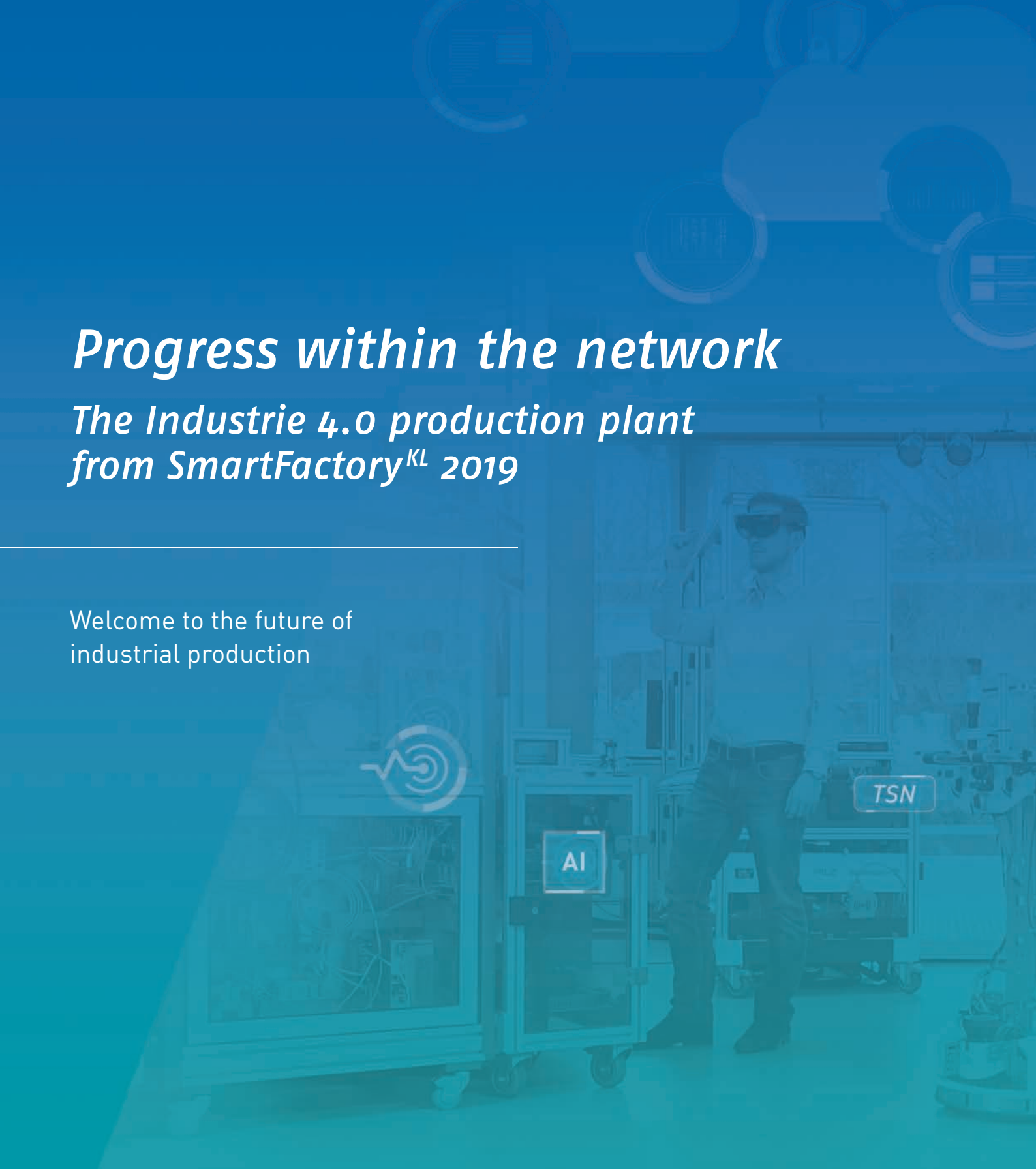
Progress within the network

The Industrie 4.0 production plant from SmartFactory^{KL} 2019

Welcome to the future of industrial production



smartFactory KL®

Industrie 4.0 – Progress within the network

The task of the ***SmartFactory***KL was defined at the time of its establishment in 2005: Pave the way for the intelligent factories of the future. As a manufacturer-independent technology platform, together with our partners, we are creating and implementing innovative factory systems in accord with the concepts of Industrie 4.0 for the manufacturing industry. Thanks to our participation in the Mittelstand 4.0 (SME) Competence Center Kaiserslautern, we assist small and medium size enterprises as well as major corporations. Interoperability is the key enabler of the fourth industrial revolution and the prerequisite for this is the development of uniform standards for manufacturer-independent compatibility between individual modules and even entire plants.

Our concept for a completely modular Industrie 4.0 production plant was introduced for the first time at the **Hannover Messe** in 2014. We have advanced its development ever since. In 2019, the 6th generation of our plant is well underway. As a result of scientific and practical exchanges, we have once again considered current trends and topics in the area of Industrie 4.0 and successfully implemented them in the production plant.

A major topic this year is the deployment of **Artificial Intelligence (AI)** in production operations. At our production plant, we show different use cases on topics such as anomaly detection, condition monitoring, and predictive maintenance. The plant clearly demonstrates how using AI makes sense and supports people in the Industrie 4.0 environment.

A highly capable and sustainable **infrastructure** is another major component of a modular Industrie 4.0 production plant. To satisfy the growing demand for flexible and efficient manufacturing methods, we have designed and built new infrastructure nodes. These nodes are scalable and can support multiple production stations. Furthermore, they are equipped with technologies like TSN (Time-Sensitive Networking) and edge computing to enable data driven applications.

Among the other innovative technologies are: the Smart Safety concept, 5G wireless technology in a flexible transport system, and the use of Augmented Reality with the aid of intelligent data glasses all combine to support the production staff.

The new application scenarios result from the cooperation of industry and science in round table discussions. As established in the spirit of our initiative, the interaction among equal partners in a consortium results in our success and the development of new research topics. We are quite proud of that. Our goal is to continue to pioneer developments, trends, and visions related to Industrie 4.0 in the future. Join us in this effort – thank you for your interest in our work.

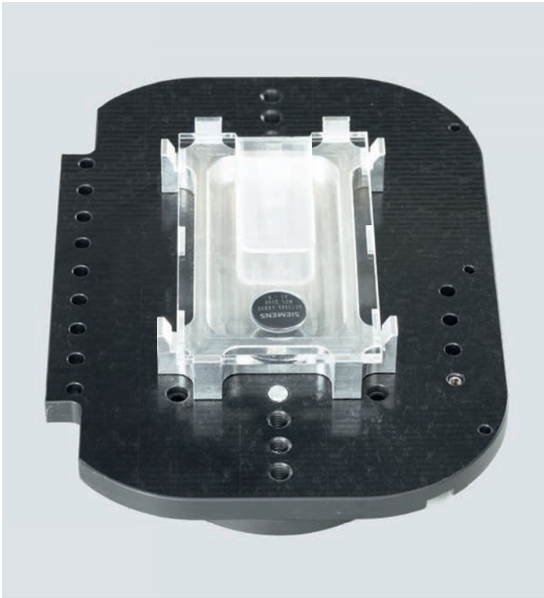
Prof. Dr. Dr. h.c. Detlef Zühlke
Chairman of the Board of the Technologie-Initiative
SmartFactoryKL

The Crosslinked Production

The ***SmartFactory***[KL] exhibits the world's first manufacturer-independent Industrie 4.0 production plant and shows just how high quality, flexible manufacturing can be efficiently implemented even for a batch size of one – regardless of whether in an existing production operation or a Green Field. Uniform interface standards enable a manufacturer-independent link to the production units, logistic systems, supply infrastructure, and IT systems. Challenging requirements already affecting production such as custom products, shorter innovation cycles, and more efficient on-site production can now be met.

A sample product is actually manufactured in the facility: A customized business card holder, where the color, laser engravings, and optional inlays can be ordered online by the customer. The product itself stores all information in a RFID tag and gives guidance to the production modules.

The production process proceeds in different ways, depending on the design and availability of the production plant's modules. The flexible transport system dynamically connects with the various production cells and manual assembly stations.



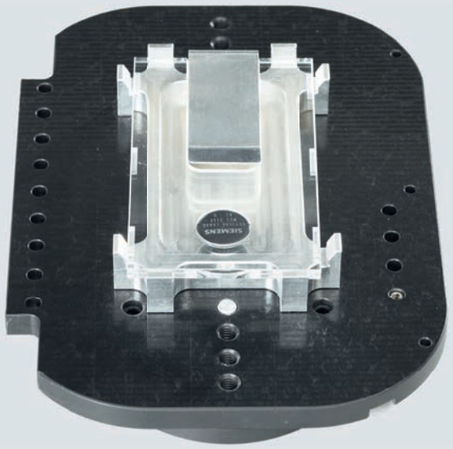
The Process Structure

Production Cell 1

1a The STORAGE MODULE by **Pilz** is an intelligent, automated warehousing module, used to store the workpiece transporters: If the central server sends a new work order to the module, thereby, requesting an additional transporter, the storage module supplies an empty workpiece carrier from storage. Empty workpiece carriers or semi-finished products can also be returned to the warehouse.

1b The module BOTTOM ENGRAVING by **Festo** initializes the digital product memory to a specific production order via RFID. The production order is loaded from a Web Server of the superordinate Enterprise Resource Planning system (ERP) via http-protocol by means of a specially developed Web Client. Corresponding to the product memory, an individual engraving is performed via a CNC engraving control.

← Workpiece carrier with plastic bottom



↑ Retaining clip is mounted onto the plastic bottom

↑ Force fitting of the base plate with the retaining clip and the cover

↑ Individual laser engraving on the top side

1c In the following production step, the CLIP MODULE by **Bosch Rexroth** mounts a retaining clip to the plastic bottom.

Production Cell 2

1d The FORCE FITTING module by **HARTING** performs the central mounting of the two housing parts. The bottom with a mounted retaining clip is assembled with the cover chosen in one of the two available colors, as per customer request. The **HARTING** module puts the lid on the base plate with a robot and embosses both parts together.

1e The module LASER MARKING by the company **Phoenix Contact** uses a laser system to put an individual engraving on the topside of the business card holder. The engraver displays the digital business card as QR code. Individual data can be flexibly changed upon the client's request right up to the corresponding process step.

Flexible Transport Systems – FTS

2 The ROBOT PLATFORM from **Festo** is a self-directed transport system, responsible for a flexible material transport between the various production lines and the manual assembly station. Additionally, the Flexible Transport System (FTS) is equipped with an optical quality control system from **Huawei**. The use of 5G wireless technology enables a fast, secure, and location-independent linking of quality data to the service provider cloud.

Production Cell 3

1f The WEIGHING MODULE supplied by **METTLER TOLEDO** measures product weight using a high precision scale. A metrological quality control is then accomplished by comparing this with the actual production status stored in the product memory.

1g The module QUALITY CONTROL performs two tasks: Product end control by means of a high-resolution camera as well as the final output of the finished business card holder.

↑ Smart data glasses help employees by providing instructions and supplemental information in a simple and understandable manner.

The human in the Industrie 4.0 environment

4 The robot platform simultaneously connects the process to a MANUAL WORKSTATION from **MiniTec**. A perfectly designed ergonomic workplace, enabled with Internet and communication technologies, supports the worker in completing assembly activities. The Augmented Reality technologies developed at ***SmartFactory***^{KL} are provided to carry out individual process steps or an entire production process manually. Augmented Reality – the super-positioning of real-time images with suggested actions – promises many advantages, particularly, for training processes and manual assembly tasks. A built-in RFID read/write device allows the worker to retrieve the current production progress of the product as well as individual customer information. Augmented Reality technologies assist in the completion of variable tasks.

In future manufacturing operations, ARTIFICIAL INTELLIGENCE (AI) is sure to be a major partner to the operators. Capable of quickly and reliably evaluating the increasingly large data volumes collected in modern production plants, it can provide filtered, context-related results to the operators. The deployment of AI in the Industrie 4.0 environment is demonstrated in several use cases at the ***SmartFactory***^{KL} production plant:
For demonstration purposes, an anomaly during operations is generated in the form of an unusual vibration at one of the stations of the Industrie 4.0 production plant at ***SmartFactory***^{KL}. An edge device records the vibration and transmits the values to the cloud. The signal is analyzed there with the aid of AI algorithms to detect the anomaly.

Another simulated anomaly, this one appearing as a grinding noise, is also generated. Acoustic recordings are continuously made of the noise environment within the production stations and then analyzed by AI algorithms. AI is able to classify any unusual noise and recognize it as an anomaly.

A third use case is based on cameras installed at the stations that film the production flow. This also results in the accumulation of large amounts of data, which can only be meaningfully evaluated by AI. This task is carried out by an intelligent computer vision service, which recognizes and analyzes the work piece to include its processing status. Using this data, the computer vision AI algorithm determines if the processing step was carried out error-free. To specify the adaptive learning process, various well-trained models of the AI algorithm are used.

A key tool in the practical implementation of the findings obtained from AI is the technology known as AUGMENTED REALITY (AR). For example, augmented reality guides the technician through the required servicing procedures at the location, perhaps assisted by data glasses. In this case, information and instructions projected in the glasses allows the worker to keep both hands free to perform and complete the work steps. The result is a more intuitive and efficient issue resolution. The use of AR greatly facilitates realizing the potential of remote maintenance, for example, an engineer working back at the office can support the technician on site.
Companies participating in the implementation of the use cases are: **EPLAN Software & Service, Haier**, **IBM**, **KIST Europe**, and **METTLER TOLEDO.**

Infrastructure

3 An efficient and flexible INFRASTRUCTURE is required if we want to combine manufacturer independent production stations and create a production process with a minimum of configuration effort.

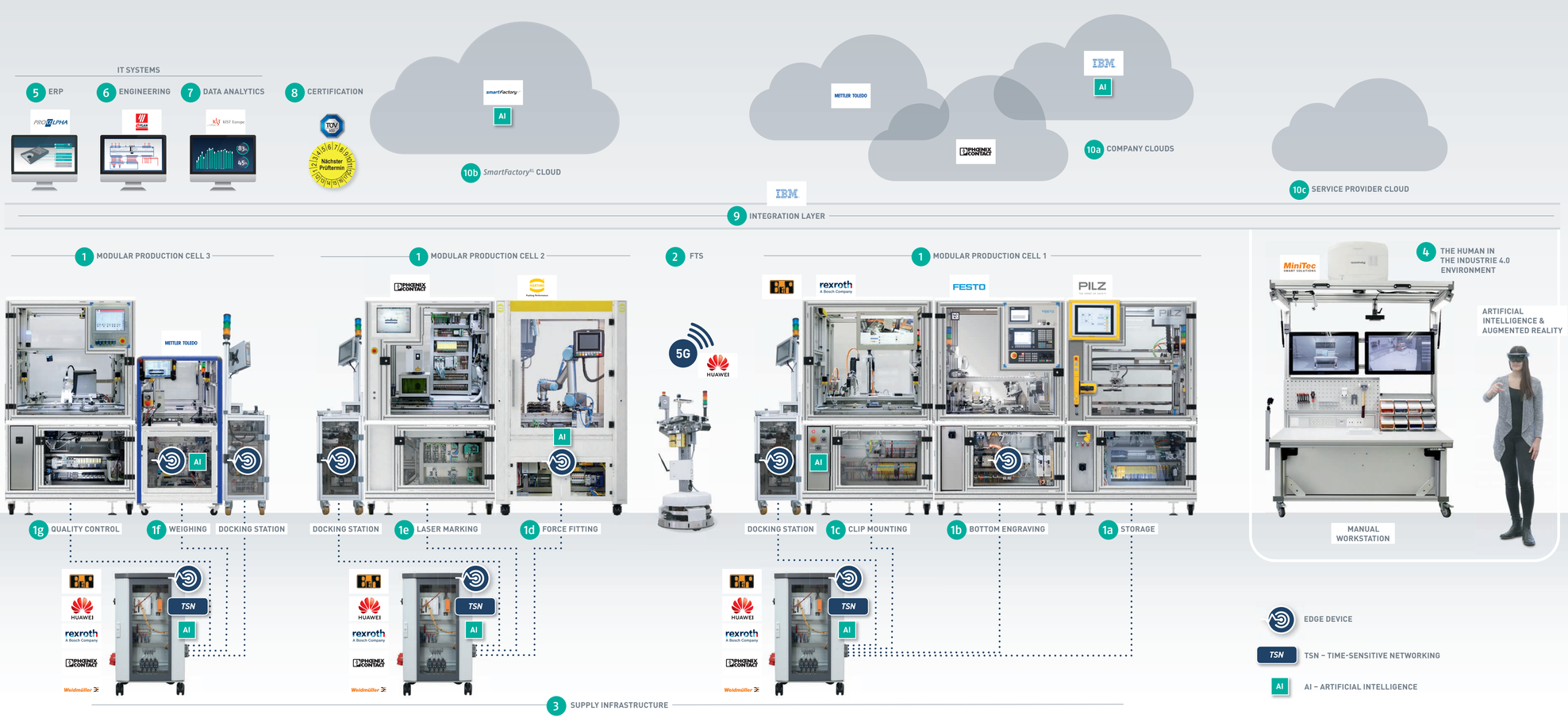
That is why the infrastructure of the Industrie 4.0 production plant was given a new scalable, star-shaped design concept this year. The infrastructure nodes support independent production cells consisting of several stations.The computing power provided by edge devices in these nodes is now available for industrial intelligence applications. This solution illustrates the next step towards the practical introduction of a standardized module interface. The production plant can now be quickly and flexibly reconfigured. In addition, a tablet display at the nodes enables a near real time visualization of the captured process data. Another feature of the new infrastructure nodes is the real time data transmission over the TSN network technology (Time-Sensitive Networking). Data is now prioritized using TSN. Through this prioritization process, flexible decision-making is possible about what data must be immediately available and where delayed transmissions are acceptable. TSN guarantees, for example, that critical safety data will be sent with the highest priority and will arrive even if the network is heavily loaded. This ensures that even in an overloaded network, reliable processing continues at that module.

The new infrastructure nodes were successfully developed in cooperation with our partners **B&R**, **Huawei**, **Phoenix Contact**, **Bosch Rexroth**, and **Weidmüller**.

←
The new infrastructure nodes supply up to 4 modules each and are equipped with technologies like TSN (Time-Sensitive Networking) and edge computing.

What are some practical uses of AI in manufacturing?

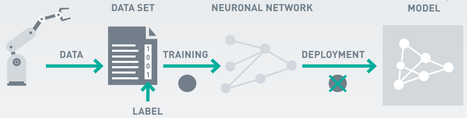
What does the smart infrastructure of the future look like?



INFORMATION TECHNOLOGY (IT)

Functioning of AI

– Supervised Learning –

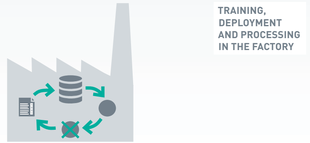


OPERATION TECHNOLOGY (OT)

Use cases

AI IN THE CLOUD A

AI IN THE FACTORY B



LEGENDE: DATA SET DATABASE TRAINING DEPLOYMENT

Integrated IT systems for the Industrie 4.0 production plant

Industrie 4.0 represents the close integration of automation systems and IT systems as well as the synchronization of the real and digital worlds. The controlling principle is to advance transparency and computer-aided optimization. Data about the products and production modules are continuously recorded digitally and connected in real-time to the IT system. Based on this digitally available information, innovative database services can be developed and realized for the manufacturing environment. The following IT systems and suppliers have been integrated in the manufacturer-independent ***SmartFactory***^{KL} Industrie 4.0 plant.

5 *Enterprise Resource Planning System (ERP)*

The Industrie 4.0 demonstrator uses the integrated ERP-SYSTEM manufactured by **proALPHA** to control the processes and ensure transparency. The software is capable of integrating the layers of the classic automation pyramid and provides a user interface for the customer. The customer uses the product configurator at the unit and, when linked to a web service, can enter intuitive and site-independent orders directly from the browser – down to lot size 1. Feedback from the system is displayed in real time in the job order and the customer receives a current status of job progress. In addition, the ERP system automatically generates service orders triggered by AI-based anomaly detection. Service orders and other helpful information on maintenance are then passed on, for example, via a tablet to the technician. Any related feedback from the technician is also recorded and stored in the system.

6 *Engineering*

EPLAN Software & Service is developing cloud-based ENGINEERING in an Industrie 4.0 environment. An interdisciplinary management approach to the automation of the individual production modules is critical for the design, efficiency, and operational safety of Cyber Physical Systems (CPS). The documented control system for the entire supply chain and the complete product life cycle is used as a comprehensive consistent database. The goal is to consider insights from the entire supply chain early in the design phase or the PLM process (product life cycle management). The generated documentation, for example, is suitable for a professionalized maintenance scenario or to optimize the energy balance.

7 *Data Analytics*

The plant data collected and provided by the integration layer is collected by **KIST**'s DATA ANALYTICS product. This enables the generation of chronological data models, which are used to derive analytical insights, for example, about the behavior of a component prior to recurring maintenance cases. Bottlenecks, rejects, rework, and downtimes can all be avoided at an early stage by comparing the historical sensor data with live data from the plant. Over the course of time and the increasing amount of data, the insights and statements have more and more precision and the process flow can be constantly optimized.

8 *Modular Certification / Safety*

The CERTIFICATION CONCEPT of **TÜV Süd** is designed for the certification of a modular and, consequently, a constantly changing production line. The certification is explained using the example of the flexible transport system: The moment the transport system docks to a production cell, it is assigned to this machine group. An emergency stop triggered at one part of the assembly module only causes an emergency stop of the transport system when it is part of this group. Besides enabling the connection of new modules with little effort, this safety concept also ensures that only relevant sections of the system are stopped in the event of safety-related shutdown. The unaffected production lines continue to operate without any risk to operational safety.

9 *Integration Layer*

The INTEGRATION LAYER of ***SmartFactory***^{KL} is achieved with the help of **IBM**s Watson IoT platform. The platform forms the central interface between OT (operation technology) and IT (information technology) and serves as a cross-layer instance for connecting the manufacturer's clouds. In terms of the vertical integration of all production processes, the integration layer takes on the role of a compiler: simultaneously, exercising data sovereignty over the shop floor. It captures content, protocols, and data formats from the plant (for example, condition data from the modules and Edge Devices) and, in a targeted manner, forwards them to the associated cloud. In addition, various analytical, cognitive, and DevOps services from the Watson IoT platform are used to map aspects like operational excellence, predictive maintenance, and quality assurance in a multi-cloud scenario in the context of horizontal integration. This makes it possible to show the product, all modules, and even decisions from the IT systems to the worker in real time (Digital Twin).

10 *Clouds*

The ***SmartFactory***^{KL} production plant employs multiple cloud-based computing solutions:
COMPANY CLOUDS from **Phoenix Contact** and **METTLER TOLEDO** are connected to the corresponding edge devices. The training of the adaptive AI systems takes place in the cloud-based solutions from **IBM**. The ***SmartFactory***^{KL} CLOUD, as a higher-level cloud platform, consolidates the data from the manufacturer clouds, checks it, and distributes it to appropriate targets – for example, to smart data glasses.
The SERVICE PROVIDER CLOUD is connected directly via 5G technology to the flexible transport system. It performs a quality control check using the optical recognition data from the workpiece. Early detection of potentially defective products enables their removal from the production flow.

Edge Devices

How can existing production facilities be digitalized? This is the central question of vertical integration asked by many manufacturing companies when retrofitting their brownfield facilities.

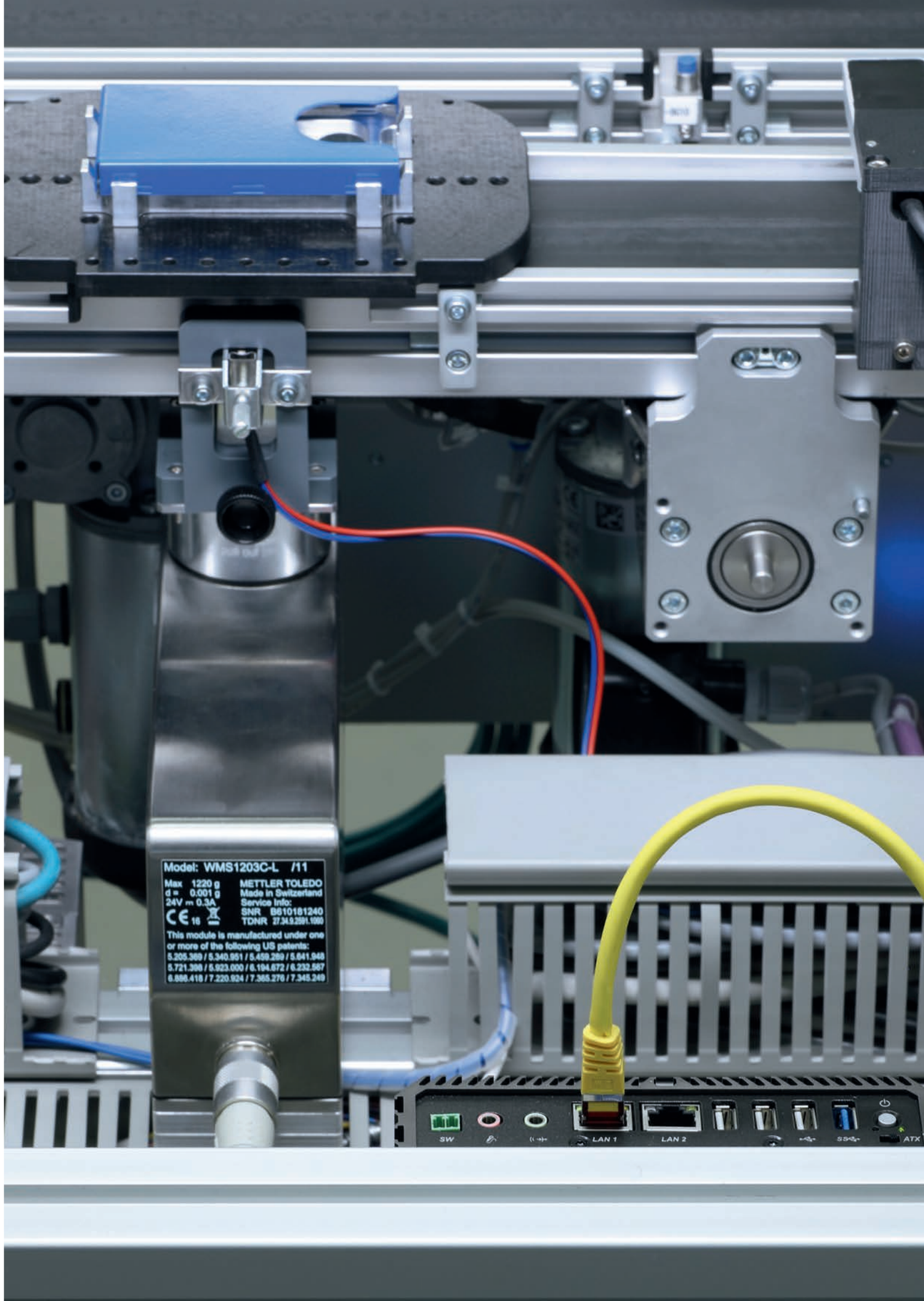
One answer is "by the use of Edge Devices". Existing automation systems, in particular, are not often prepared for universal networking. Implementing such a connection, in terms of simple and cost-effective retrofitting, can be done with Edge Devices, a kind of complex small computer.

The ***SmartFactory***^{KL} plant integrated several Edge Devices from **B&R**, **Harting**, **METTLER TOLEDO** and **Phoenix Contact**. In keeping with the manufacturer-independent approach on which the system is based, various solutions from different manufacturers are used.

At the controller interface (the "southbound" interface), partner companies have implemented various technical options. In all cases, additional sensors ensure condition data like the flow of compressed air in pneumatic actuators, the power consumed by electrical equipment, or the controller data are measured, without any interference with the existing systems and controls.

All Edge Device solutions share a common IT interface (the so called "northbound" interface), provided via standard OPC UA. This corresponds to the communication protocol defined by the ***SmartFactory***^{KL} partner consortium. To achieve maximum added value, data are securely sent to the ***SmartFactory***^{KL} Cloud via MQTT protocol after conversion at the integration layer to be evaluated. By means of smart data analytics in the context of condition monitoring, conclusions are drawn concerning the plant status and, for example, predictive maintenance can be initiated.

The new infrastructure nodes are equipped with edge devices to enable extensive data capture. Edge computing technology is also used at the infrastructure nodes. As a result, not all of the captured data is forwarded; rather, it is subject to pre-processing and filtering at the edge. By reducing the amount of data to be transmitted, costs and dead time are significantly reduced.



Many Partners, One Common Project: Progress within the Network!

The realization of Industrie 4.0 demands ideas and collaboration, as well as the eagerness to experiment and willingness to learn. Because in order to develop the intelligent factory of tomorrow, new technologies and concepts are needed, which can only be developed, tested and implemented jointly in a strong network. For this reason, various partners, which are among the leaders in their respective fields, are involved in the realization of the first manufacturer-independent Industrie 4.0 plant.

On July 6, 2017, B&R became a business unit of the ABB Group. As a global leader in industrial automation, B&R combines state-of-the-art technology with advanced engineering to provide customers in virtually every industry with complete solutions for machine and factory automation, motion control, HMI and integrated safety technology. With Industrial IoT communication standards like OPC UA, POWERLINK and openSAFETY as well as the powerful Automation Studio software development environment, B&R is constantly redefining the future of automation engineering.

www.br-automation.com

EPLAN provides software and service solutions in the fields of electrical, automation and mechatronic engineering. The company develops one of the world's leading design software solutions for machine and panel builders. Both standardised as well as customised interfaces to ERP and PLM/PDM systems ensure data consistency along the whole value chain. EPLAN was founded in 1984 and is part of the owner-operated Friedhelm Loh Group.

www.eplan.de/en

Festo is the world leader in automation technology and world market leader in technical training and advanced training. Pneumatic and electric drive technology by Festo stands for innovation in the industry and process automation – from the individual product to the ready-to-install solution. Innovations for highest possible productivity of the customers, worldwide presence and close system partnership with the customers are the trademarks of Festo. The company employs 20,100 employees in more than 60 countries all over the world.

www.festo.com

Pushing Performance

The HARTING Technology Group is global market leader in the field of electrical and electronic connection technology. The worldwide presence includes 13 production plants and branches in 44 countries. Some 5,000 employees generated sales of EUR 762 million in 2017/18.

www.harting.com

Huawei is a leading global information and communications technology (ICT) solutions provider. Its products and solutions are deployed in over 170 countries, supporting the communication needs of one-third of the world's population. Huawei offers the most complete telecom product portfolio in the industry to customers in Europe and worldwide. It caters to the needs of telecom carriers, enterprises and consumers by providing competitive end-to-end ICT solutions and services.
Huawei employs over 180,000 people with more than 80,000 being engaged in research & development. The European Research Center of Huawei Technologies Duesseldorf GmbH is the largest of HUAWEI's 16 R&D centers.

www.huawei.com

IBM supports companies on their way to Industry 4.0. IBM offers consulting, conception and realization as well as the necessary solution components, such as IoT platform, analytics, cloud, security as well as infrastructure and edge technologies. Hundreds of clients are using IBM Watson AI capabilities in their manufacturing lines, as intelligent assistants at the workplace, to control cyber-physical systems or in predictive maintenance and quality assurance. ***SmartFactory***^{KL} shows a large part of it: from Plant Service Bus for OT-IT integration, Watson Studio as Analytics Platform to IBM Cloud and Watson IoT for Digital Twin.

www.ibm.com

KIST Europe

The Korea Institute of Science and Technology (KIST) Europe is the governmental R&D institute of Korea in Europe, founded in 1996 in Saarbrücken. KIST Europe is a specific expertise in terms of innovation-oriented research & industry support as an open R&D platform between Korea and Europe. Our employees do on-site research in Europe for globalization of Korean science and technology in the fields of environmental safety, bio sensor & materials and smart convergence (SC). SC is aiming to accompany and to contribute to actively design evolutions of the 4th industrial revolution in research and development on national and international level.

www.kist-europe.com

METTLER TOLEDO

METTLER TOLEDO is a leading global manufacturer of precision instruments. The Company is the world's largest manufacturer and marketer of weighing instruments for use in laboratory, industrial and food retailing applications. The Company also holds top-three market positions for several related analytical instruments and is a leading provider of automated chemistry systems used in drug and chemical compound discovery and development. In addition, the Company is the world's largest manufacturer and marketer of metal detection systems used in production and packaging.

www.mt.com

rexroth A Bosch Company

As one of the world's leading suppliers of drive and control technologies, Bosch Rexroth ensures efficient, powerful and safe movement in machines and systems of any size. It enables fully connected applications with intelligent components, tailored system solutions, and services. Bosch Rexroth offers its customers hydraulics, electric drives and controls, gear technology and linear motion and assembly technology, including software and interfaces to the Internet of Things.

www.boschrexroth.com

TÜV SÜD

As a partner in the ***SmartFactory***^{KL} technology initiative, TÜV SÜD provides support throughout the development and continuous improvement of the world's first manufacturer-independent Industry 4.0 production facility. TÜV SÜD's experts are focusing on the development of a modular certification scheme. In this context, they are primarily involved in designing methods and a standard for the development and evaluation of Industry 4.0 components, machine modules and systems. Through more than 24,000 employees across over 1,000 locations, TÜV SÜD adds value to its customers, inspiring trust in a physical and digital world.

www.tuv-sud.com

MiniTec THE ART OF SIMPLICITY

From a single module to a complete solution: What started with miniature linear guides in 1986 developed into an internationally renowned full-service provider with more than 360 employees in twelve factories and over 60 partners and service points worldwide. The MiniTec modular system with its proven and flexibly deployable components for automation technology and plant engineering is valued and used by leading companies all over the world.

www.minitec.de/en

PHOENIX CONTACT

Phoenix Contact is the worldwide market leader of components, systems and solutions in the area of electric engineering, electronics and automation. Together with customers and partners, we are actively shaping solutions to convert the digitalization of our world into the intelligent production of tomorrow.
Here, our experience in machine building, process expertise in manufacturing, and our products for intelligent automation are convincing. To overcome the challenges of the future, Phoenix Contact is implementing Industrie 4.0 in its own production lines. Producing batch sizes of 1 at the same cost of mass production has become a reality.

www.phoenixcontact.com/industrie40

Weidmüller

Weidmüller is your partner for Industrial Connectivity. As experienced experts, we support customers and partners all over the world with products, solutions and services in the industrial environment of energy, signals and data. We are at home in your industries and markets and know the technological challenges of tomorrow. We continue to develop innovative, sustainable and valuable solutions for individual requirements. Together, we set standards in Industrial Connectivity.

www.weidmueller.com

PILZ THE SPIRIT OF SAFETY

The Pilz Group is a global supplier of products, systems and services for automation technology. The family business is based in Ostfildern and employs around 2,400 staff. With 42 subsidiaries and branches, Pilz creates worldwide safety for man, machine and the environment. The technology leader provides complete automation solutions comprising sensor, control and drive technology – including systems for industrial communication, diagnostics and visualisation. An international range of services with consulting, engineering and training completes the portfolio. Pilz solutions are used in many industries beyond mechanical engineering, such as wind energy, railway technology or the robotics sector.

www.pilz.com

PROαLPHA

The proALPHA group is the third largest provider of ERP for medium-sized manufacturing and trading companies in the DACH region. For more than 25 years, proALPHA has offered a powerful ERP solution as well as consulting, support, training, and maintenance services from one source. The ERP solution features a wide range of functions that allow all processes along the value-added chain to be controlled. Among our customers are more than 2,000 medium-sized companies from 50 countries and from various industries, such as mechanical and plant engineering, electronics and high tech, metal working, plastics, wholesale, and automotive and supply industries.

www.proalpha.com

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