

Progress within the network

*The Industrie 4.0 production plant
from SmartFactory^{KL} 2018*

Welcome to the future of
industrial production

Industrie 4.0 – Progress within the network

The mission of **SmartFactory^{KL}** was already defined when it was established back in 2005: "Pave the way for the intelligent factories of the future." As a manufacturer-independent technology demonstrator, together with our well respected partners and our work at the Mittelstand 4.0-Competence Center (SME 4.0) Kaiserslautern, we continue to realize innovative factory systems based on the concepts of Industrie 4.0 and put them to practical use: in large, medium, and small companies. The prerequisite for this is interoperability, recognizing that uniform standards for manufacturer-independent compatibility between individual plant modules and entire plants are the key enablers of the fourth industrial revolution.

We introduced our concept of a completely modular Industrie 4.0 production plant for the first time at **Hannover Messe** in 2014 and, have further developed it ever since. In 2018, visitors are experiencing the 5th generation of our plant. The central research question for us this year is: How can an existing production facility be digitalized? Our solution: **Retrofitting with Edge Devices**.

Various Edge Devices are supplied by our partner companies for integration in our demonstrator. Although they have different technical designs, the devices all serve the same function: they capture the condition data from the production machinery, which is forwarded from the existing integration layer via a standard OPC UA communication protocol to a cloud platform. Intelligent data analysis allows conclusions to be drawn as to the condition of the units and, for example, maintenance work

can be initiated as required. This effectively increases the plant's vertical integration.

To show the modularity and flexibility of the plant, the production process is divided into four lines: three automated production lines and the manual assembly station. The flexible transport system connects all the lines and is equipped with an optical quality control system, achieved with 5G technology and integrated into the extended modular safety concept.

Other innovative technologies all combine to support the production employees: the holistic approach to integrating different cloud solutions supplied by our partners, an innovative infrastructure concept, and the use of Augmented Reality with the aid of intelligent data glasses.

The basic structure for the expanded Industrie 4.0 production plant was developed by the working groups at **SmartFactory^{KL}**. The new application scenarios are a result of the round table discussions and cooperation between industry and academia. According to the spirit of our initiative, interaction among equals is the key to our success. It is what has led to the successful development of new research topics together with our partners. We are very proud of that.

Our goal is to continue to pioneer developments, trends, and visions for Industrie 4.0 in the future. Join us in this endeavor – thank you for your interest in our work.



Prof. Dr. Dr. h.c. Detlef Zühlke

Chairman of the Board of the Technologie-Initiative SmartFactory KL e.V

„Industrie 4.0 has been a familiar buzzword for many years – but, more than ever, we are now observing the introduction of specific ideas and concepts into production facilities around the world.

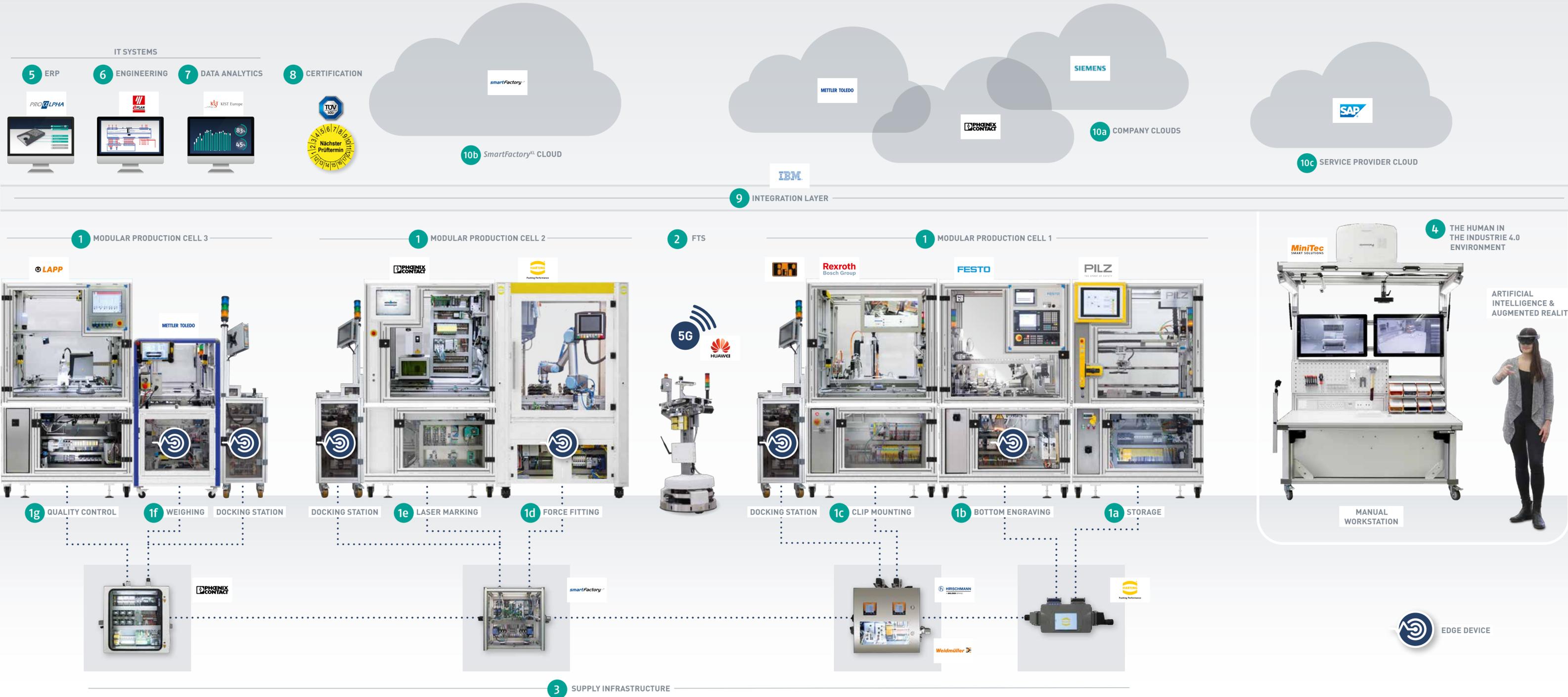
SmartFactory^{KL} performs pioneering work since 2005 and I am very proud to present our project, which brings Industrie 4.0 closer to the industrial implementation.”



What added value is provided by vertical integration?

What roles do humans play in the Industrie 4.0 environment?

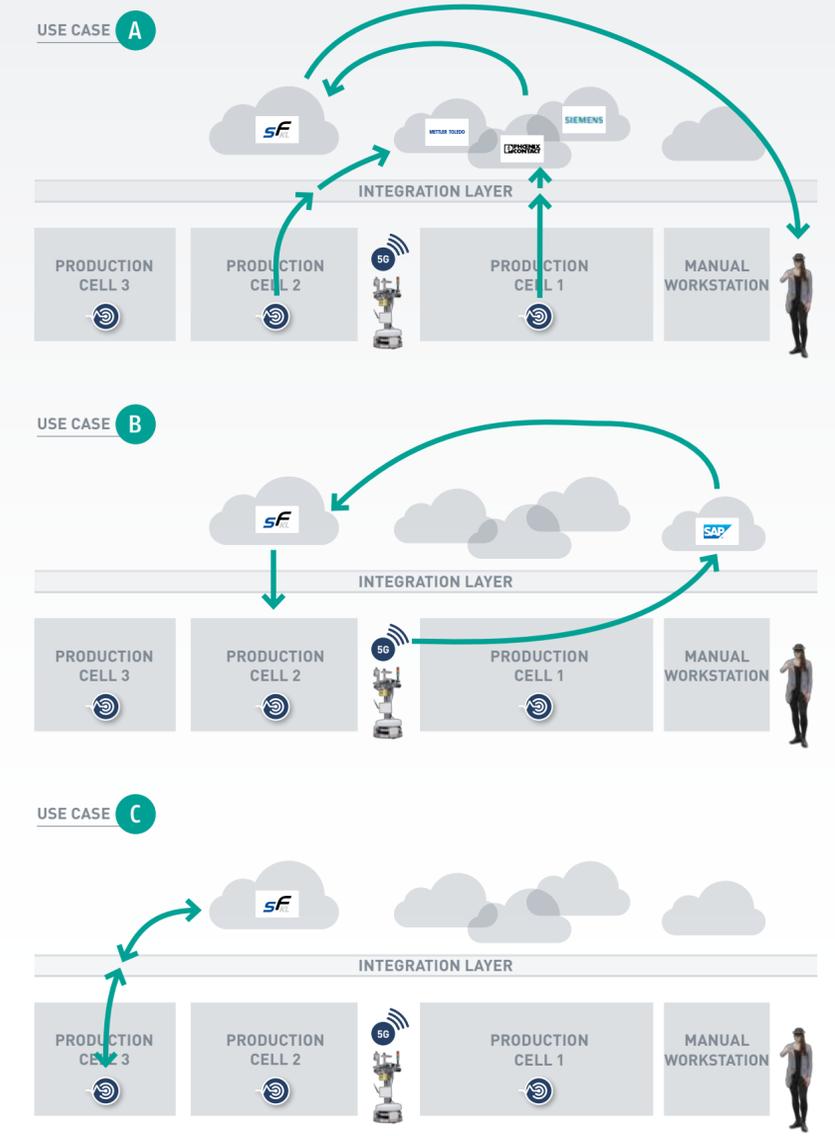




INFORMATION TECHNOLOGY (IT)

OPERATION TECHNOLOGY (OT)

Vertical Integration within the Industrie 4.0 plant



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.

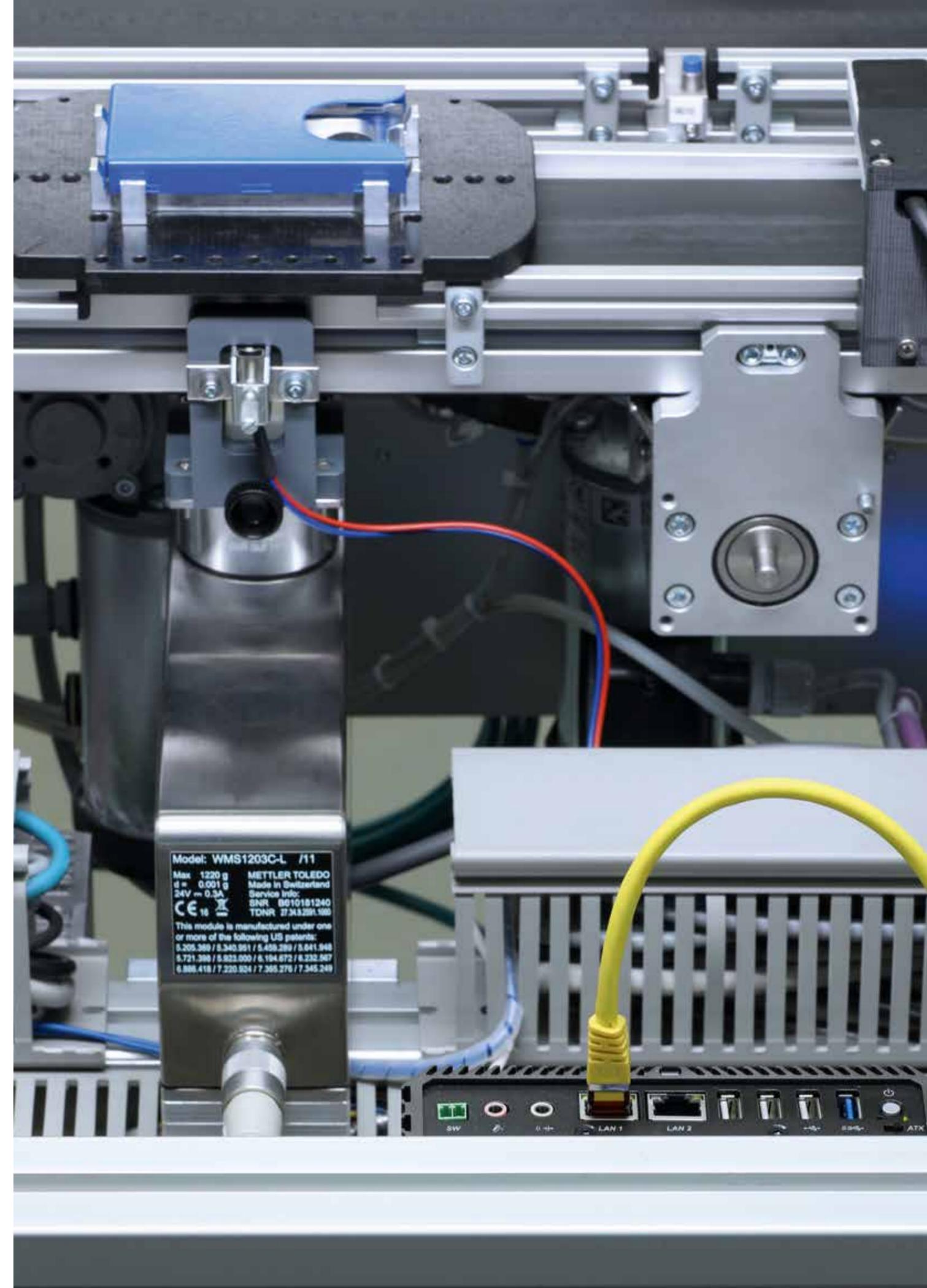
One answer is “by the use of Edge Devices”. Existing automation systems, in particular, are not often prepared for universal networking. Implementing such a connection, in terms of simple and cost-effective retrofitting, can be done with Edge Devices, a kind of complex small computer.

The *SmartFactory*^{KL} plant integrated several Edge Devices from **B&R**, **HARTING**, **METTLER TOLEDO**, **Phoenix Contact** and **Siemens**. 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 (use case ). 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 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** by **Lapp** 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. Workers are also supported when carrying out mobile tasks using tablets, smart phones, smart watches, or smart glasses.

The use of **ARTIFICIAL INTELLIGENCE** to merge and evaluate the data from various sources allows the filtering of data to provide workers with relevant information only. **AUGMENTED REALITY** systems are the proper means for this. For example, at the scene of the action, workers are guided through the process with the aid of data glasses. Information and work instructions are projected into the glasses at the same time so the user has both hands free to carry out the work.

Infrastructure

A powerful, flexible infrastructure is required to universally combine manufacturer-independent production modules with a minimum of configuration effort. Such an infrastructure can assume all major supply and management functions. These functions include the energy supply, data routing, and comprehensive safety controls. The infrastructure is the connecting lifeline between the production modules, which are otherwise fully autonomous. It is also modular in design and enables the connection of manufacturer-independent production modules. Standard plug connectors link manufacturer-specific infrastructure boxes that are designed as separate boxes, each with two module supply interfaces.

3 **HARTING, Phoenix Contact, Belden/Hirschmann** and **Weidmüller** supply the infrastructure boxes as independent, yet compatible proprietary developments that supply the system.

→
Manufacturer-specific infrastructure boxes enable a standardized connection of the production modules. Plug&Produce becomes reality.



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 integrated ERP system by **proALPHA** controls the processes in the Industrie 4.0 demonstrator and keeps them transparent. The solution is able to create an integration between the levels of the classic automation pyramid and provides an user interface for the customer. The product configurator in conjunction with a Web Service allows intuitive and location-independent orders in the browser by the customer down to batch size one. Feedback from the plant is observable in real-time and the customer is informed about the current status of production progress.

6 Engineering

EPLAN Software & Service is responsible for engineering the Industrie 4.0 demonstrator. 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 **IBMs 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 uses a variety of cloud solutions, which fall into three categories: The **COMPANY CLOUDS** from **METTLER TOLEDO**, **Phoenix Contact** and **Siemens** are connected to the associated Edge Devices (use case **A**). The **SmartFactory^{KL} CLOUD**, as higher-level cloud platform, consolidates the data in the separate clouds, checks it, and makes a targeted distribution. In this way, the **SmartFactory^{KL} Cloud**, for example, can draw conclusions from faulty or deviant data and communicate the appropriate maintenance instruction to the worker via the hololens. The **SERVICE PROVIDER CLOUD** from **SAP** is directly linked via 5G technology to the flexible transport system and carries out the actual quality control using the optical recognition data from the workpiece (use case **B**).

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 Software & Service develops CAx, configuration and mechatronic solutions and advises companies on how to optimise their engineering processes. Both standardised as well as customised interfaces to ERP and PLM/PDM systems ensures data consistency in product development, order processing and manufacturing. Factors for success in engineering include a consistent customer focus, global support and innovative development and interface expertise. As a global player, EPLAN supports over 45,000 customers around the world with more than 120,000 installations.

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 18,800 employees in 62 countries all over the world.

www.festo.com



As a specialist for industrial communication technology, Hirschmann™ – a Belden brand – develops innovative solutions oriented towards high customer demands with regard to performance, efficiency and security of investment. Hirschmann™ offers a complete range of Ethernet products for data communication in applications of critical importance to companies. These include Layer 2 and Layer 3 switches as well as security and wireless LAN systems that enable a standardized company-wide communication infrastructure.

www.hirschmann.de/en



IBM supports companies on their way to Industrie 4.0: Vertical and horizontal integration, optimization of manufacturing, maintenance and products as well as more efficient processes are the basis for the success of our customers. IBM offers consulting, design and implementation as well as the necessary solution modules, such as platforms/infrastructures, analytics, cloud, security and edge technologies. IBM AI functions can support production, e.g. as an intelligent assistant at the workplace, in controlling cyber-physical systems or in predictive maintenance and quality assurance. This makes Industrie 4.0 a reality.

www.ibm.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 4,600 employees generated sales of EUR 672 million in 2016/17.

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 Dueseldorf GmbH is the largest of HUAWEI's 16 R&D centers.

www.huawei.com



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



Headquartered in Stuttgart, Germany, the Lapp Group is a leading supplier of integrated solutions and branded products in the field of cable and connection technology. The Group's portfolio includes standard and highly flexible cables, industrial connectors and cable entry systems, customized system solutions, automation technology and robotics solutions for the intelligent factory of the future. The Lapp Group's core market is in the industrial machinery and plant engineering sector. Lapp Kabel has more than 40 sales companies, 17 production sites and approx. 100 national partners worldwide. They employ 3,770 people.

www.lappkabel.com



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



Pilz is technology leader in safe automation technology. In addition to the head office in Ostfildern near Stuttgart, Pilz is represented by subsidiaries and branches on all continents. Pilz's mission is to automate plant and machinery in such a way that the safety of man, machine and the environment is always guaranteed. For this purpose, the company develops and markets sensors, controllers and drive technology. The range of products is being expanded to include appropriate software tools, diagnostic and visualisation systems, as well as a comprehensive range of services.

www.pilz.com



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



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



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 1,800 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



Economical, precise, safe, and energy efficient: drive and control technology from Bosch Rexroth moves machines and systems of any size. The company bundles global application experience in the market segments of Mobile Applications, Machinery Applications and Engineering, and Factory Automation to develop innovative components as well as tailored system solutions and services. Bosch Rexroth offers its customers hydraulics, electric drives and controls, gear technology, and linear motion and assembly technology all from one source.

www.boschrexroth.com



Siemens AG is a global technology powerhouse that has stood for engineering excellence, innovation, quality and reliability for 170 years. The company is active around the globe, focusing on the areas of electrification, automation and digitalization. One of the world's largest producers of energy-efficient, resource-saving technologies, Siemens is a leading supplier of efficient power generation and power transmission solutions and a pioneer in infrastructure solutions as well as automation, drive and software solutions for industry.

www.siemens.com



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The Digital Business Services organization provides consulting, education, custom development, and support services. We deliver quality, short time to value, and reduced implementation cost with our strong industry expertise, our outcome-based portfolio, and our pre-assembly delivery model. Our 25,000+ Service & Support professionals focus on business outcomes for a faster time to value and reduced total cost of implementation and ownership. We bring together all the expertise required to help be successful with your SAP solutions.

www.sap.com/services



With around 25,000 staff at over 800 locations, TÜV SÜD ensures quality, safety and sustainability worldwide. In its Digital Service Business Line, the company focuses consulting, training, testing and certification services related to Industrie 4.0. The experts assist companies in unlocking the potential offered by digital transformation, identifying any vulnerabilities in the IT security of industrial automation and control systems and developing appropriate protection measures. Adopting an approach that combines safety, security and competitiveness, the experts supply integrated services for delivering operational reliability, IT security and analytics.

www.tuv-sud.com



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