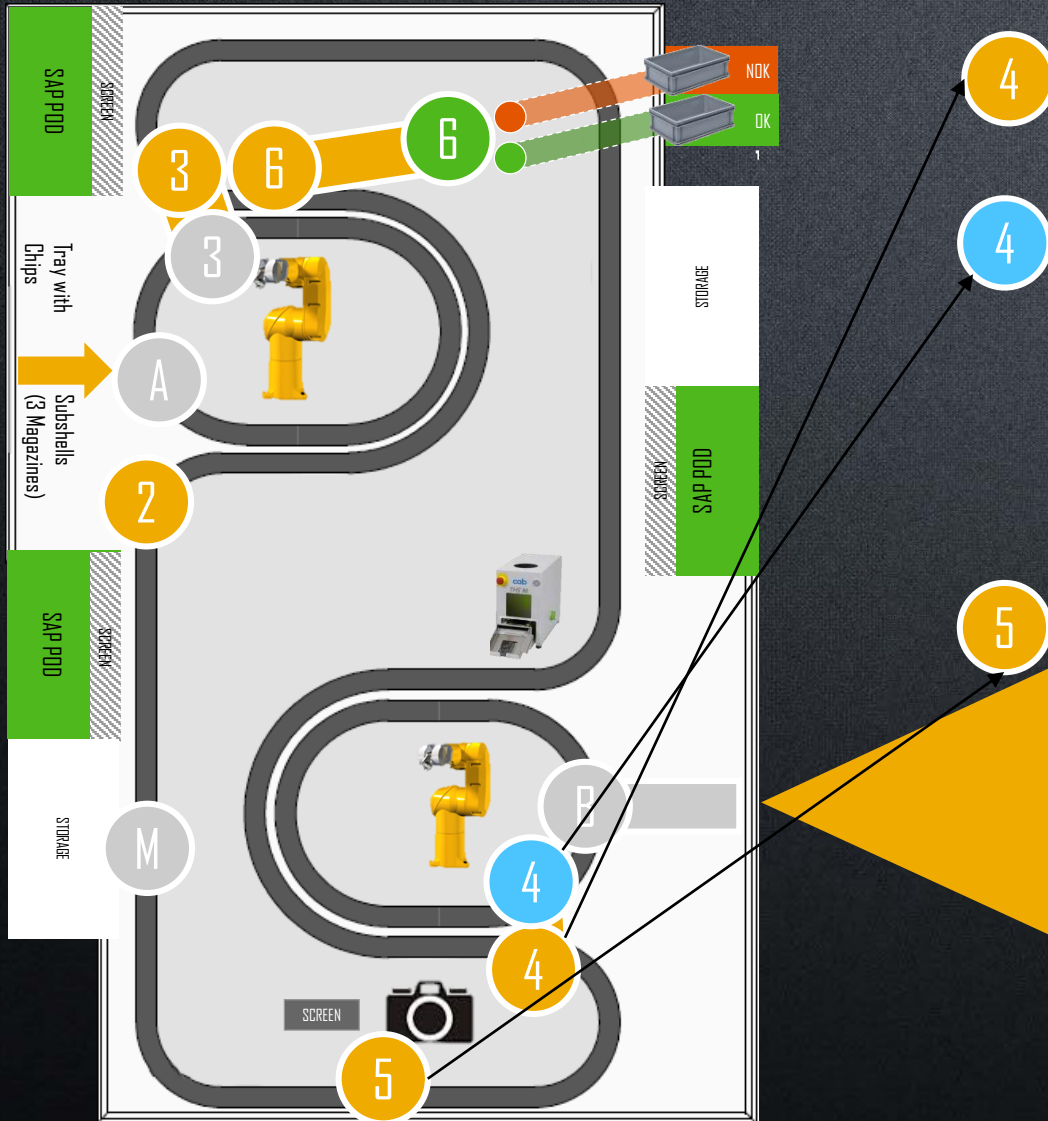
The System Layers

The Digital Plant in the Extended Supply Chain



Automation Workflow Example

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...

Loop M → PCo: "Mover with SFC 123 arrived at Pos Y4"

PCo → Loop B: "Move SFC 123B to Pos B4"

Loop B → PCo: "Mover with SFC 123B arrived at Pos B4"

PCo: (Get Lock for Rob B)

PCo → Rob B: "Do Job #3 – Handle SFC123"

Rob B → PCo: "Job #3 – Handle SDF123 done"

PCo → Loop B: "Release Mover" (move on)

PCo → Loop M: "Move SFC 123 to Pos 5"

Loop M → PCo: "Mover with SFC 123 arrived at Pos 5"

PCo → Cam: "Take Photo [Par: expected colour blue]"

Cam → PCo: "Camera result: [not blue, URL to .jpg ...]"

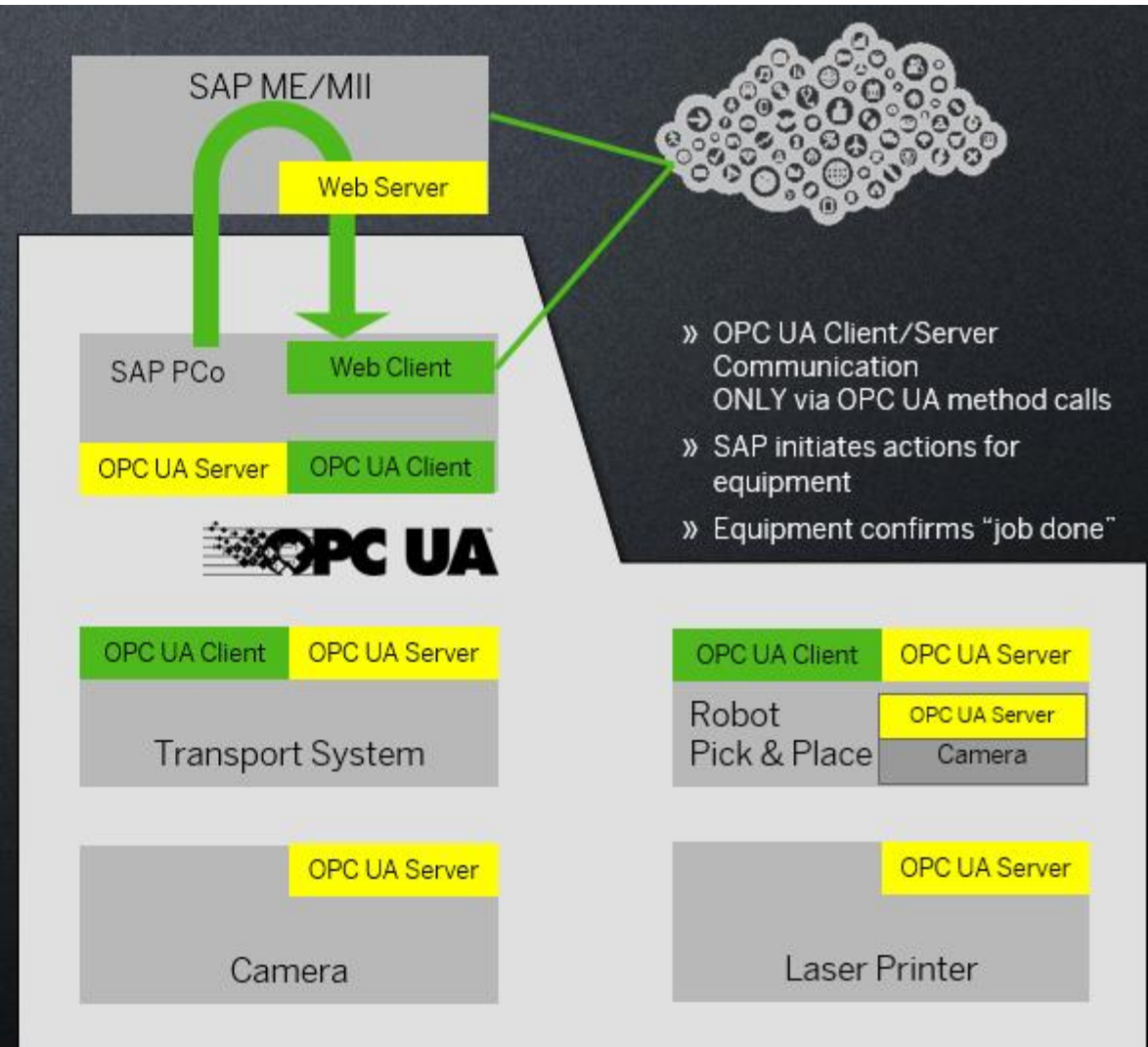
Log Non-Conformance in ME-System

...

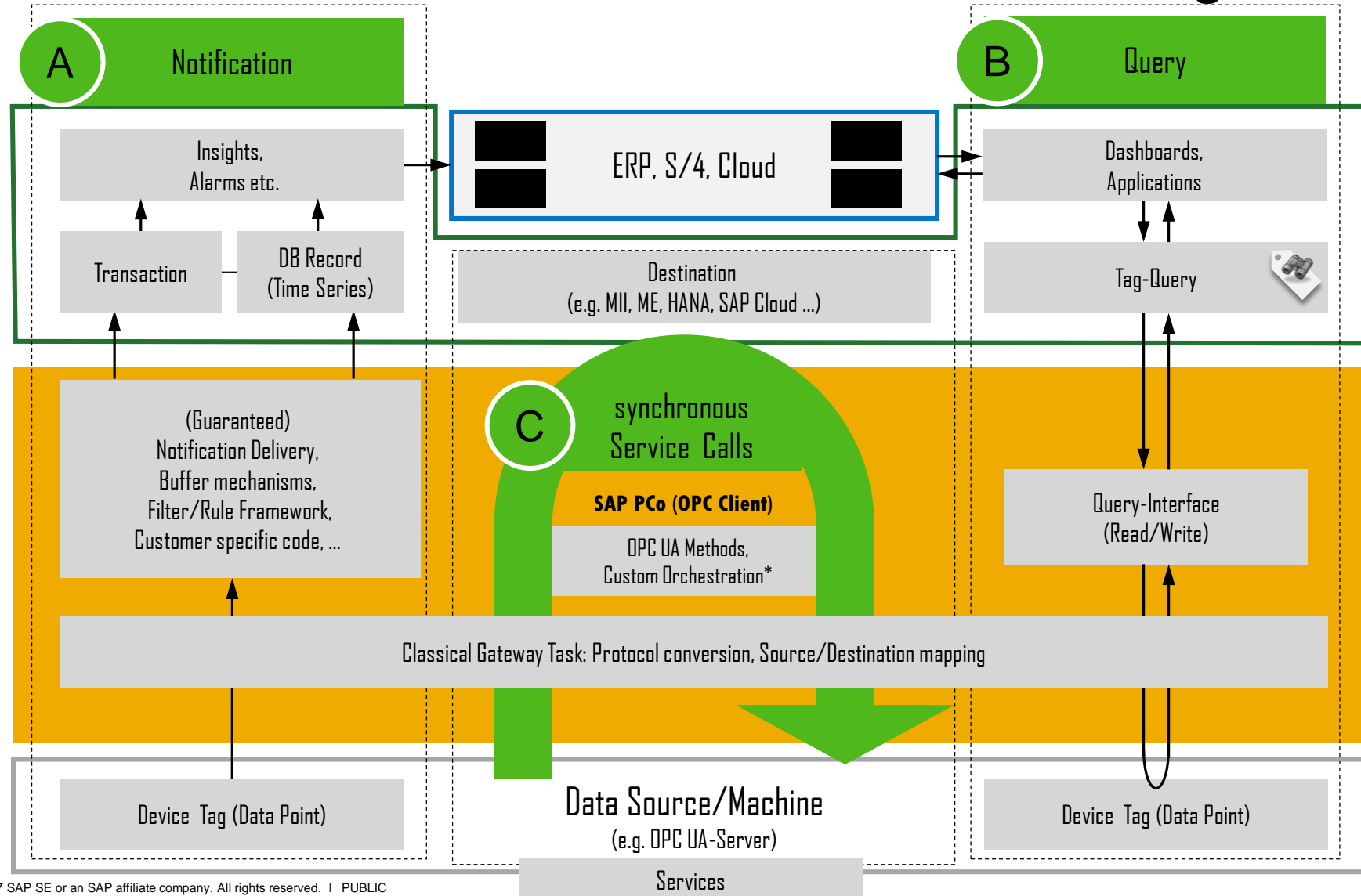
Real Life Example: Open Integrated Factory – Generation 2017

Machine Units seen as Service Providers and Service Consumers (SOA)

- (1) Each machine unit is independent
 - » In a departure from convention, the units are not linked to each other by a single program inside a single PLC
 - » Each unit comes with its own controller
- (2) Units are talking to each other on the basis of OPC UA
 - » From business perspective (production order details like routing and recipe/set-points) the units are orchestrated by SAP Plant Connectivity (Vertical Integration)
 - » From technical perspective, some machine units – here Camera and Robot - exchange information directly (Horizontal Integration)
- (3) Units are OPC UA Client and OPC UA Server at the same time
 - » A server can offer tags, events and methods
 - » A client can consume/react on tag changes and events and can call methods
- (4) Units publish their capabilities
 - » a Service Oriented Architecture with regards to hardware is possible



SAP Plant Connectivity: OPC Client and OPC Server Communication Patterns in Context of Machine Integration



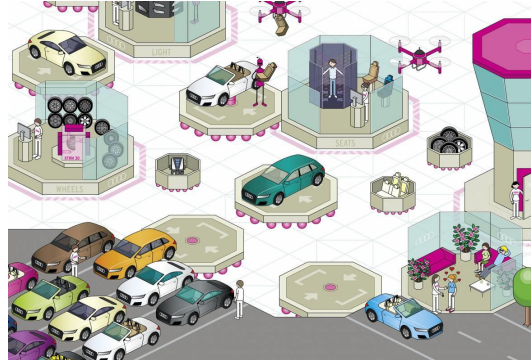
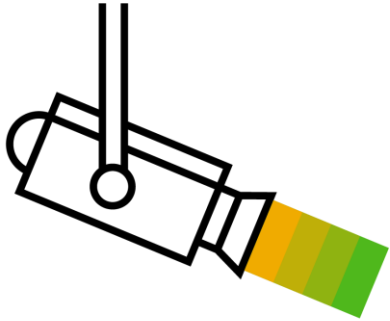
*Project specific configuration/implementation



Autonomous Agents based on OPC UA in Production

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Challenges to Manufacturing Today...



Source: <http://blog.audi.de/2016/11/23/modulare-montage-statt-fließband>



Cyber-Security

- » Increasing Interoperability = Increasing Vulnerability
- » Manage Complexity

Modular Assembly

- » Assembly Line replaced by Cellular Manufacturing
- » New organizational structures require ad-hoc decisions
- » Increasing Interoperability

AI / Machine Learning

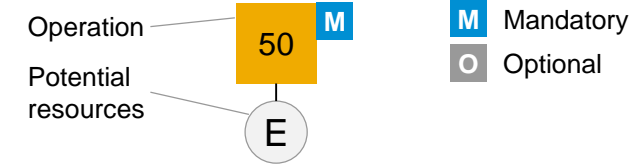
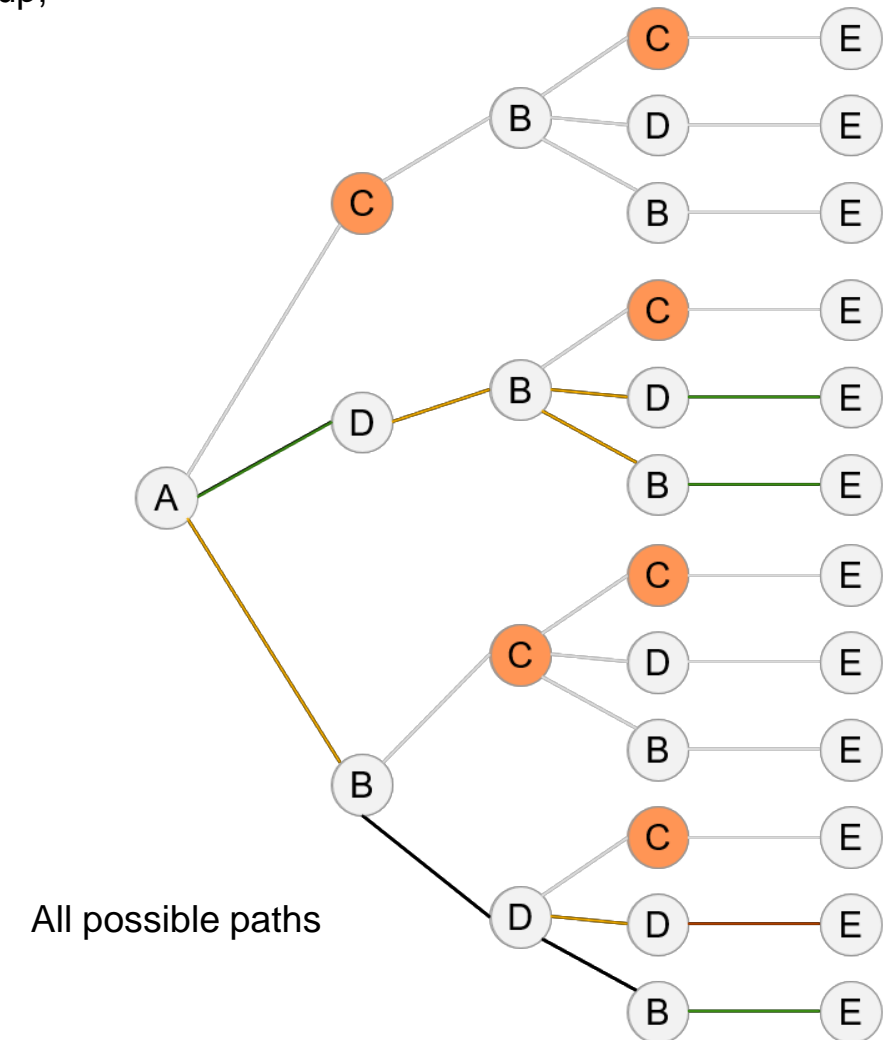
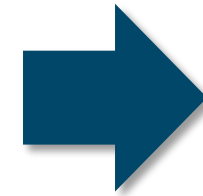
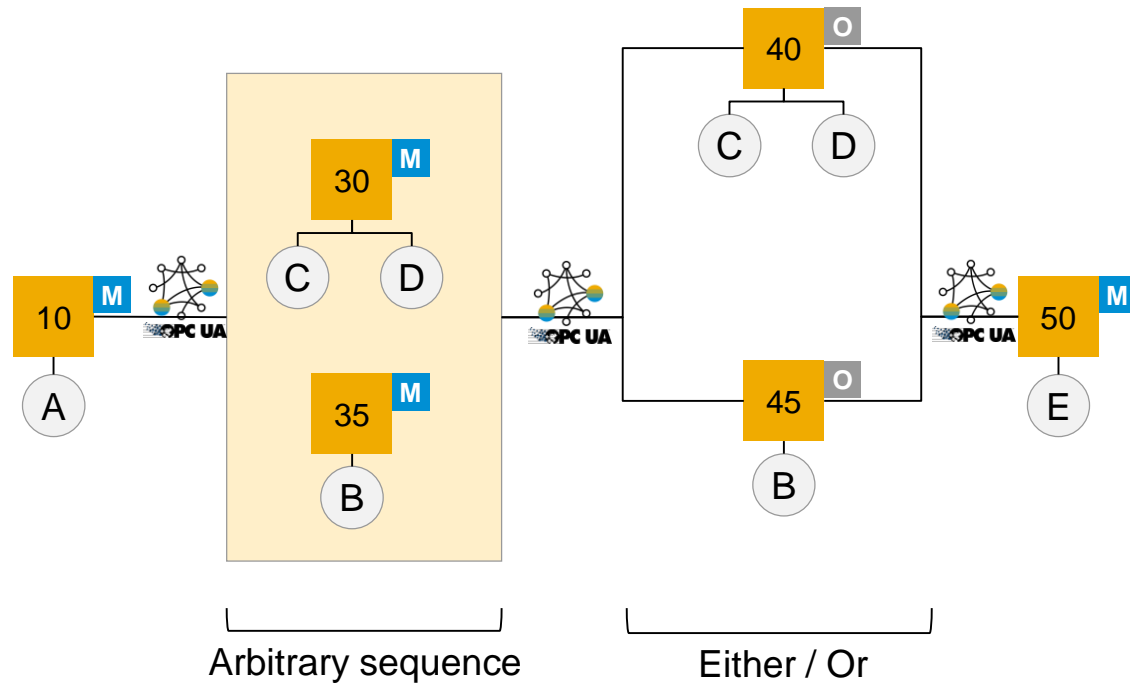
- » Insight to Automation (immediate action)
- » Pattern Recognition
- » Autonomous Systems, Edge Processing

Challenges to Manufacturing Today...

Modular Assembly

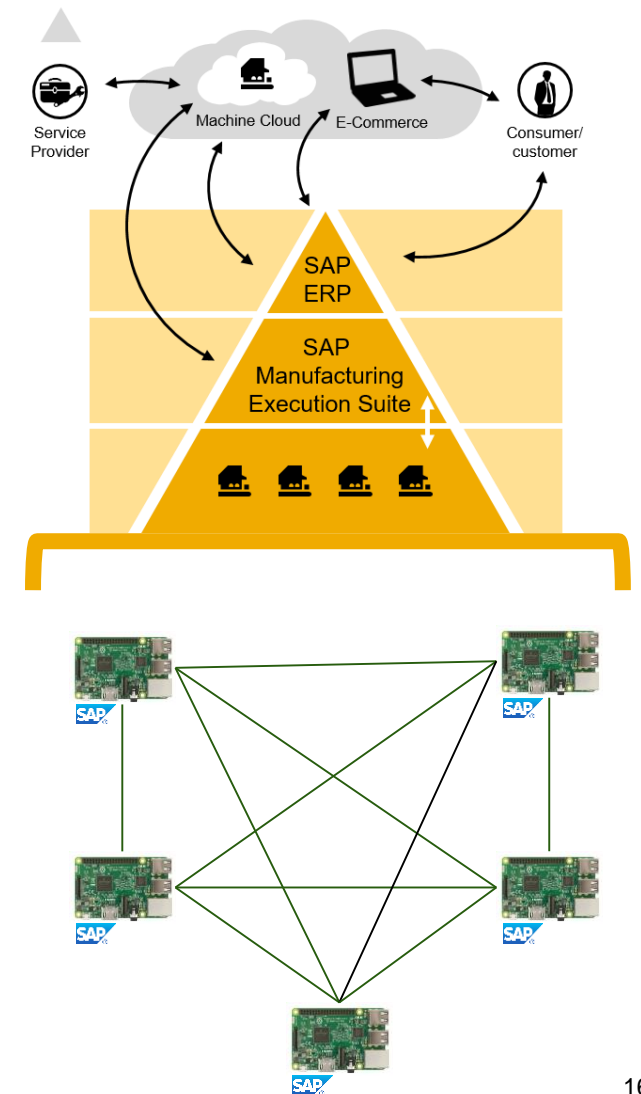
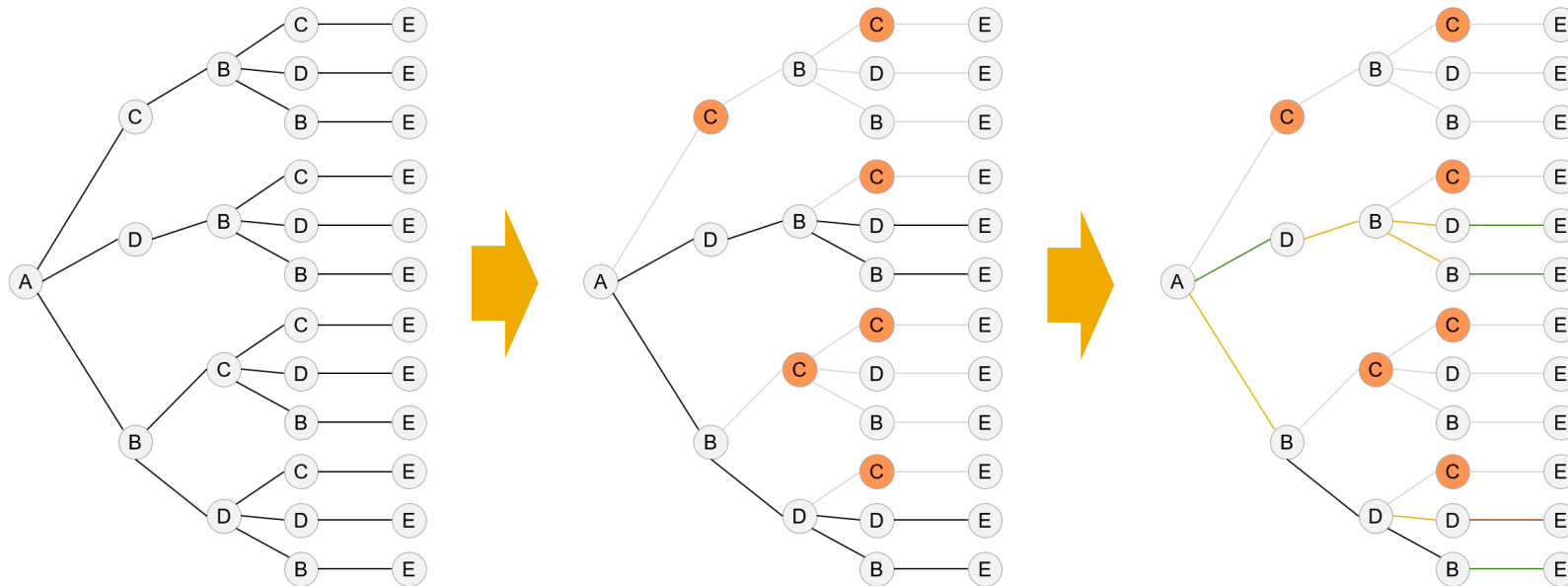
Modular Assembly

- » Dynamic Routing → alternative operations, alternative resources
- Ad-hoc decisions based on frequent machine-to-machine communication (status, set-up, availability ...) linked to business data (order details, master data ...)



AI / Machine Learning

» Autonomous Systems, Edge Processing



Embedded Software to Automation Process

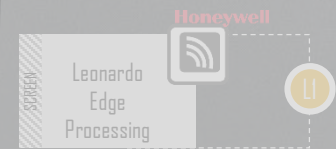
Make-to-Order Process

Engineer-to-Order Process

Digital Manufacturing Insights

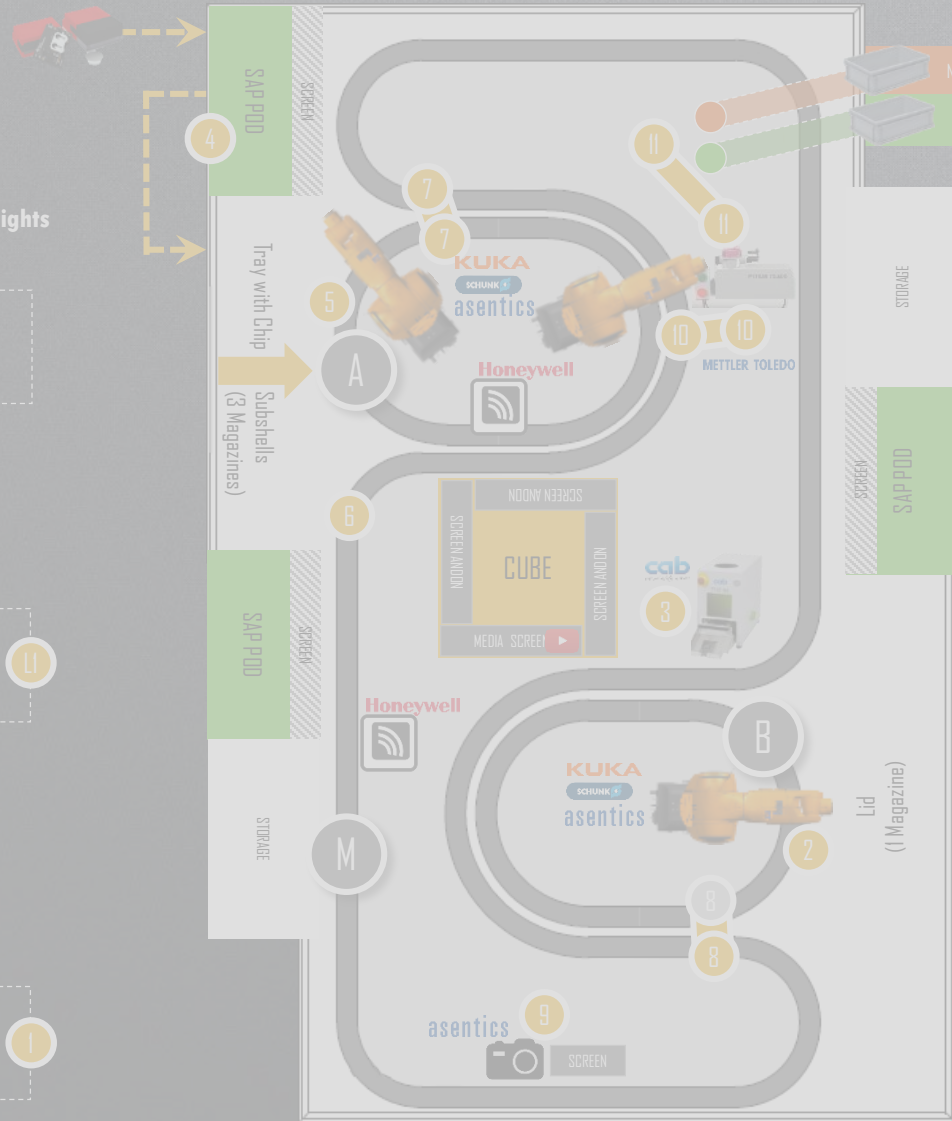


Machine Learning Process

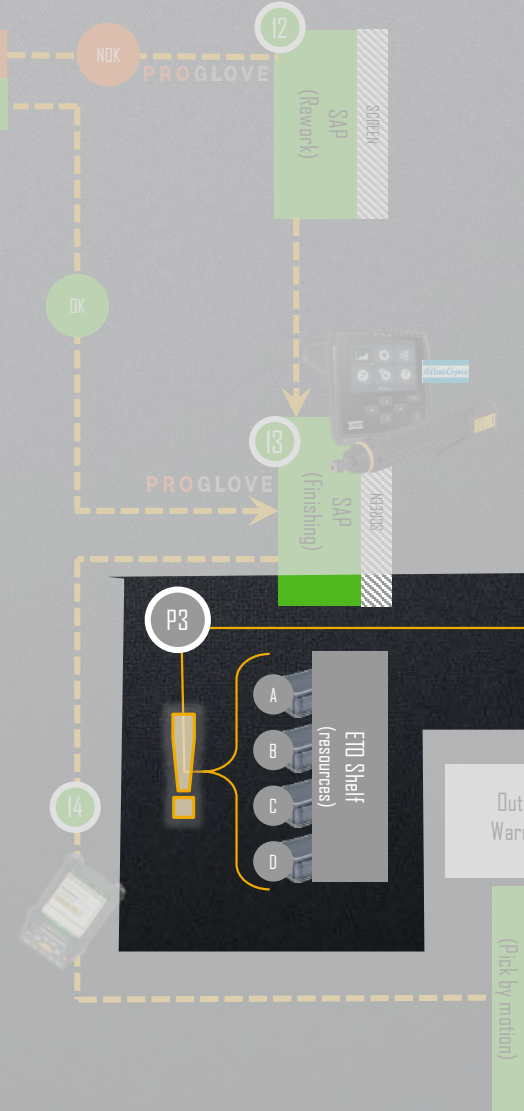


PROCESSES

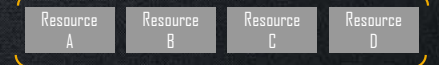
- >> Make-to-Order
- >> Engineer-to-order



Overall: IT/OT Convergence

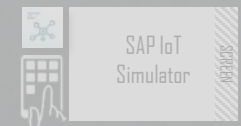


Autonomous Agent Process



Outbound Warehouse

Shelf (Pick by motion)



Handover to IoT Simulator Process



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Transforming Manufacturing
with Autonomous Agents



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Generation 2017

Low Cost Set-up for
demonstrating a powerful
concept of modern
Manufacturing Execution



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Generation 2017

Resource A - D could represent
e.g. 4 (identical) packing
machines



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Generation 2017

A single box could represent
e.g. an Autonomous Guided
Vehicle (AGV) or just a kind of
Handling Unit



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Generation 2017



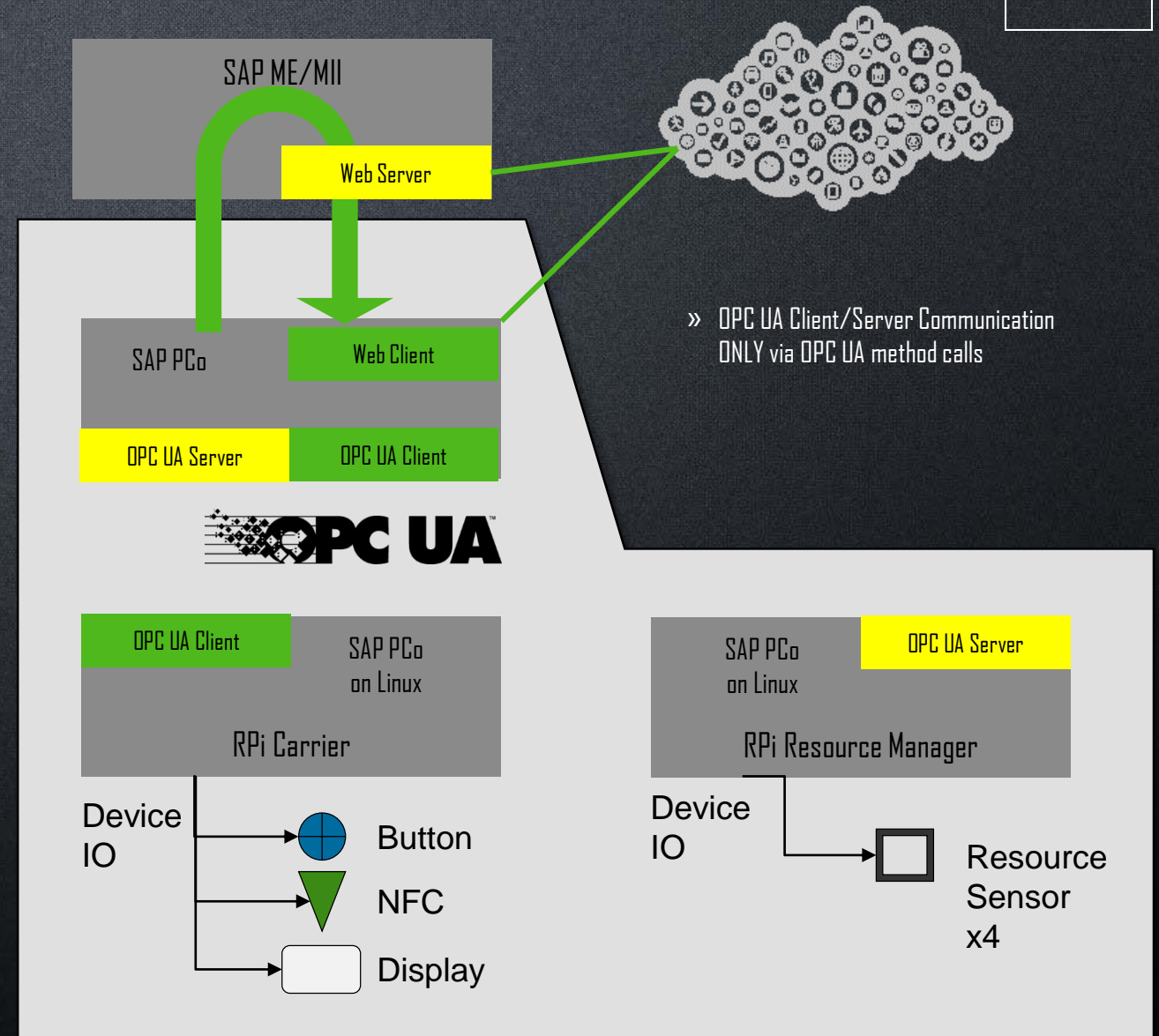
- each Box one RPi with OPC UA Client
- all Resources managed by another RPi3 with OPC UA Server

Technical Basis

SAP Plant Connectivity on RPi Linux

- (1) Networking over Wireless LAN
- (2) Software Development
 - » .Net Mono Framework
 - » OPC UA 1.0.3 libraries
 - » Custom-developed .Net dll to provide RPi Device IO connectivity

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Negotiation can start -
pressed Button initiates
communication via WiFi



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First step: SAP PCo on RPi as OPC UA Client to
SAP PCo as OPC UA Server wrapping the SAP MES:
“get_current_sfc” (means get the Production Order from MES which is
in work right now)



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Second step: SAP PCo on RPi as OPC UA Client
to other SAP PCo as OPC UA Server managing the
(four) resources: “get_free_resource”

Behind this method any
sophisticated logic could run

-
e.g. a machine learning
based algorithm!



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Generation 2017



Logic on OPC UA Server RPi
proposes and allocates the
appropriate Resource
(OPC UA Method response)

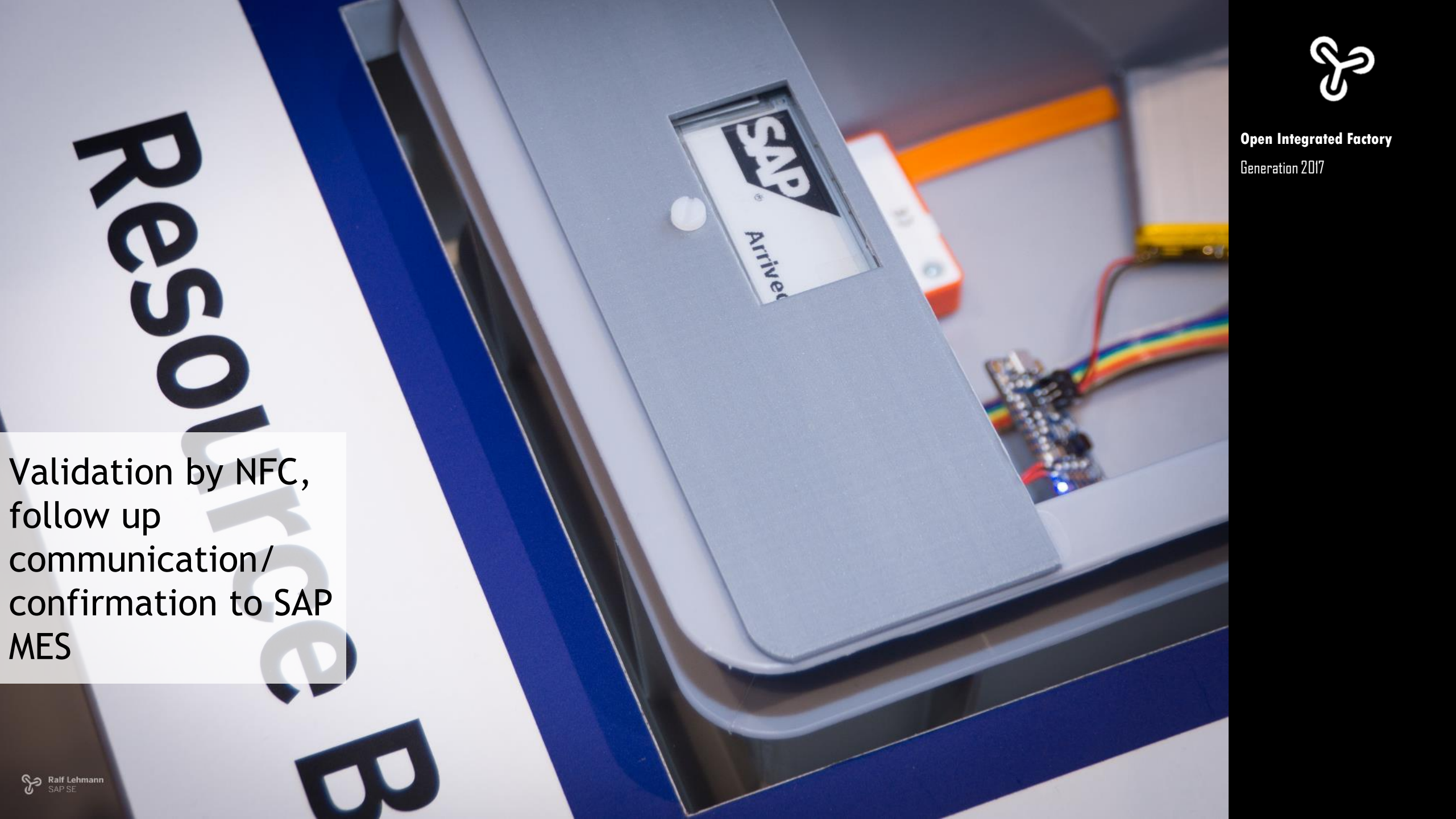
Resource C



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Generation 2017

Validation by NFC



Validation by NFC,
follow up
communication/
confirmation to SAP
MES



Open Integrated Factory

Generation 2017

Resource B



... at shop floor
much easier thanks
to



Open Integrated Factory
Generation 2017



Short comment about challenges of OPC UA ...?

PUBLIC

OPC DAY FINLAND 2017

11.10.2017 #OPCWA #OPCDAYFINLAND #AUTOMATION #OPCDAY



Thank you!

BECKHOFF



Rexroth
Bosch Group



Thank you.

Contact information:

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0049 6227 740142

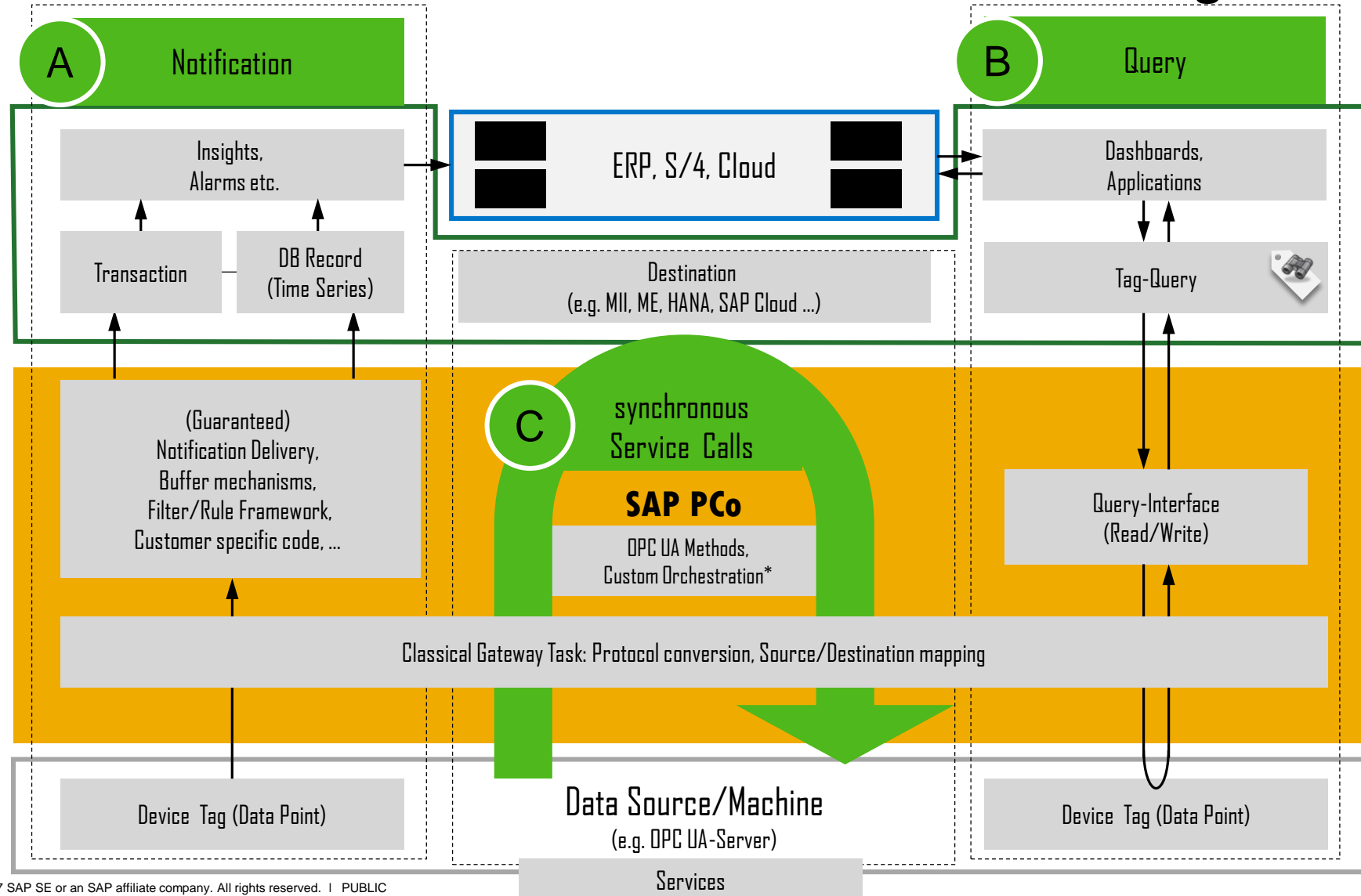
ruediger.fritz@sap.com



Appendix

PUBLIC

SAP Plant Connectivity: OPC Client and OPC Server Communication Patterns in Context of Machine Integration



*Project specific configuration/implementation

SAP Plant Connectivity – more than just a simple Gateway for Connectivity

SAP Cloud/ SAP Leonardo Platform

SAP Business Suite, S/4 HANA

ABAP NetWeaver, DB

REST-WS +
MQTT

Other PCo

OPC UA Server
or
WebServer

SAP MII

Proprietary
(TCP/IP) or
SOAP -WS

SAP ME

SOAP-WS,
ODATA-WS

SAP EWM

Socket

SAP Data
Streaming

Proprietary
(TCP/IP based),
REST

RFC, SOAP-WS,
ABAP Push Channels (WebSocket)
ODBC, ODATA, REST

SAP Plant Connectivity (PCo)

- OPC UA Server for configurable Methods
- WebServer for configurable Methods
- WebSocket-Server for Query Access

Supported protocols:

- ✦ **OPC UA, MQTT, OPC DA, OPC HDA, OPC A&E, Citect, IP2I, Osisoft PI (2), Proficy Historian, File-Monitor (2), ODBC, OLE DB, Socket, Modbus**
- ✦ SDK for **proprietary, specific agents** (e.g. ifm Linerecorder, UDP, RFC1006, Euromap 6x, Atlas Copco Open Protocol, Kafka and multiple other project specific implementations)



DCS
PLC



MES



Plant DB



Plant Data
Collection



Plant
Historian



Wireless
Integration

Devices, Logic Controllers, Historians



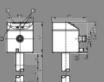
LIMS



SCADA / HMI



Environmental
Building Management



Sensors

Customer Or... 31393

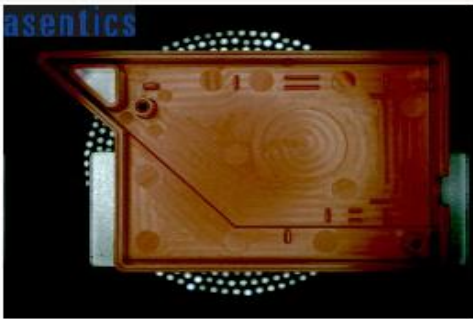
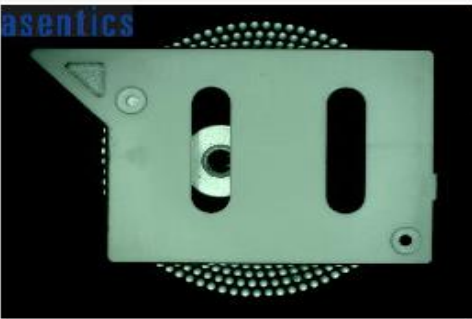
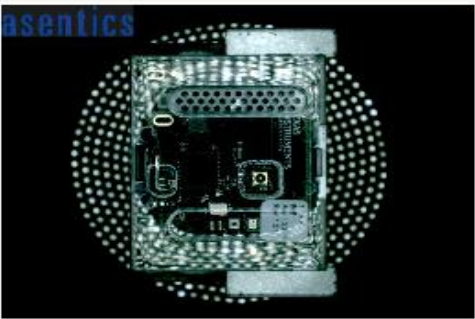
Get Pictures

Close Window

C...

Top Tray

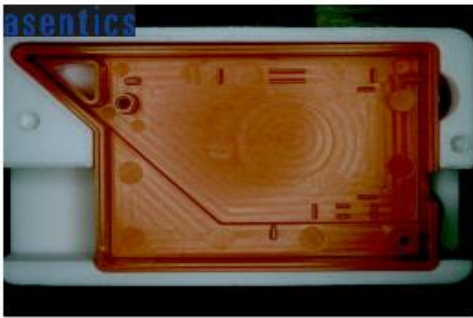
Bottom Tray



Chip in M...

Top Tray in Pr...

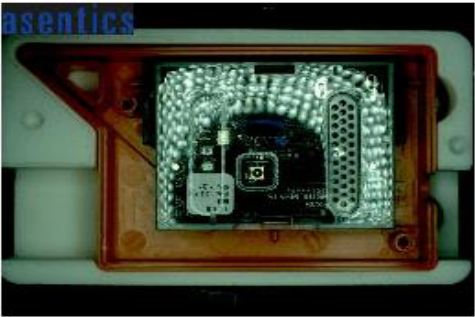
Bottom Tray in Mo...



Chip in Bottom Tray

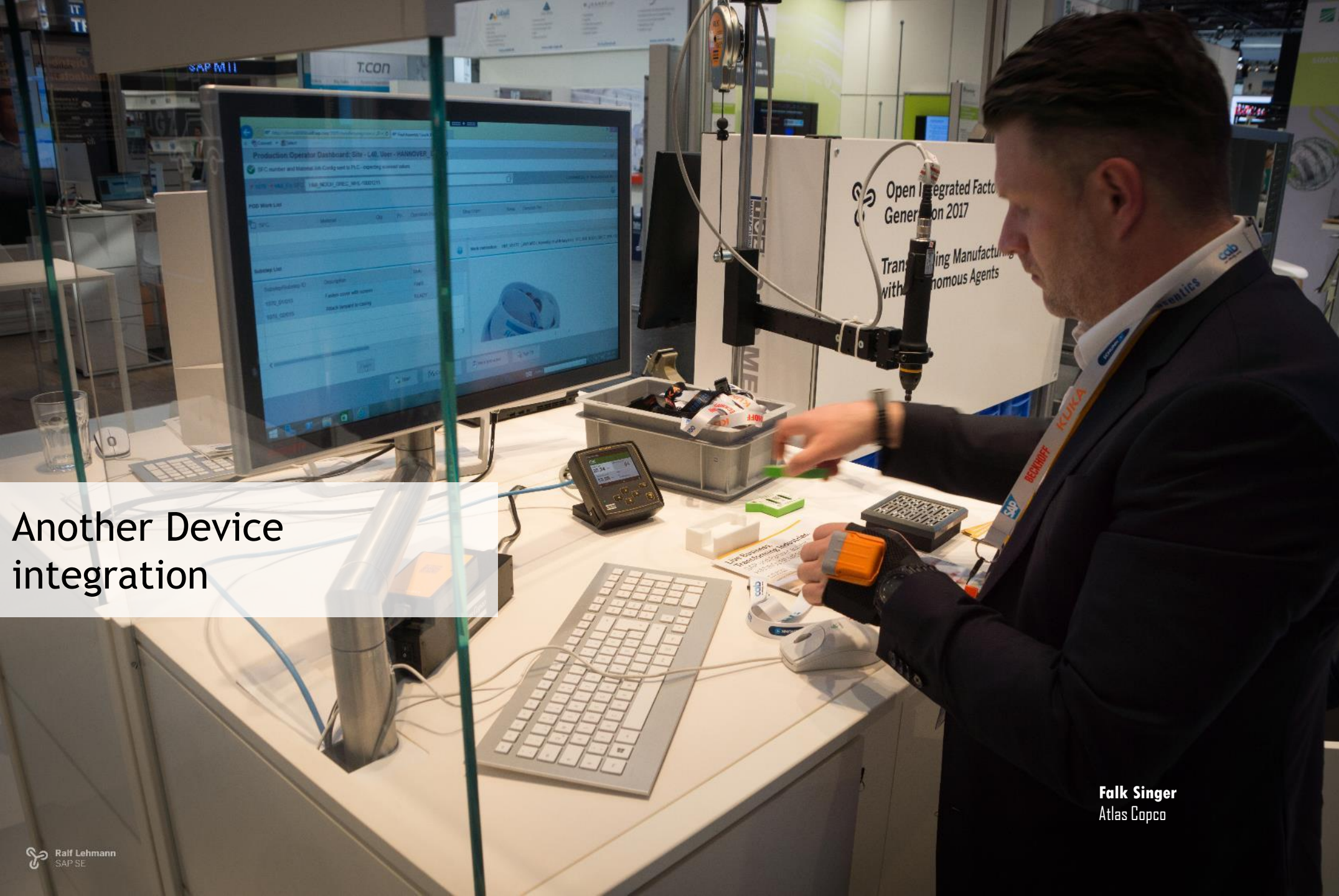
Top Tray in M...

Finshed Product



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Each production step
documented and
available for
analytics



Another Device
integration



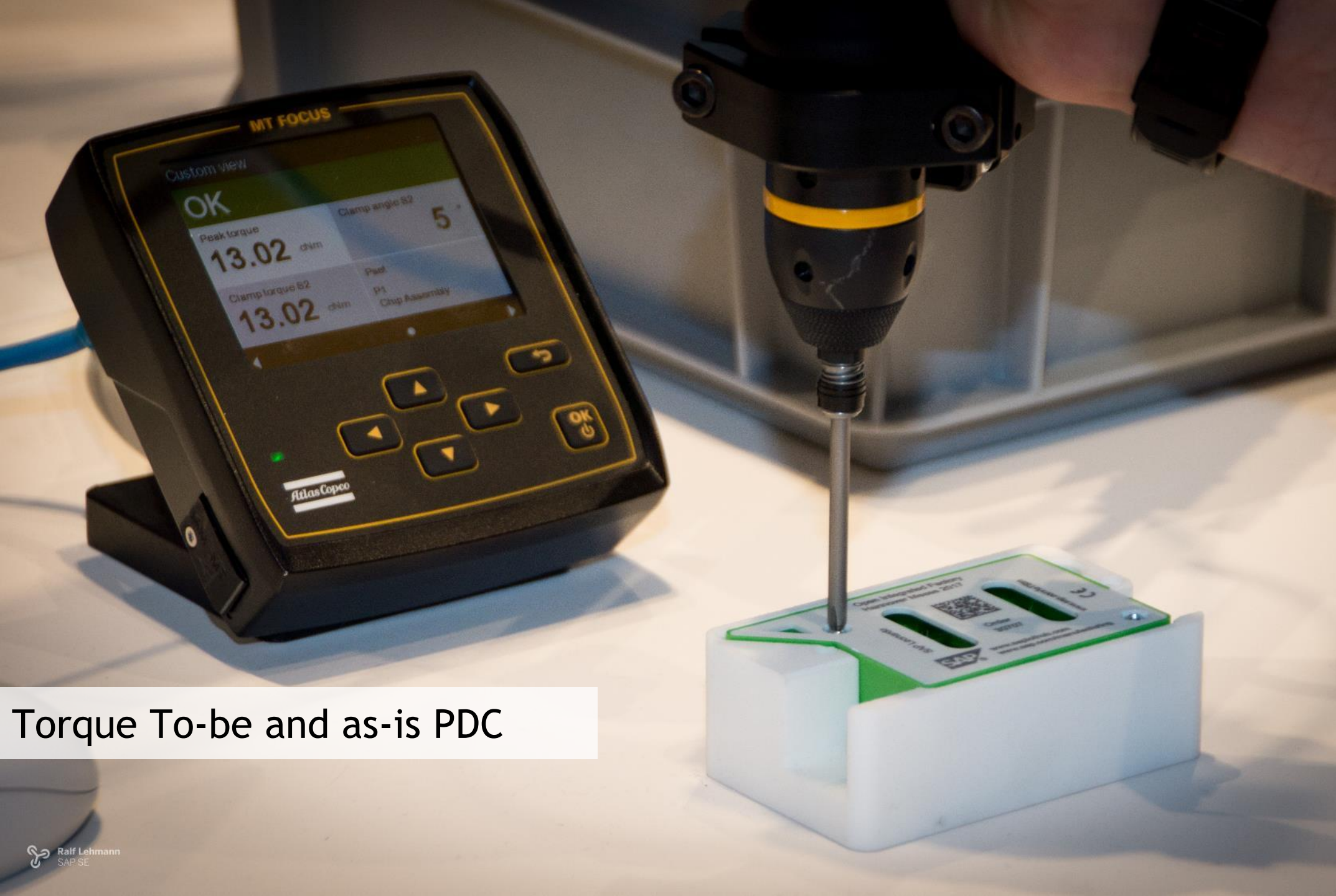
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Generation 2017

Falk Singer
Atlas Copco



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Generation 2017



Torque To-be and as-is PDC

Plant Connectivity – An Example of Configuration

Management Console (Administrator)

Plant Connectivity Edit View Tools Help

Source Systems

- OpCuaCamera_Simulation
- OpCuaMettlerToledo
- OpCuaMettlerToledo__1
- OpCuaRobotAC
- OpCuaRobotB
- OpCuaXts
- uaDemoCloudChipProcessing
- uaDemoCloudPictureTransfer
- uaKVPPProductive
- uaPcoMeAsyncCaller
- uaPcoPrinterLock
- uaPcoRobotALock
- uaPcoRobotBBlock
- uaPcoRobotClock
- uaPcoServerXts
- uaServerXts
- ZZ_MyOPCUA_Source_Pointing_to_KVPBufferAgent
- ZZZ_OPCUA_DATASource

Destination Systems

- m_1030_01_MoverArrivedAtPosM
- m_1030_02_MoverArrivedAtPosA
- m_1030_03_RobJobDoneA_ChipToSubshell
- m_1040_01_MoverArrivedAtPosM
- m_1040_02_MoverArrivedAtPosB**
- m_1040_03_RobJobDoneB_CoverToSubshell
- m_1050_01_MoverArrivedAtPosM_Camera
- m_1050_99_GetSetpointGroup
- m_1055_01_MoverArrivedAtScale
- m_1055_02_RobJobDone_ShellToScale
- m_1055_99_Weighing
- m_1060_01_RobJobDone_Disposal
- m_2030_01_ChipAssemblyCompletedA
- m_2030_02_MoverArrivedAtPosA
- m_2030_03_RobJobDoneA_ChipToMover
- m_2030_99_ChipAssemblyCompleted
- m_3010_01_MoverArrivedAtPosB
- m_3010_02_RobJobDone_CoverToPrinter

Agent Instances

- [2] new_uaServerXts
 - 0000_01_MoverStatusB
 - 0000_03_RobJobDoneA_PauseMode
 - 0000_03_RobJobDoneB_PauseMode
 - 0000_03_RobJobDoneC_PauseMode
 - 1020_01_MoverArrivedAtPosM
 - 1020_02_RobJobDoneA_SubshellToMover
 - 1030_01_MoverArrivedAtPosM
 - 1030_02_MoverArrivedAtPosA
 - 1030_03_RobJobDoneA_ChipToSubshell
 - 1040_01_MoverArrivedAtPosM
 - 1040_02_MoverArrivedAtPosB
 - 1040_03_RobJobDoneB_CoverToSubshell
 - 1050_01_MoverArrivedAtPosM_Camera
 - 1050_01_MoverArrivedAtPosM_Camera_PauseXts
 - 1055_01_MoverArrivedAtPosM
 - 1055_02_RobJobDoneC_ShellToScale
 - 1060_01_RobJobDoneC_Disposal
 - 2030_01_ChipAssemblyCompletedA
 - 2030_02_MoverArrivedAtPosA
 - 2030_02_MoverArrivedAtPosA_PauseXts
 - 2030_03_RobJobDoneA_ChipToMover
 - 3010_01_MoverArrivedAtPosB
 - 3010_01_MoverArrivedAtPosB_PauseXts
 - 3010_02_RobJobDoneB_CoverToPrinter
 - 3010_03_MoverArrivedAtPosB_3
 - 3020_01_RobJobDoneB_CoverToMover

Multiple Call Destination System m_1040_02_MoverArrivedAtPosB

Destination System Calls Variables and Calculations General Settings

Sequence of Destination System Calls

Step #	Destination System	Go To	Exception Handling	Branching Condition	Description
5	uaRobotBListLocks				
10	mUtilGetDependentSfc				Get SFC on ring M from SFC on ring B
20	mRobotBBlock			if('tempRobotBlockSuccess', 40, 30)	Lock robot B with SFC on ring M
30	mMoverToEhrenrundeB			999	
40	uaMEStartSfc				
50	uaRobDoJobB				Tell robot to put printed cover onto subshell

Assignment of Variables

Step #	Destination System	Cal	Destination System Variable	Data Type	Create New Variable	Variable Name	Data Type	Variable Value Assignment
5	uaRobotBListLocks		outHandles	System.String[]		tempRobotBBlocks	System.String	Assigned
10	mUtilGetDependentSfc		inSfc	System.String		inSfcB	System.String	At Start
10	mUtilGetDependentSfc		inWorkcenterSource	System.String		tempWorkcenterSource_HMI_XTSB	System.String	At Start, Calculated
10	mUtilGetDependentSfc		inWorkcenterTarget	System.String		tempWorkcenterTarget_HMI_XTSM	System.String	At Start, Calculated
10	mUtilGetDependentSfc		outSfc	System.String		tempSfcM	System.String	Assigned
20	mRobotBBlock		inSfc	System.String		tempSfcM	System.String	Assigned
20	mRobotBBlock		outRobotBlockSuccess	System.Boolean		tempRobotBlockSuccess	System.Boolean	Assigned
30	mMoverToEhrenrundeB		inSfcB	System.String		inSfcB	System.String	At Start
30	mMoverToEhrenrundeB		inPosB	System.Int16		inPosB	System.Int16	At Start
40	uaMEStartSfc		inSfc	System.String		tempSfcM	System.String	Assigned
40	uaMEStartSfc		inOperation	System.String		1040	System.String	At Start, Calculated
40	uaMEStartSfc		inResource	System.String		HMI_M4	System.String	At Start, Calculated
50	uaRobDoJobB		zSFC	System.String		tempSfcM	System.String	Assigned
50	uaRobDoJobB		nJob	System.Int16		tempRobotBJob_CoverToSubshell	System.Int16	At Start, Calculated
50	uaRobDoJobB		ReturnValue	System.Int16				

AI / Machine Learning with immediate action on automation level

» SAP PCo (OPC Client) → Cloud / Data Lake → Apply Model to Dynamic Edge Processing → SAP PCo to Automation

