
KUKA

KUKA

Requirements for Time Sensitive Networks in Manufacturing

Why right now?
Because Industry 4.0 needs it!

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Senior Developer System Engineering

Our current product portfolio

Market position KUKA Roboter (sold Robots 2012)

1

Germany

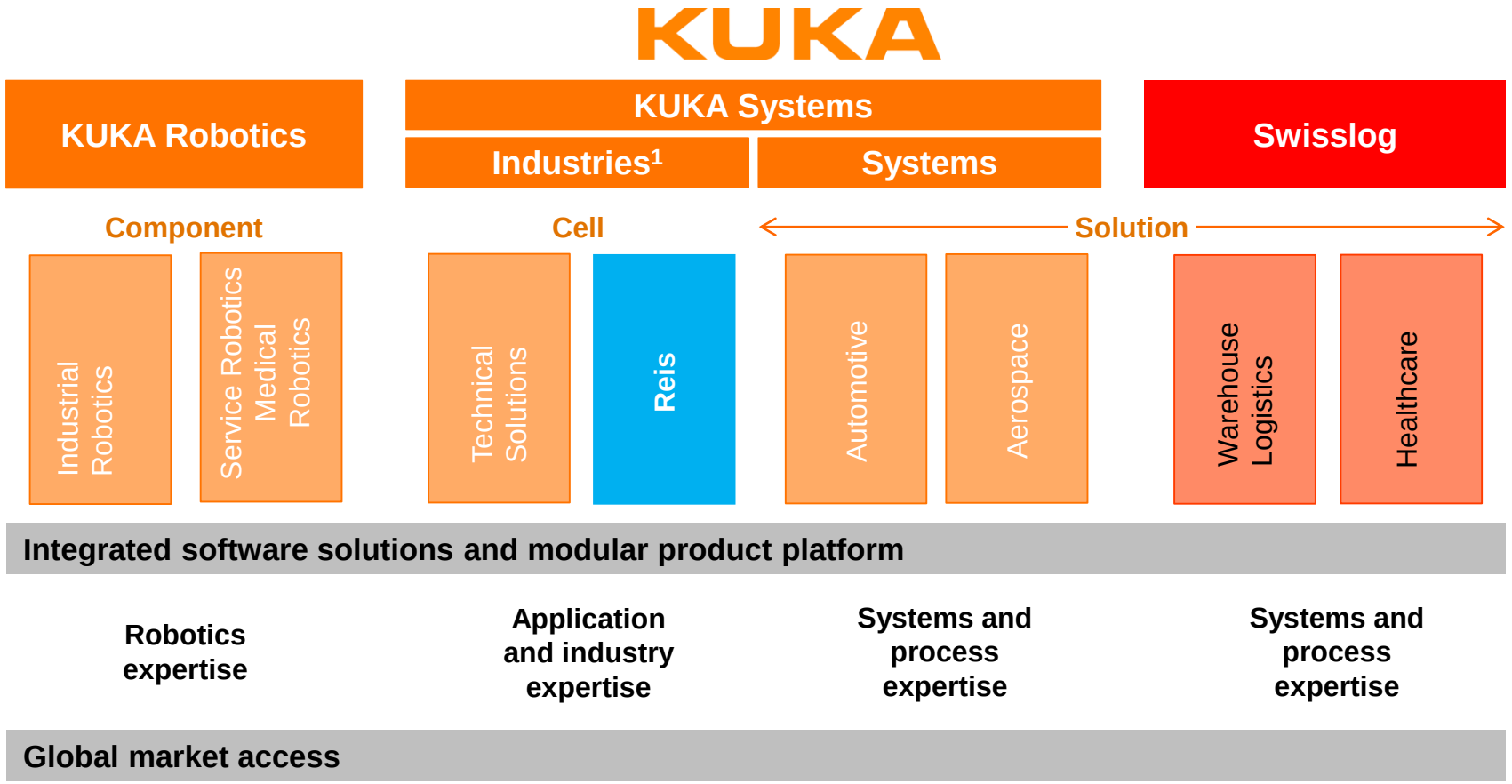
1

Europe

2

World

KUKA AG - Strategy



1) In planning

Industrial Internet

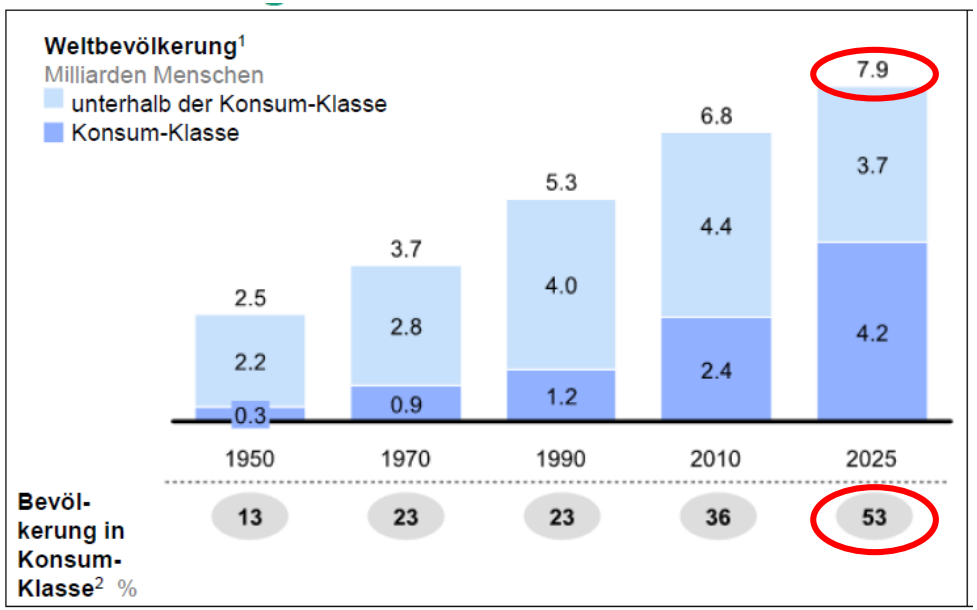
- IIC covers five industries
  - Healthcare
  - Transportation
  - Energy & Utilities
  - Public Sector
  - Manufacturing
- There will not be only one M2M protocol over several industries
- Industry 4.0 covers only one industry: Industrial Automation

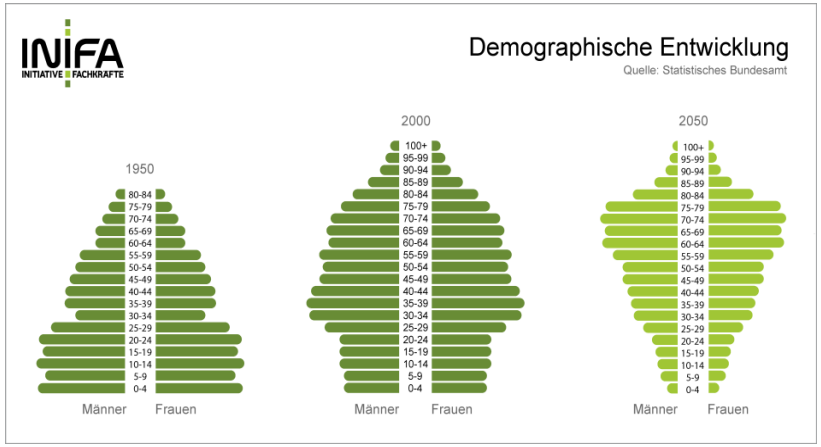
Industry 4.0: Industrial Automation for Manufacturing

Manufacturing

Process Manufacturing	Hybrid	Discrete Manufacturing
▪ Oil	▪ Oil in Cans	▪ Cans, Bottles
▪ Natural Gas	▪ Natural Gas in Bottles	▪ Cars, Trucks, Trains, Ships, Airplanes
▪ Pharmaceutical	▪ Pharmaceutical in Pills	▪ Electronic Devices
▪ Food & Beverage	▪ Food in Portions, Beverage in Bottles	▪ Smart Phones
▪ Chemical	▪ Paints in Cans	▪ TV-Sets
▪ Paints	▪ …	▪ Computers
▪ Textiles		▪ Furniture
▪ …		▪ Toys
		▪ …

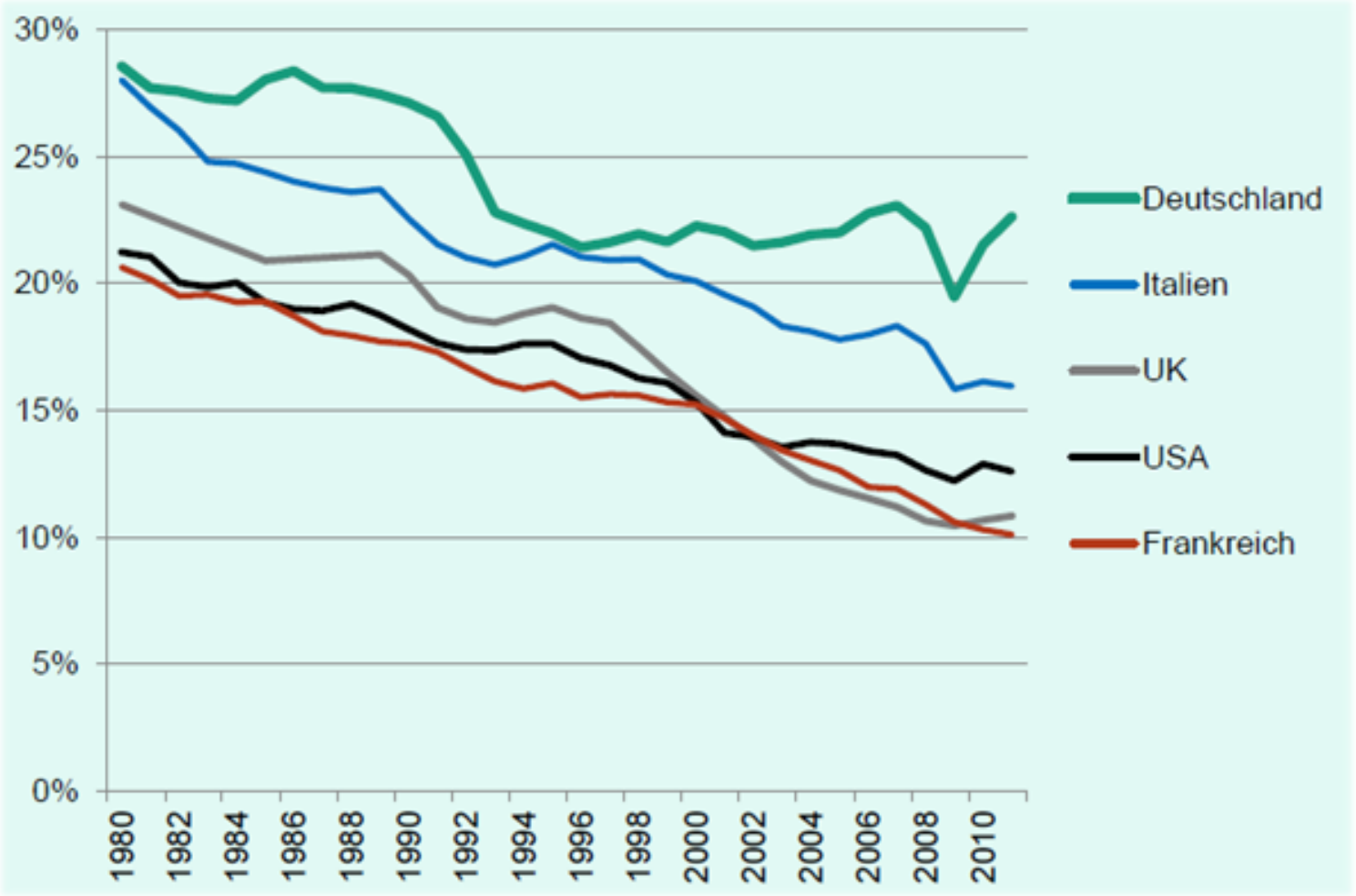
Why Industry 4.0? Challenges of the future





- In 2025 there are ~8 Billion people on earth, >half of them in the „Consumer-Class“
- People are getting older, in Germany we are getting less
- Consequences for Germany: Keep automated manufacturing in Germany, export products, export manufacturing technologies and manufacturing know how
- Robots and other machines as assistant systems for humans (Human Robot Coop.)
- Information sources and decision helpers through IT-systems like Smart Devices

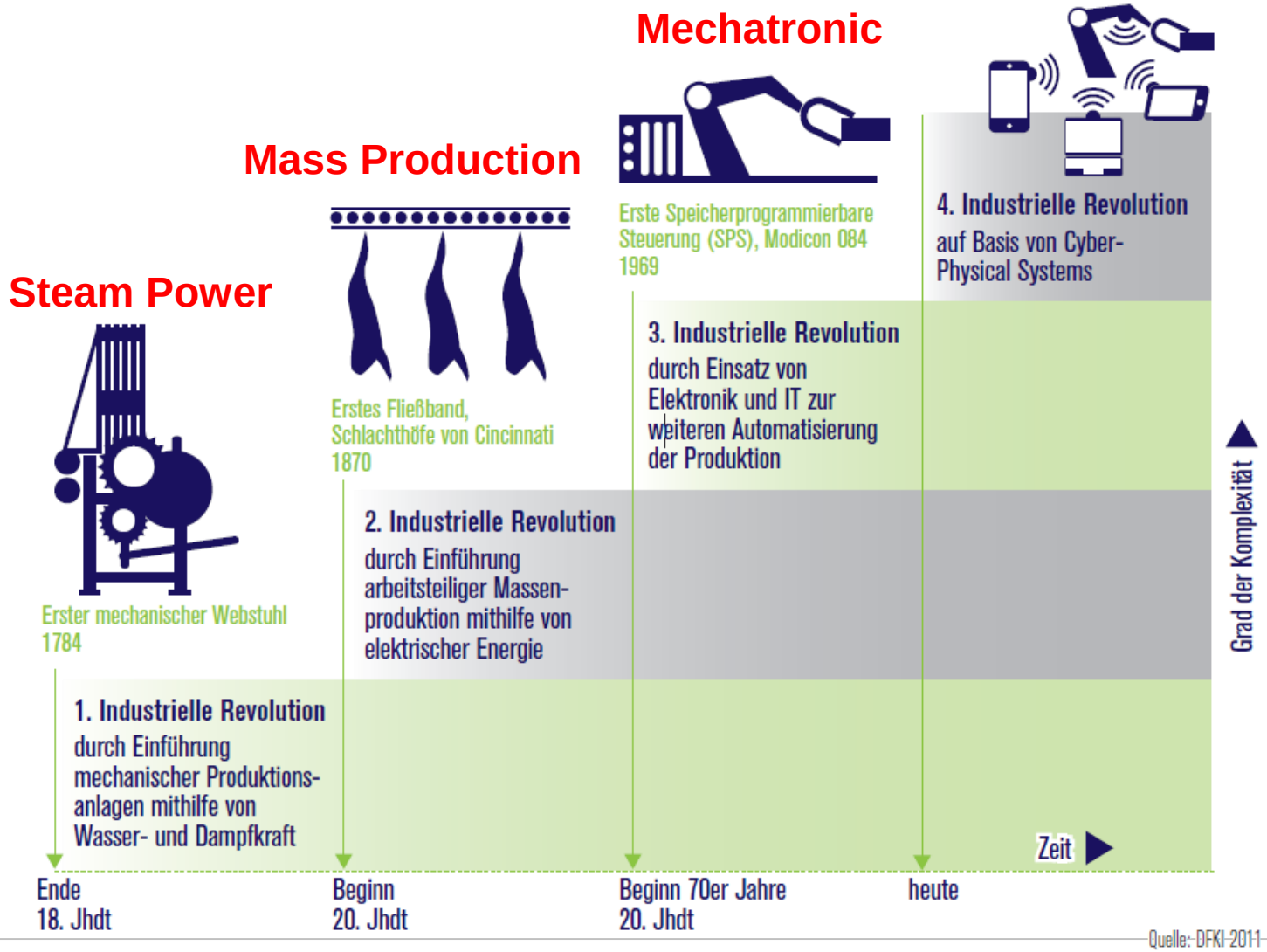
Why Industry 4.0? Countries must Revitalize Manufacturing



Quelle: UNData: Gross Value Added Manufacturing/Total Gross Value Added

What is Industry 4.0?

Cyber Physical Systems



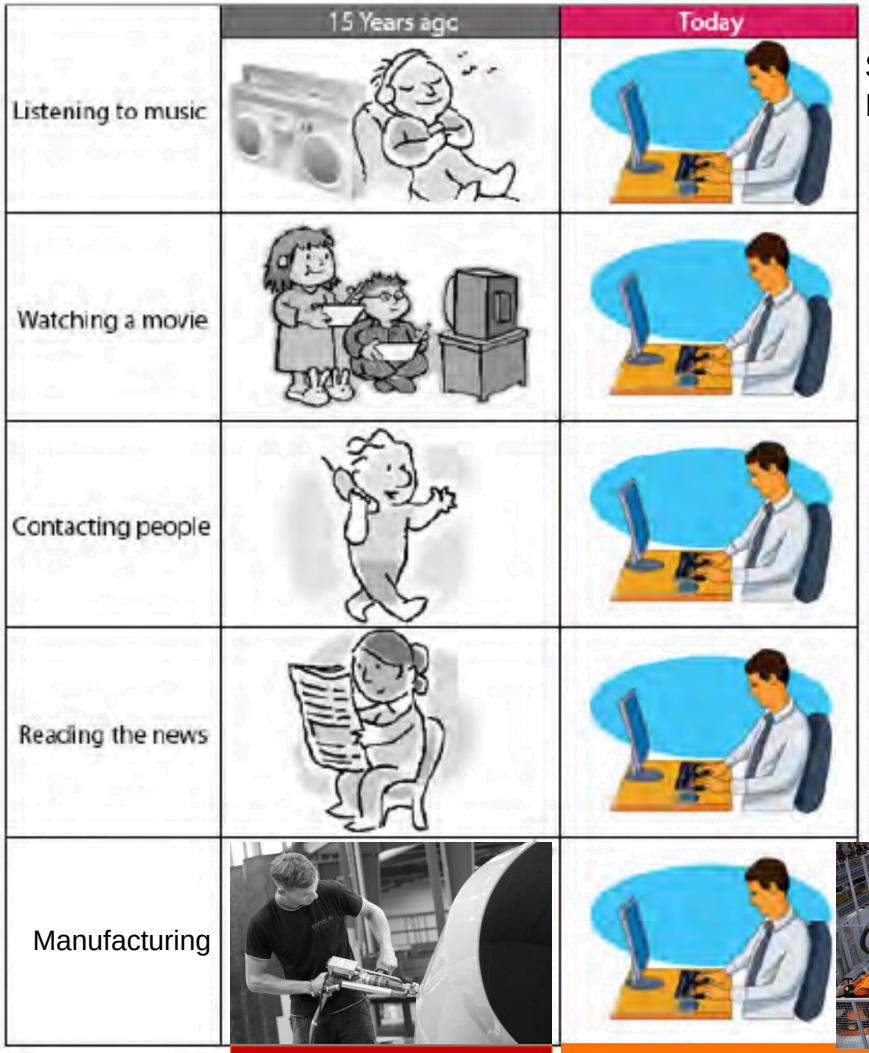
Quelle: DFKI 2011

Industry 4.0 is the thorough Digitalization of the Manufacturing Industry

“A fundamental new rule for business is that the Internet changes everything.”

Bill Gates, 1999

- …but in 1999 this only addressed the internet of people!
- The Internet of Things will change much more!
- I.e. Manufacturing



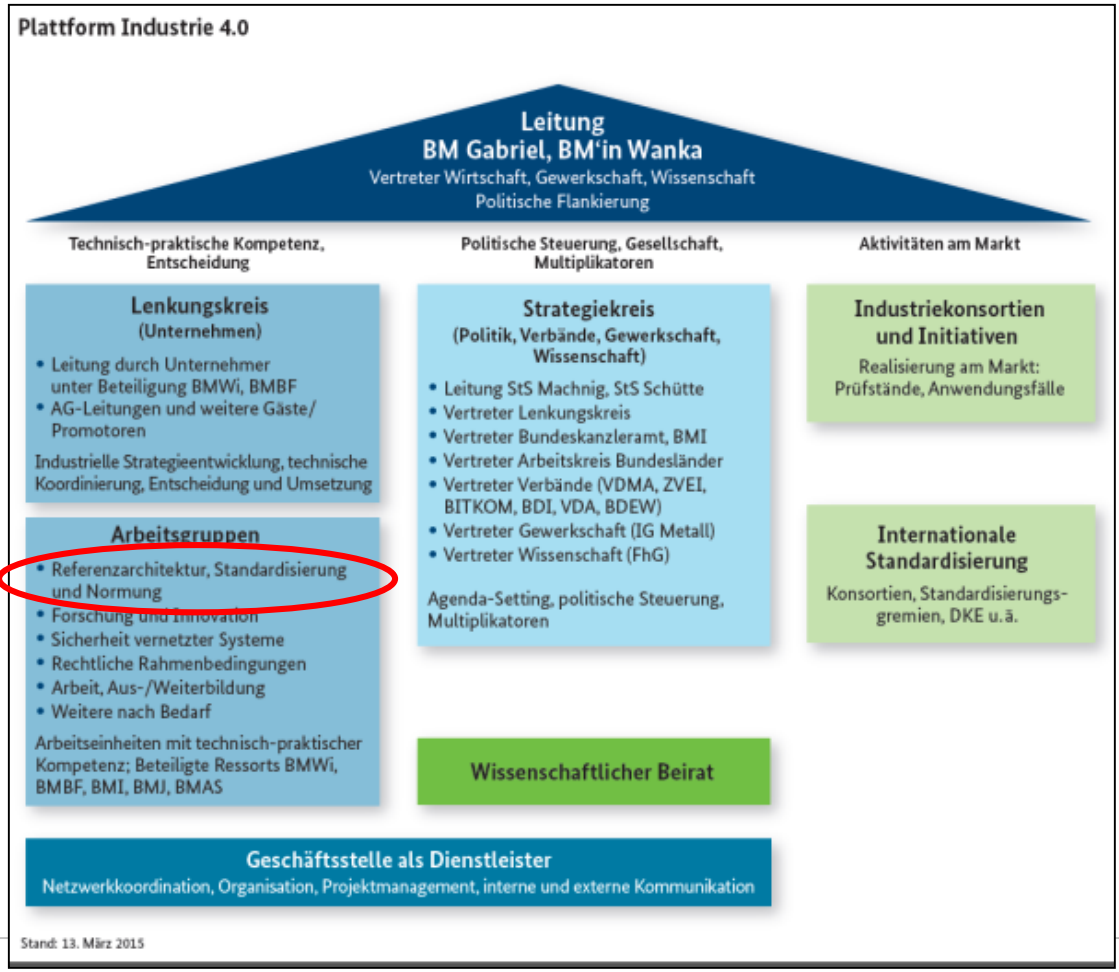
Source: IIC

Chancellor Angela Merkel on the Hannover Fair 2013…

- …receives the Industrie 4.0 realization suggestions paper from acatech

Industry 4.0 was invented in Germany

- Industry 4.0 is one of ten „Future Projects" of the German Government
  - 200 Mio. € grants
  - Controlled by the German Government
    - Minister for Economic Affairs & Energy Siegmar Gabriel
    - Minister for Education & Research Johanna Wanka
  - I am a vice chairman in the "Reference Architecture and Standardization" working group
- OPC UA is agreed as the standard protocol for M2M communication by the steering committee
- After German cars and German beer, Industry 4.0 is another perfect German export article…



Taiwan / China

- Terry Gou defines Industry 4.0 as:
  - Cloud computing
  - Big data
  - Mobile devices
  - Robots
- Employees related:
  - smart living
  - smart work networks

http://www.manufacturingglobal.com/lean/391/Terry-Gou-steers-Foxconn-towards-an-Industry-40-future

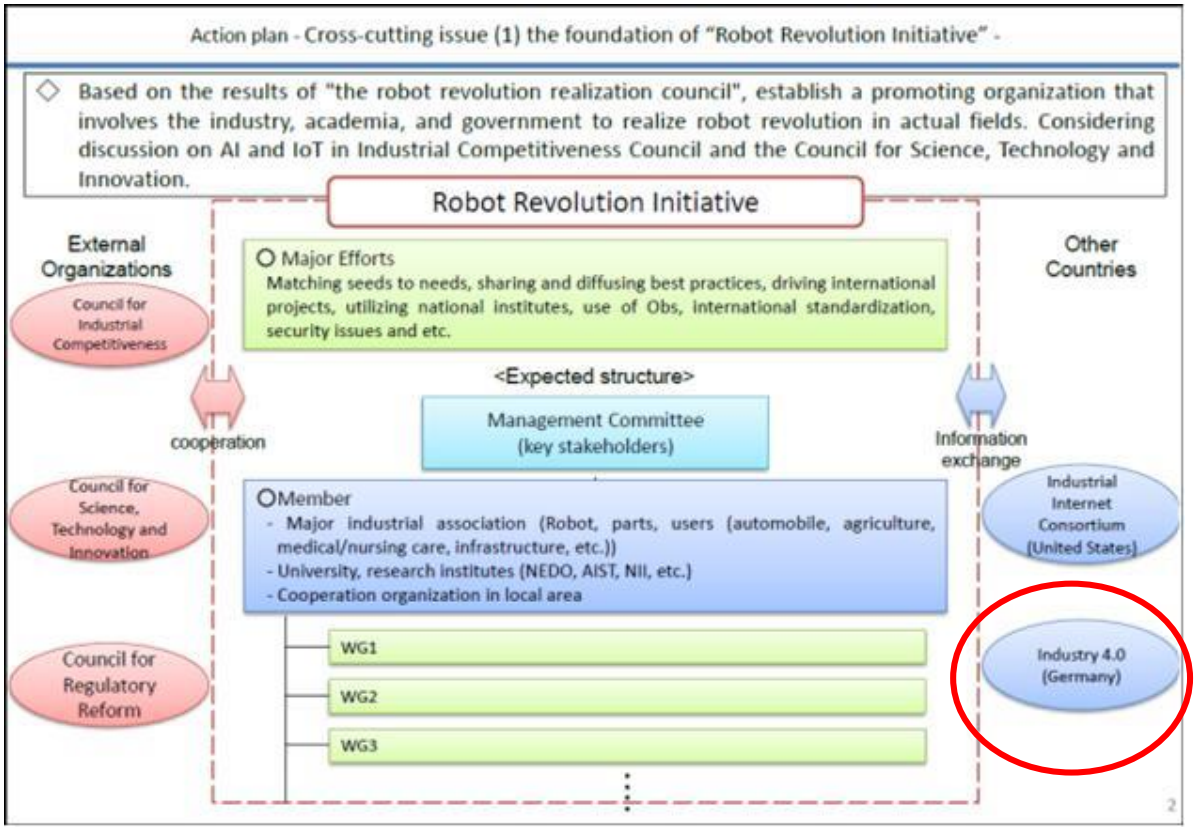
Taiwan

- This picture is used by the Taiwanese government to push the local enterprise to get involved in Industry 4.0 as fast as possible

http://www.stockfeel.com.tw/%e5%b7%a5%e6%a5%ad4-0%e4%b8%8d%e5%90%8c%e6%96%bc%e8%b1%90%e7%94%b0%e7%94%9f%e7%94%a2%e6%96%b9%e5%bc%8f/

Japan

- Robot Revolution Initiative
  - Ministry of Economy, Trade and Industry (METI)
- Industrial Value Chain Initiative
  - Omron, Toyota, Denso, Fujitsu, Hitachi, Panasonic, Mitsubishi



http://www.meti.go.jp/english/press/2015/0123_01.html

China

- “Made in China” 2025
  - Ministry of Industry and Information Technology (MIIT)

http://www.miit.gov.cn/n11293472/n11293832/n11293907/n11368223/16489095.html

USA

- President Obama launched the „Nationwide Network for Manufacturing Innovation (NNMI)“ http://manufacturing.gov/welcome.html
- On December 16, 2014, the President signed the “Revitalize American Manufacturing Act” into law
- Cincinnati Mayor, John Carnely, signed a proclamation to state "Cincinnati to be Industry 4.0 Demonstration City”
- Planned cooperation between the Industrial Internet Consortium (IIC) and Industry 4.0 Platform
  - KUKA to join IIC

Proclamation

City of Cincinnati

Be It Proclaimed:

Whereas, Dr. Jay Lee, Dept of Mechanical and Materials Engineering of the University of Cincinnati and the IMS Center have been at the forefront of the Industry 4.0 global revolution in manufacturing technology; and

Whereas, Dr. Jay Lee, Dept of Mechanical and Materials Engineering of the University of Cincinnati and the IMS Center/Industry 4.0 will enhance Cincinnati's stature as a city that provides global leadership in technology; and

Whereas, Dr. Jay Lee, Dept of Mechanical and Materials Engineering of the University of Cincinnati and the IMS Center/Industry 4.0 will help Cincinnati regain its former glory as a city riding the wave of new manufacturing revolutions; and

Whereas, Dr. Jay Lee, Dept of Mechanical and Materials Engineering of the University of Cincinnati and the IMS Center/Industry 4.0 and their work helping manufacturers increase their productivity, and therefore, create new wealth in investment capital and jobs for the Cincinnati region.

Now, Therefore, I, John Cranley,

Mayor of the City of Cincinnati do hereby proclaim December 1, 2014 As

"Cincinnati to be the Industry 4.0 Demonstration City"

in Cincinnati.

IN WITNESS WHEREOF, I have hereunto set my hand and caused this seal of the City of Cincinnati to be affixed this first day of December in the year Two Thousand and Fourteen.

John Cranley, Mayor
City of Cincinnati

Industry 4.0 and Robots

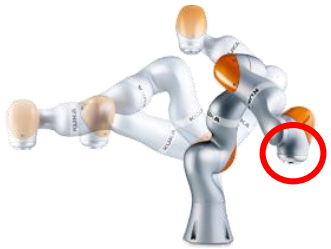
- In many “Industry 4.0” pictures there are industrial robots carrying manufacturing processes

- The same robot can carry a lot of different tools
- ➔ Robots are the most flexible automation devices

- The number of combinations robot / tool is getting more and more dynamic
  1. One robot changes process tools by automatic tool changer
  2. Mobile robots

KUKA industrial robots are „partly completed machines“

- EU Machinery Directive 2006/42/EG:
  - …are not allowed to have CE marking
  - …must have assembly instructions and a declaration of incorporation
- Have „Hands“, but no Fingers…
  - …this makes them very flexible
  - …can grab several tools directly



Integration of process tools into robots

Robot	Welding	Gluing	Screwing

Mechanics

Controllers

Integration of process tools into robots and robots into cells or machines

- There are at least 50+ other manufacturing processes a robot can carry
  - Gripping, Sawing, Drilling, Laser, Molding, Plasma Cutting, Water Cutting, Rivet, Trimming, Seam, Deburring, Grinding, Polishing, Painting…
- Each process comes with its own controller (PLC, embedded system)
- The robot controller must be able to communicate with all the process controllers dynamically (tool changer) and ad hoc (mobile)
- Such “process robots” are going to be integrated into “higher” systems:
  - Cells, Machines (PLCs, embedded controllers) ➔ Lines ➔ Halls ➔ Plants

Example:
- 1 x 10 x 5 x 20 x (6+6) x 10 = **120.000** Sensors/Actuators on proprietary field busses
- 1 x 10 x 5 x 20 x (6+6) = **12.000** Controllers on **OPC UA and TSN**

White = done by the system integrator

Colour = done by device manufacturers

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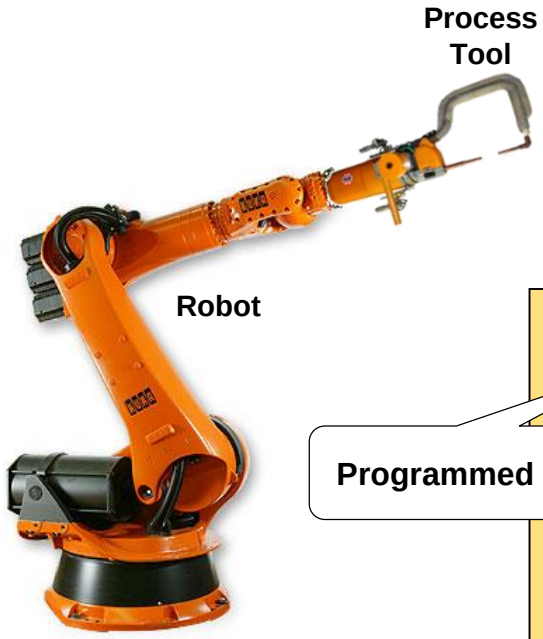
Integration of process tools into robots



Robot

Robot Controller

Process Tool

Programmed

Robot Controller

Robot Application in Robot Language

Handshake via I/O-Bits

Communi-cation

Configured

Process Controller

Process Controller Firmware

Handshake via I/O-Bits

Communi-cation

Process Controller

Communication: Fieldbus

Configured

Robots

Processes

White = done by the system integrator

Colour = done by device manufacturers

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Integration of robots into cells or machines

Machine

Programmed

Machine Controller

Machine Application in Machine Language

Handshake via I/O-Bits

Communi-cation

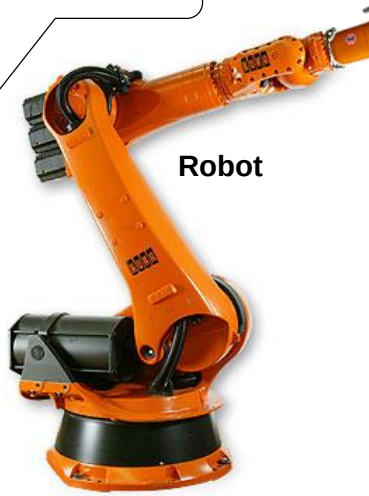
Programmed

Robot Controller

Robot Application in Robot Language

Handshake via I/O-Bits

Communi-cation



Robot

Robot Controller

Communication: Fieldbus

Configured

Cells, Machines

Robots

Example: EUROMAP 67

- Standardized Interface between injection molding machines and robots
  http://www.euromap.org/files/EU%2067_Ver_1.9_Aug2013.pdf

This EUROMAP recommendation defines the connection between the injection moulding machine and the handling device / robot. This is intended to provide interchangeability.

DO0 :MAC: Mould Area Control (A3/C3)	DI0 : x
DO1 : A6 : Enable mould closure	DI1 : ZA6 : Mould closed
DO2 : A7 : Enable full mould opening	DI2 : ZA7 : Mould open position
DO3 : B2 : Robot operation mode	DI3 : ZB2 : Enable operation with robot
DO4 : B3 : Enable ejector back	DI4 : ZB3 : Ejector back position
DO5 : B4 : Enable ejector forward	DI5 : ZB4 : Ejector forward position
DO6 : B5 : Enable core pullers 1 to 1	DI6 : x
DO7 : B6 : Enable core pullers 1 to 2	DI7 : x


Euromap67

☹ Bits based communication is by far to limited to fulfill the requirements of the future

☹ Bits can not take or return parameters

☹ Both sides must be programmed or at least configured

☹ Fieldbus communication must be configured

White = done by the system integrator

Colour = done by device manufacturers

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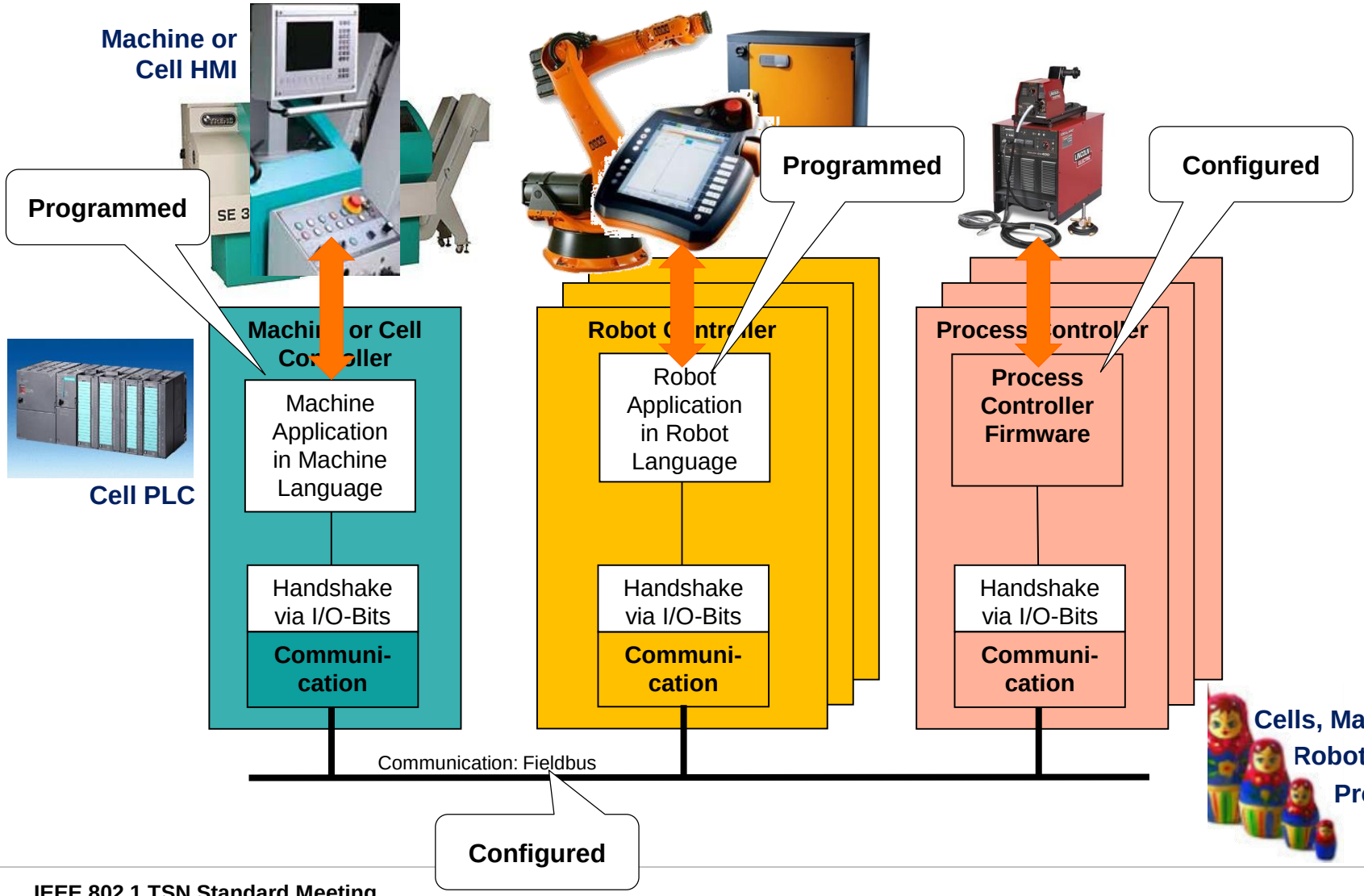
The whole Mess



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Colour = done by device manufacturers

KUKA RaaS®

The Industry 4.0 Solution

Robotic as a Service®

Public Cloud

Private Cloud

HMIs in Smart Devices "anywhere"

Edge Cloud Controller

Machine Controller
- SOA Server Offering "Machine Services"
- Semantic Self Desc.
- Communi-cation

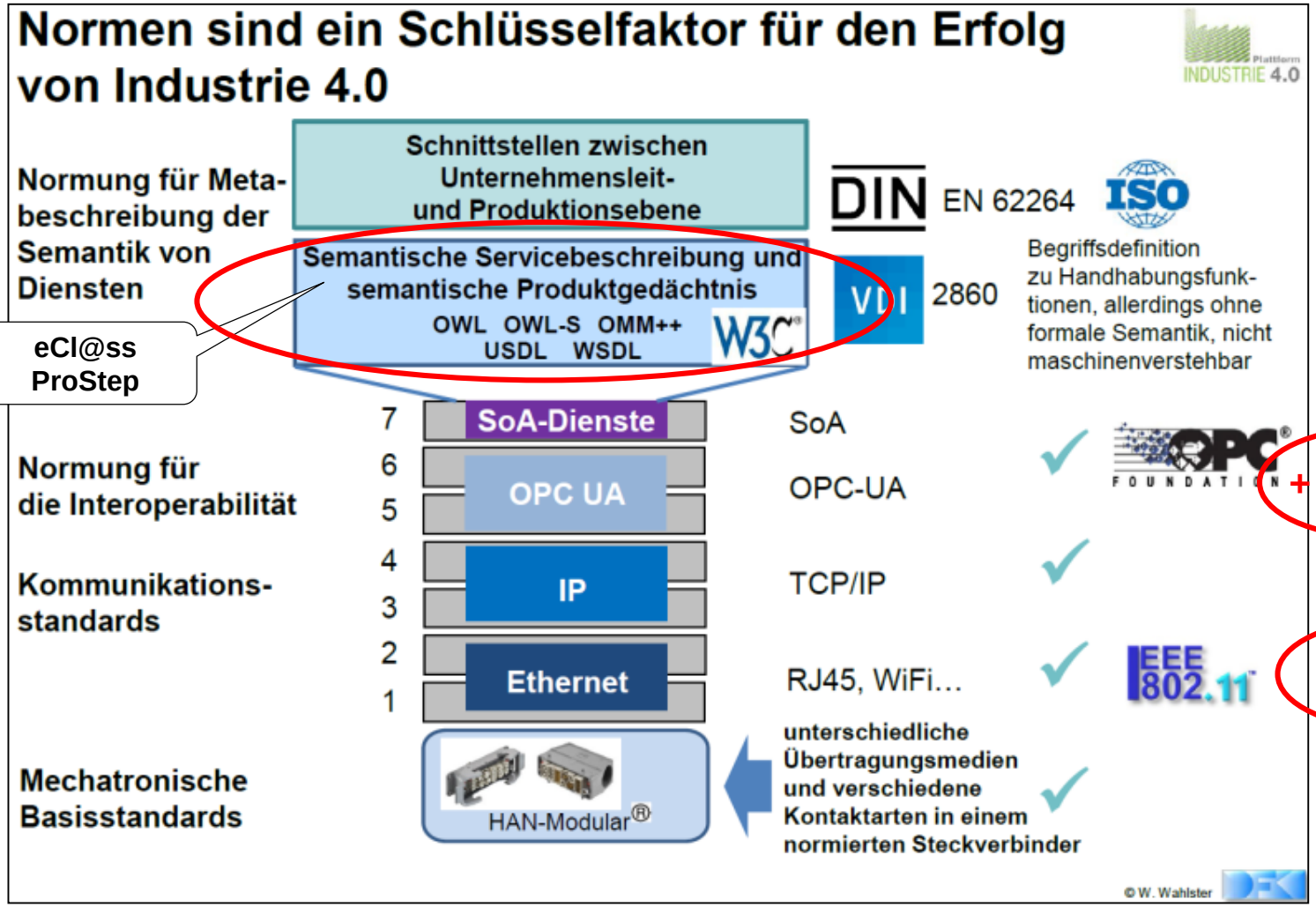
Robot Controller
- SOA Server offering "Movement" Services
- Semantic Self Desc.
- Communi-cation

Process Controller
- SOA Server Offering "Welding" Services
- Semantic Self Desc.
- Communi-cation

Communication: OPC UA, TSN, Ethernet

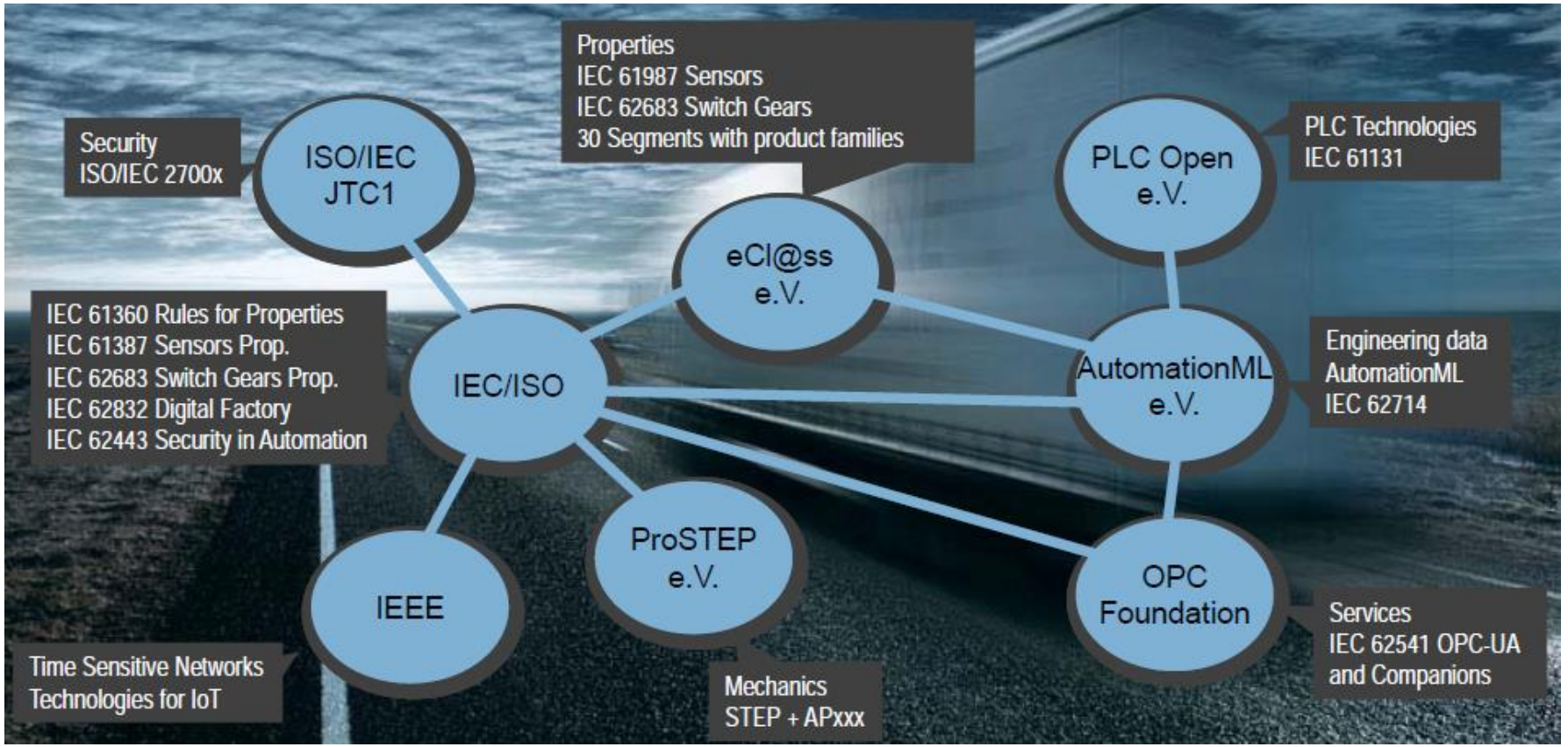
Programmed

The enhanced communication stack of Industry 4.0

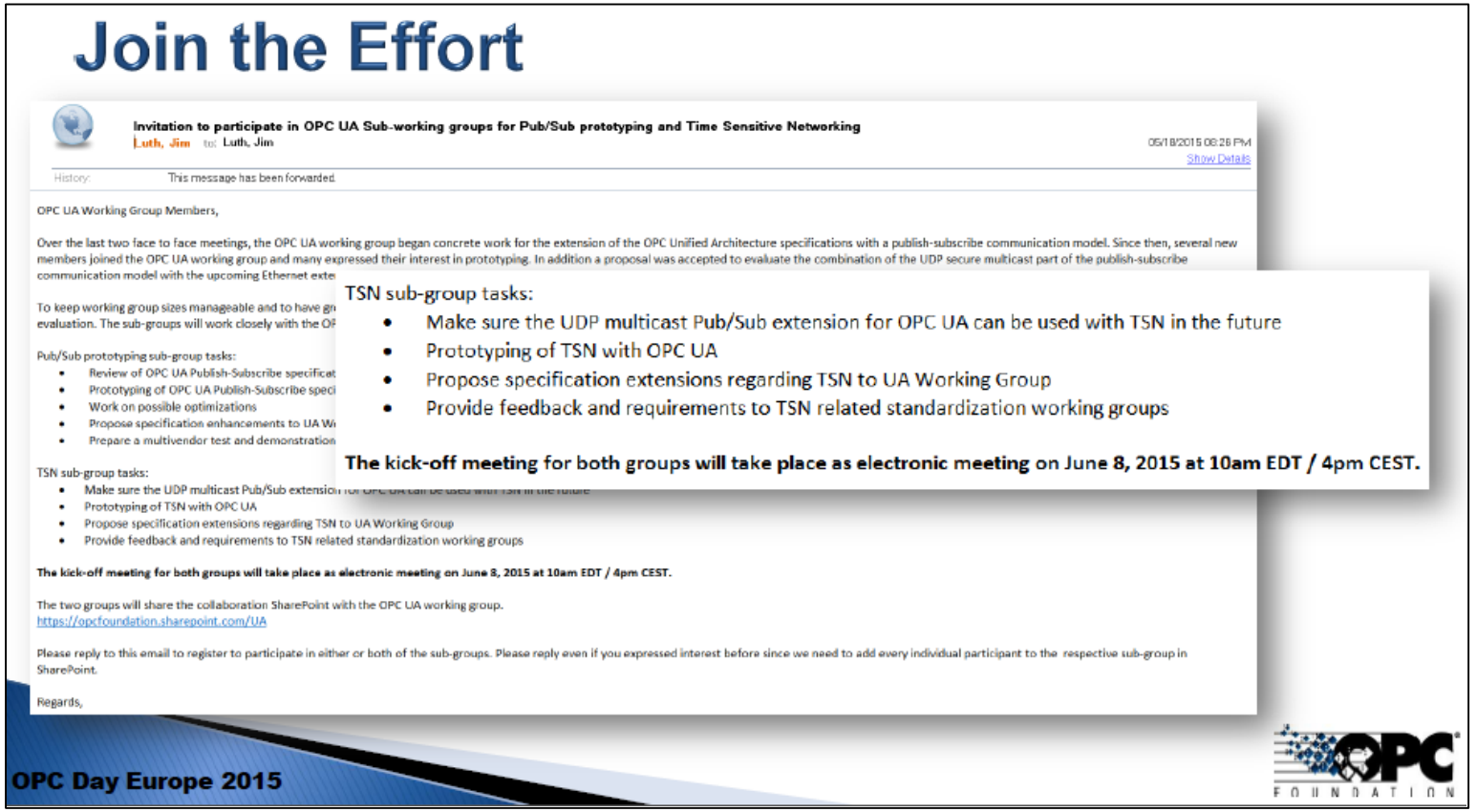


Standards are key to Industrie 4.0

- The secret of success: Interoperability!
- All Industrie 4.0 companies should agree on only one standard per task



OPC Foundation is going to start a TSN Working group on June, 8th 2015

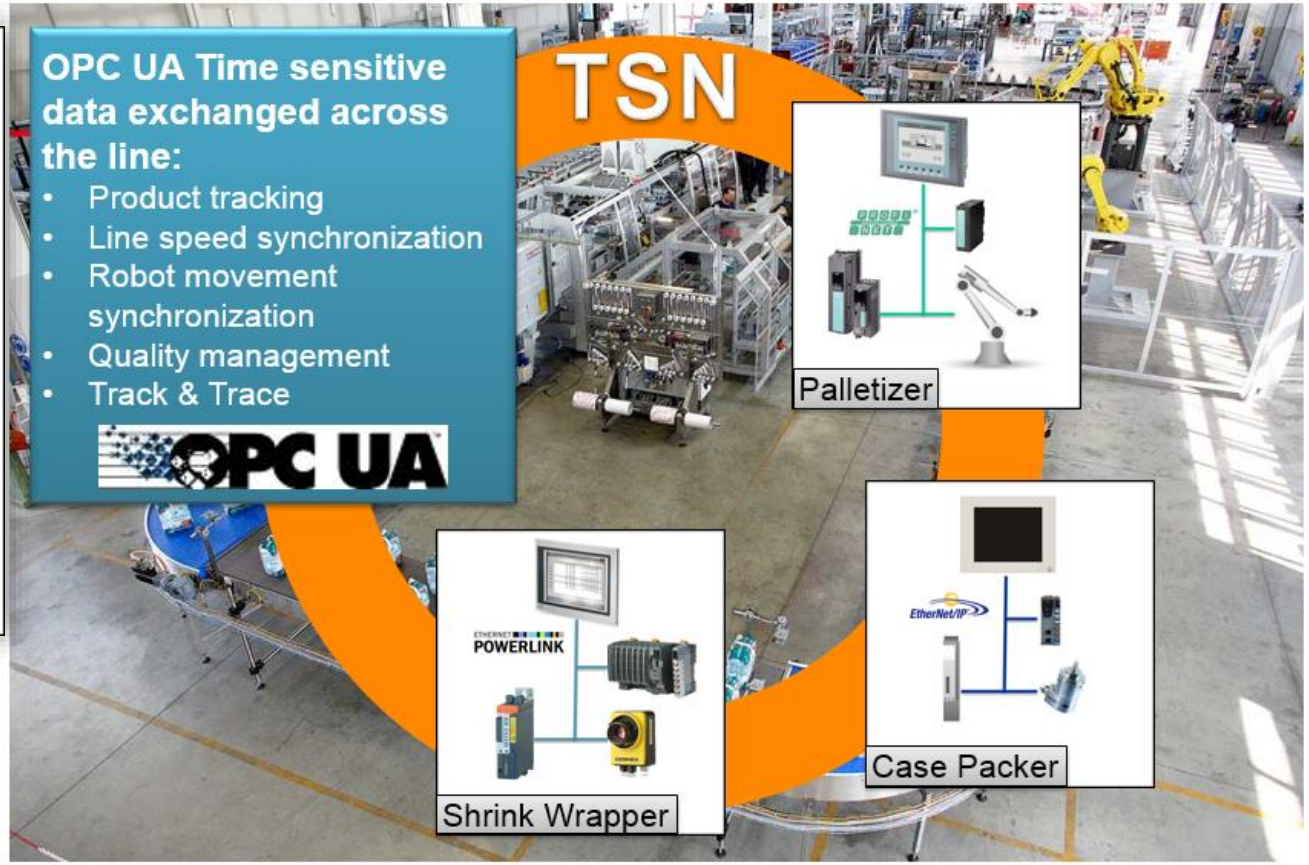


- Big support from > 20 automation companies
  - ascolab, B&R, Beckhoff, Bosch Rexroth, Deutsche Telekom, Festo, Harting, Hirschmann/Belden, National Instruments, Sigmatek, Trumpf, TTTech

Packaging Use Case of B&R, Austria

"The addition of TSN and the publisher-subscriber model will greatly expand the range of potential OPC UA applications"

Stefan Schönegger,
Marketing Director B&R



TRUMPF Laser Use Case 1

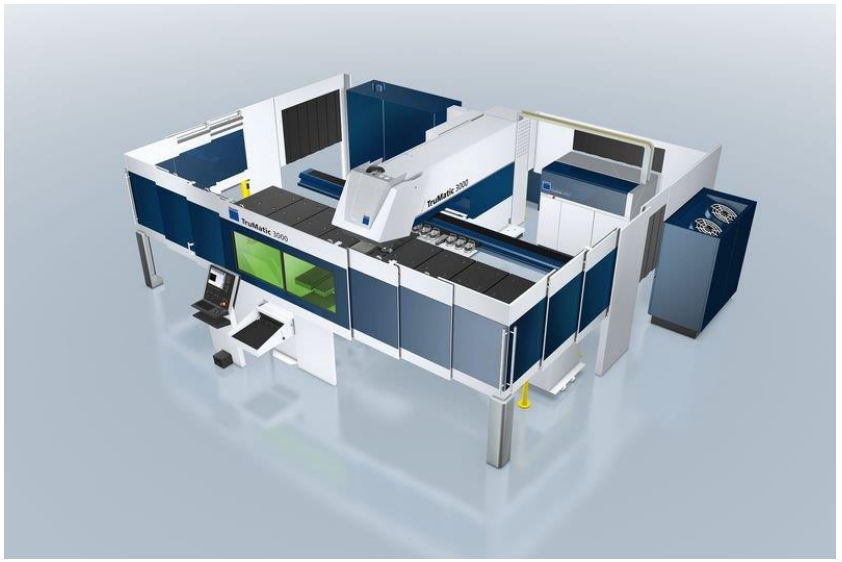
Benefit: Production clock rate may reduced for at least 100ms per part

- System:
  - TRUMPF Laser with RT Linux
  - TRUMPF scanner optic for laser welding
  - TRUMPF Touch Panel PC with RT Linux
  - 100bT Ethernet connection
- Requirements
  - Deterministic response time from start of computer vision to Computer Visions result delivery.
- Without deterministic data communication the time between two parts in a clocked production line has to be set to the worst case response time! This directly affects the quantity of pieces per shift.

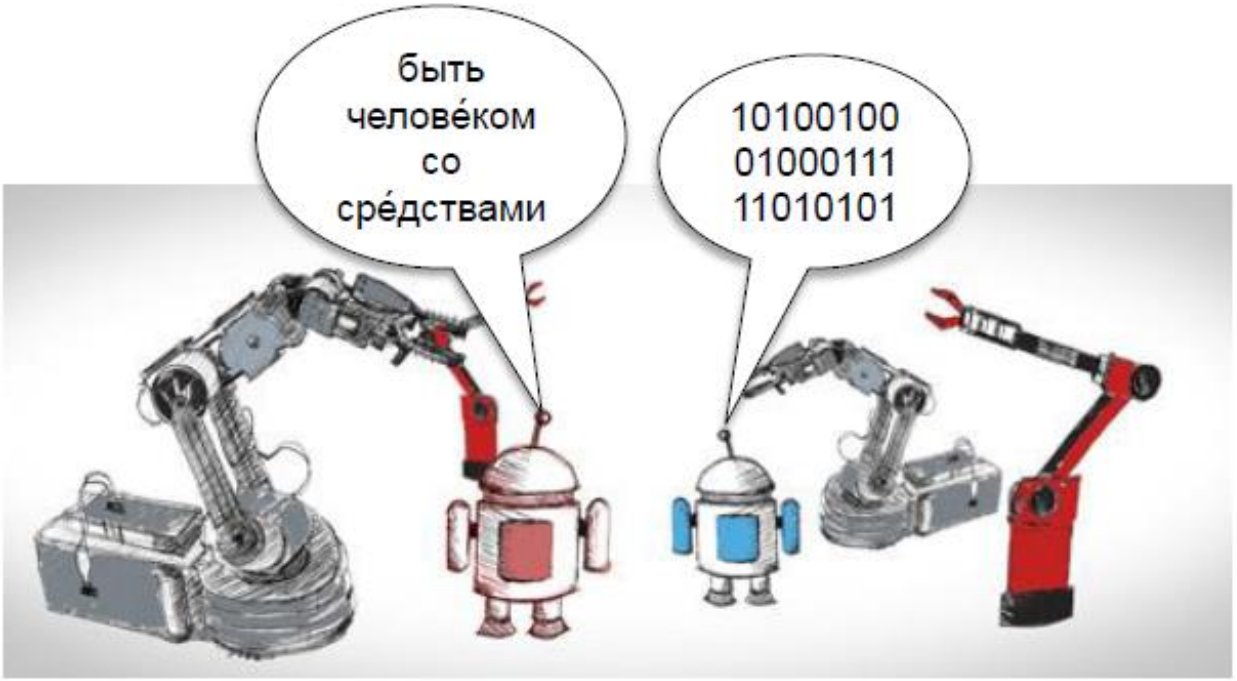
TRUMPF Laser Use Case 2

Benefit: cost and complexity reduction for cabling and interfaces

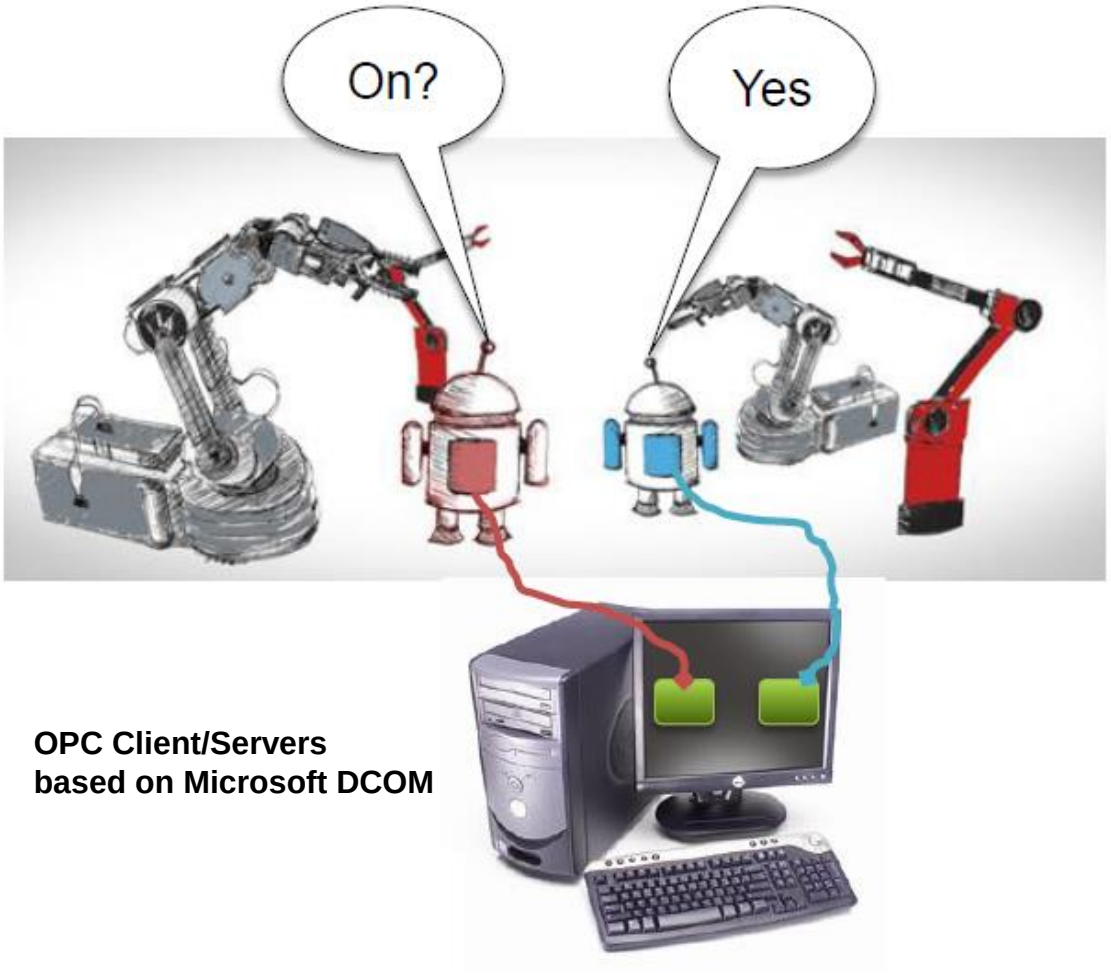
- System: TRUMPF machine for laser cutting
  - PLC / NC for motion control
  - Laser
  - 100bT / 1000bT Ethernet connection
- Requirements
  - Single communication connection with complex non real-time data, i.e. diagnostic, files
  - deterministic commands between motion control and laser beam control
- With a single deterministic data connection between the components of a laser machine, costs may be reduced. Currently TRUMPF has to use fieldbus and OPC technology in combination to deal with complex data and deterministic cyclic data.



Before OPC UA

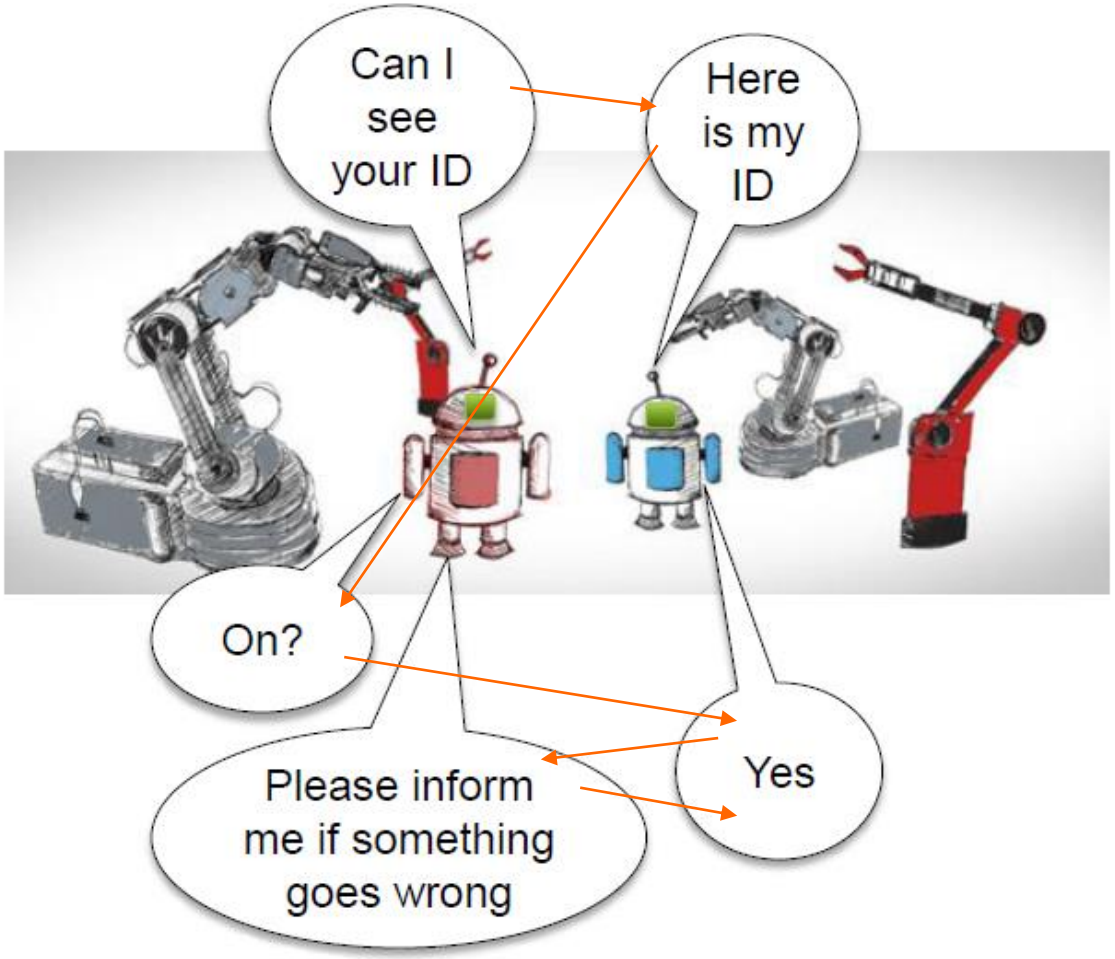


With Classic OPC

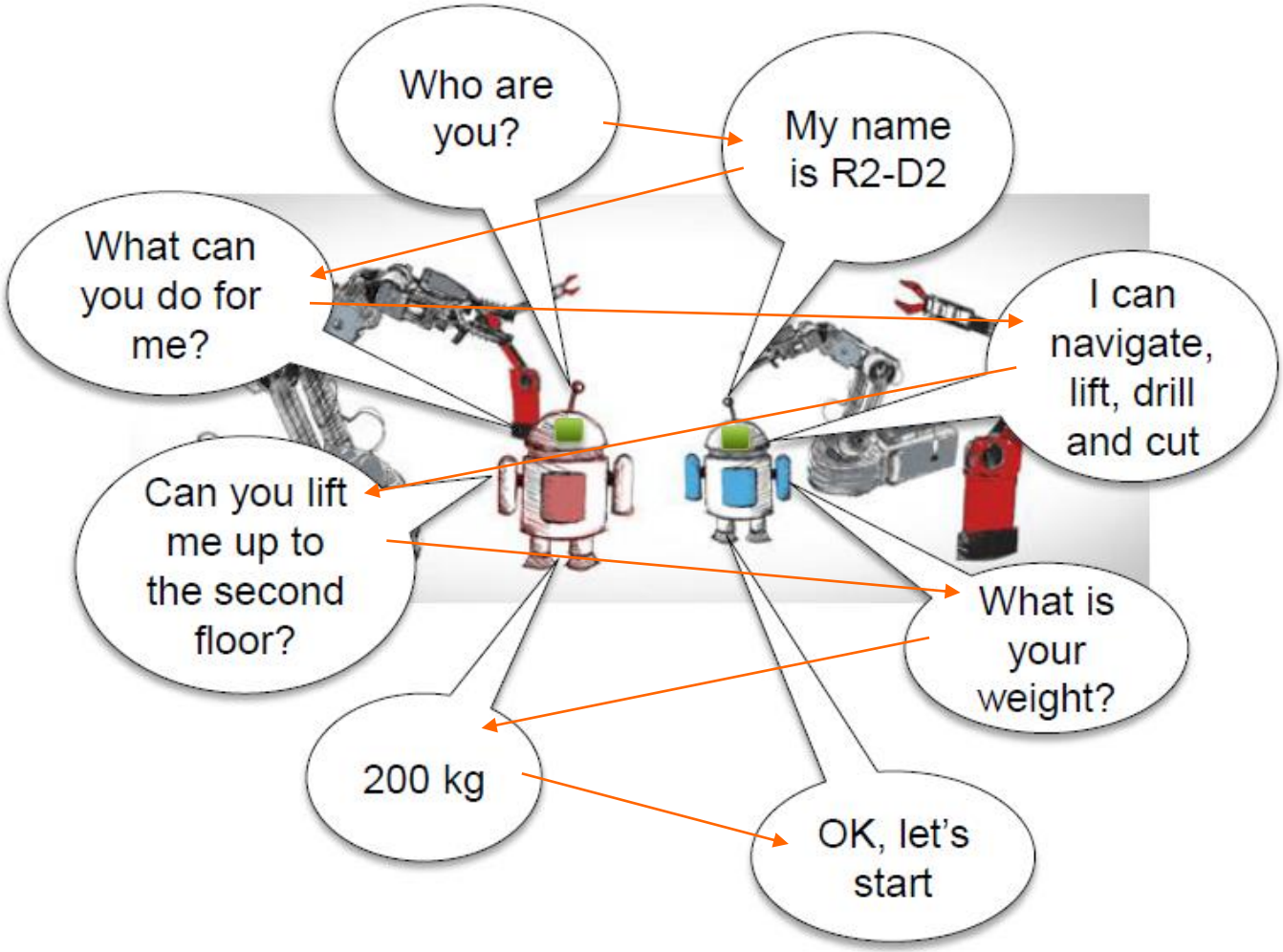


OPC Client/Servers
based on Microsoft DCOM

With OPC Unified Architecture

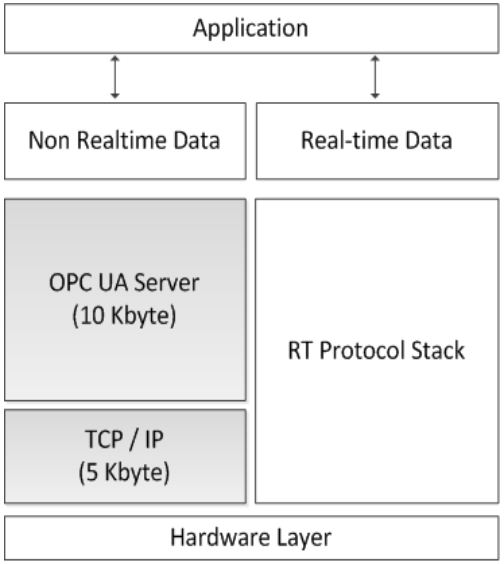


With OPC UA Information Models



OPC UA is Object Oriented and SOA-ready

- >450 OPC Foundation members and thousands of OPC-compliant products
- Several Stack Implementations including several Open Source ones
- Frequently Plug Fests and Certification to ensure interoperability
- OPC UA is an information centric layered architecture
  - Object Oriented !!!
  - SOA-capable (offer, discover, interact with and use device capabilities)
  - Build in Security, not just added
  - Platform independent, Stacks available in C++, Java, .Net
  - Scalable
- OPC UA is much more than a protocol
- IEC 62541 Standard
- OPC UA Server Fits in 10KB Object Code



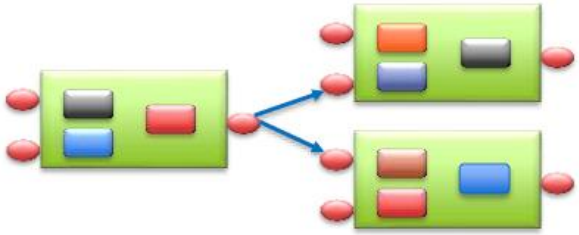
DDS is “Data Centric”. Data Centricity was yesterday!

Data Centric is the *Opposite* of OO

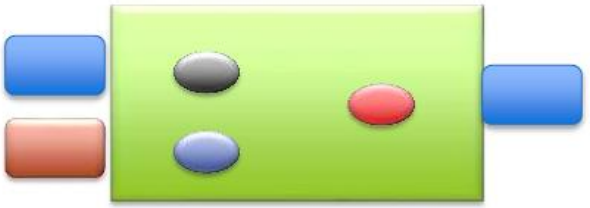
OPC UA

Object Oriented
- Encapsulate data
- Expose methods

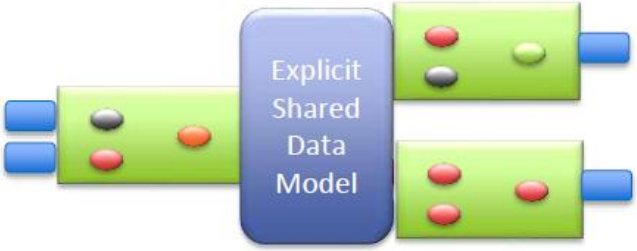
= SOA



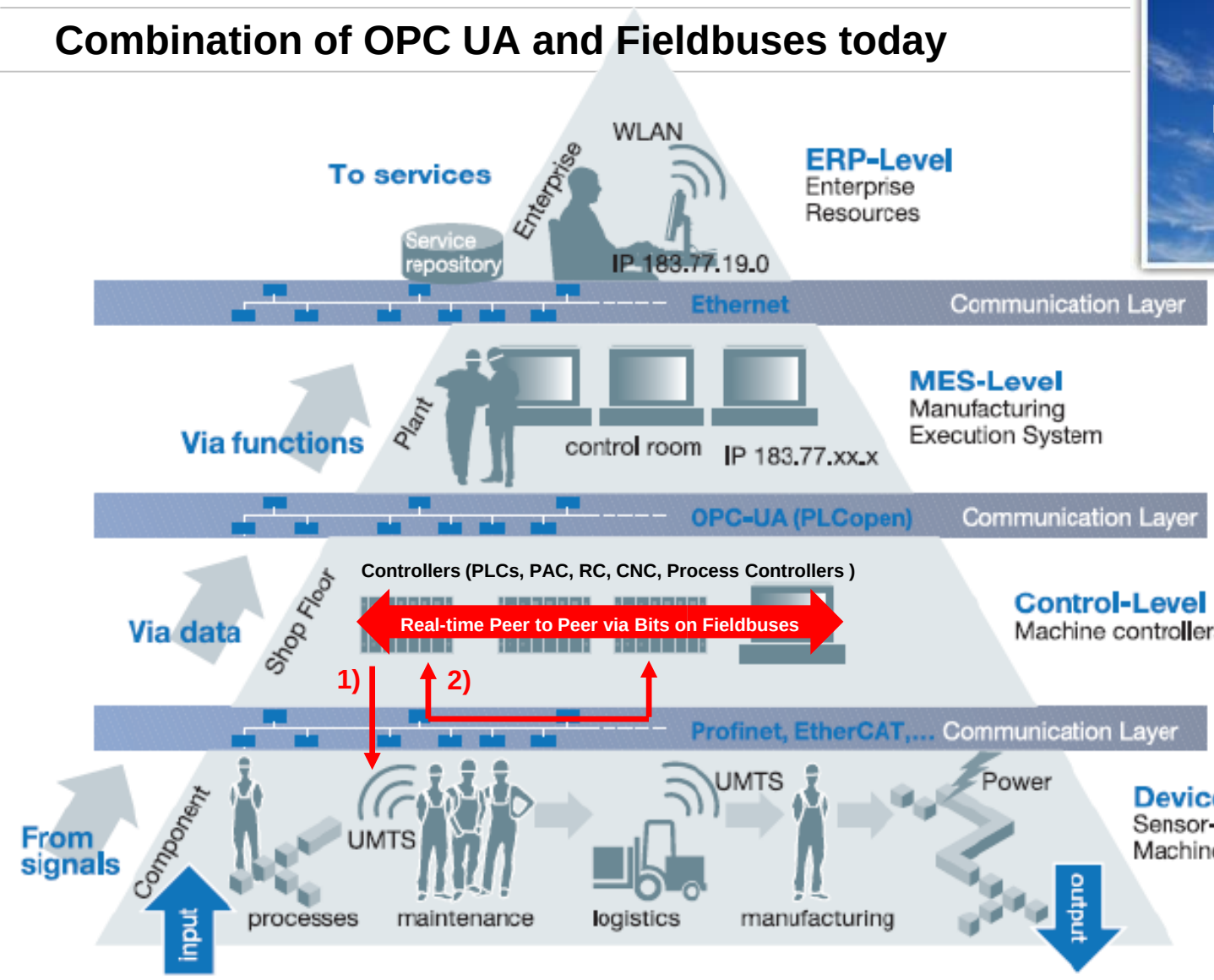
DDS



Data Centric
- Encapsulate methods
- Expose *data*



Combination of OPC UA and Fieldbuses today

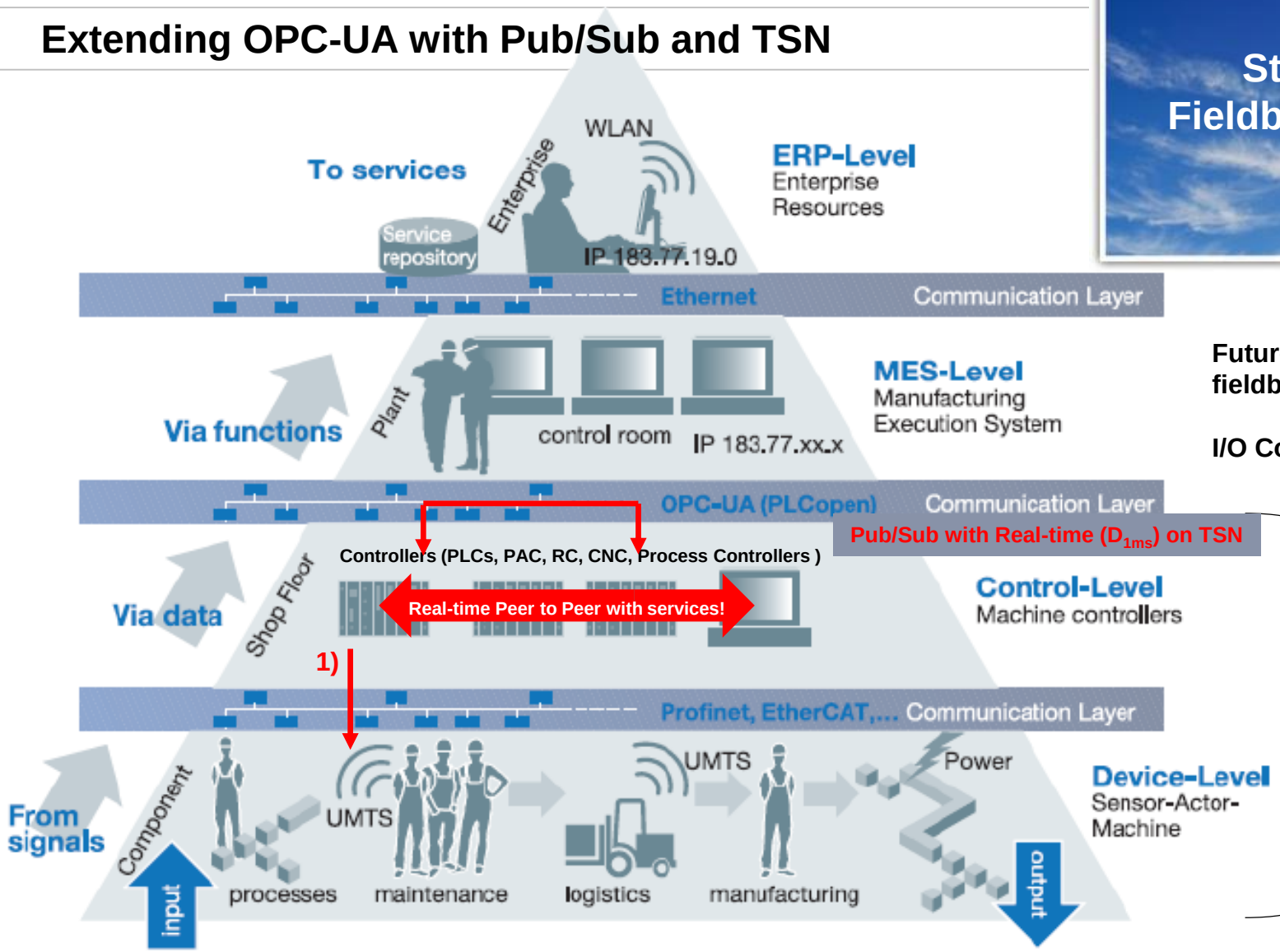


Today's usage of fieldbusses:

1. **I/O Communication**
2. **M2M Peer to Peer**

Real–time critical with $D_{<1ms}$

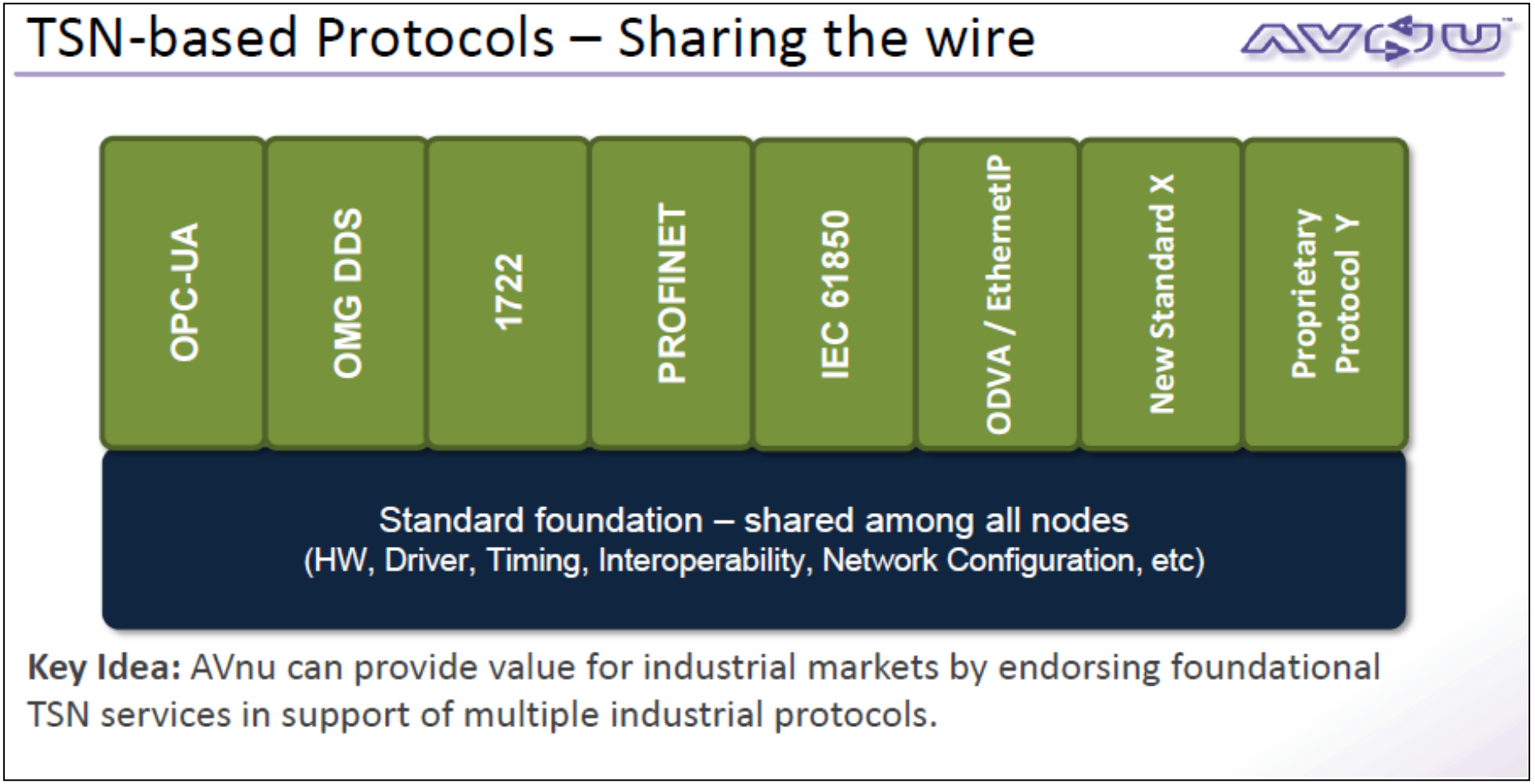
Extending OPC-UA with Pub/Sub and TSN



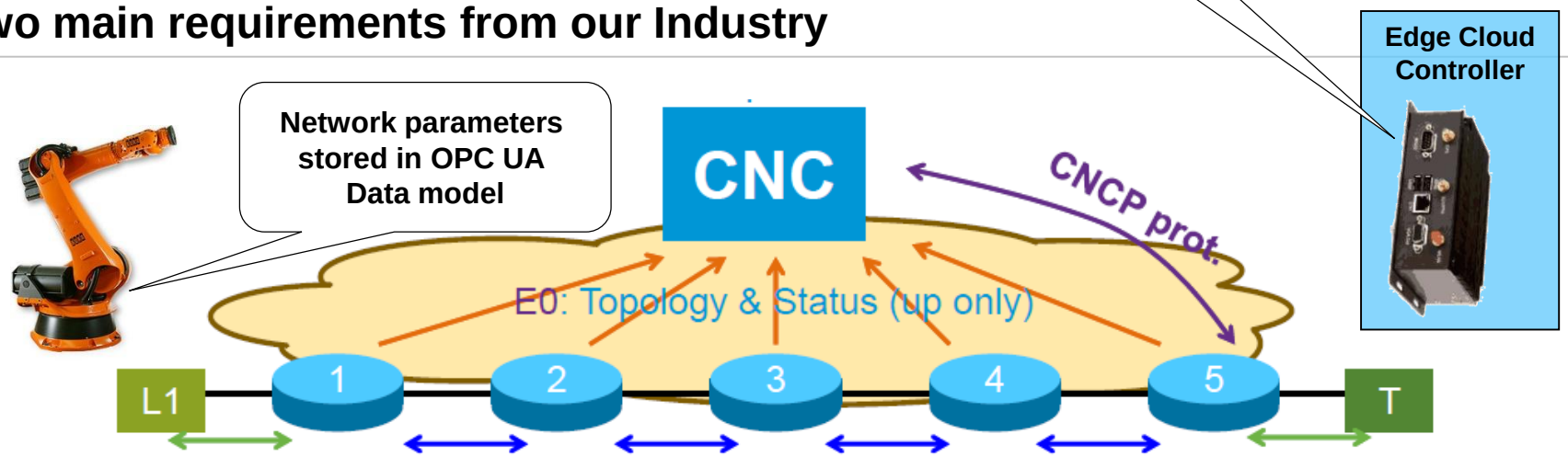
Future usage of fieldbusses:

I/O Communication only

Other legacy and proprietary consortia standards will follow towards TSN



Two main requirements from our Industry



1. No network or other configurations via configuration tools!
   - Just programming against APIs
   - Devices which cannot be programmed directly are configured via non real-time OPC UA
   - Network parameters must be mapped into an OPC UA data model
2. The CNC “god box” should not be necessary for regular work
   - Just necessary during system set up or changes
   - It configures all the infrastructure components
   - Those store their configuration in NVRAM

Thank you for the invitation and your Attention

- Questions?