



Progress within the network

The Industrie 4.0 production plant from SmartFactory^{KL}

Welcome to the future of
industrial production



| *smartFactory^{KL}*

Industrie 4.0 – Progress within the network

Industrie 4.0 – a topic that has long since found its way into the manufacturing world. Whether an Industrie 4.0 project, an appropriate business model, a new business segment, or advanced supplier relationships – digitalization is the acknowledged state of the art. Now is the time to reap the promised advantages of Industrie 4.0, develop the standards, and drive the implementation forward.

The aim of **SmartFactory^{KL}** is to pave the way for the intelligent factory of tomorrow. As a manufacturer-independent technology platform, we create innovative factory systems according to the Industrie 4.0 concept and, in cooperation with our partners, implement them in industrial enterprises of small, medium or large sizes, also given by the work of our “Mittelstand 4.0-Kompetenzzentrum Kaiserslautern”. The prerequisite is interoperability. Uniform standards are the key enablers of the fourth industrial revolution, ensuring manufacturer-independent compatibility between individual units and entire systems. Our network of renowned partners from industry and research develops the concepts, standards, and solutions that form the basis of highly flexible automation technologies.

We first introduced our concept for a completely modular Industrie 4.0 production plant in 2014, and have continued development ever since then. To further highlight

the flexibility of the system, especially, when applying it to an existing production environment – “Brown Field” approach – we expanded the demonstrator with an additional logistic component, based on a mobile robot platform. It is thus possible, to realize a crosstown production, which connects two production cells and a manual workstation, what is displayed within the new demonstration layout. It also requires an even deeper integration of the IT systems into the process. In parallel, we have also created a new safety concept that lets us implement a modular safety system.

The structure of the Industrie 4.0 production plant was prepared by the Working Groups of the **SmartFactory^{KL}**. This new use case arose because of the close cooperation on eye height of industry and science. Caused by the common work in our renowned consortium, as the idea of our initiative describes it, new research topics could successfully be compiled. We are proud of that.

To give the public a taste and an early glimpse of our ongoing development work, we present a Time Sensitive Networking (TSN) demonstrator that achieves real-time data transmissions via TSN Ethernet at the **Hannover Messe 2017**.



Prof. Dr. Dr. h.c. Detlef Zühlke

Chairman of the Board of the Technologie-Initiative SmartFactory KL e.V
Scientific Director, Innovative Factory Systems (IFS) department at DFKI



„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.”

*How to integrate
Industrie 4.0 in an existing
production process?*

*What is the added value provided by
a comprehensive information flow
across all levels of the enterprise?*

*What support can be provided to
the worker in the
production environment of the future?*



*The task:
Flexibility in the Age
of Industrie 4.0*

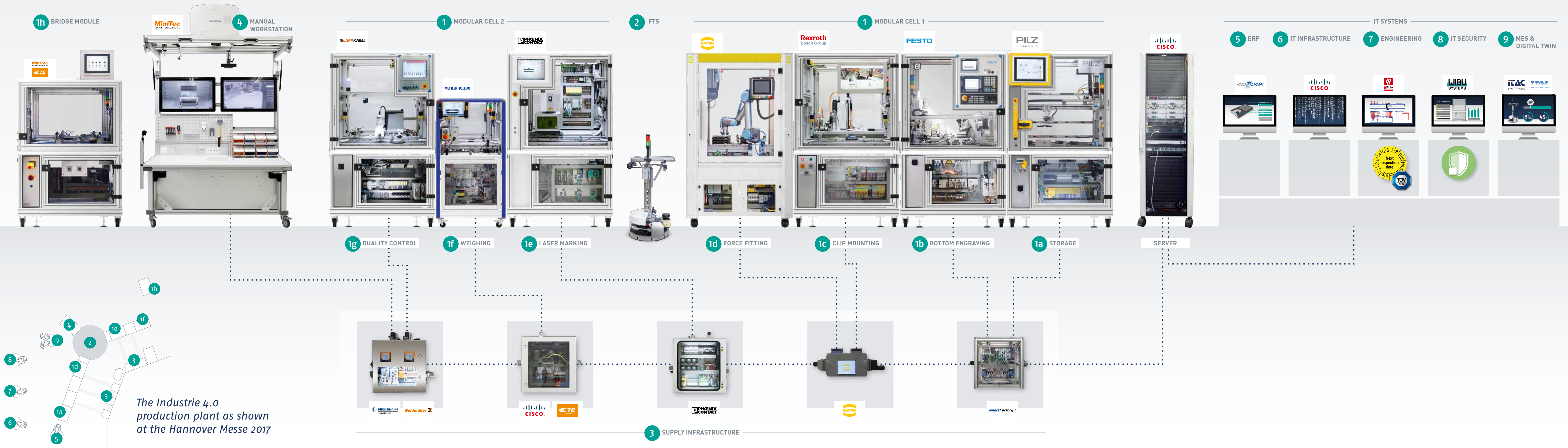
The 18 partner organizations involved in the *Smart-Factory*^{kl} Industrie 4.0 production plant have expanded their comprehensive technology demonstrator to new levels through close and collegial collaboration. To account for market demands for ever-shorter life cycles, increasing product customization, and worldwide competitive price pressure, the partner network creates new solution approaches.

The expanded demonstrator features a new layout this year: The modules are no longer constructed in series, but instead are spread over two production cells and the manual workstation. Thanks to the flexible transport system that features a robot platform as its central element as well as conveyor belts to each module, the product (a business card holder) can be flexibly produced in different ways. In addition, the production modules function hand in hand with the higher-level infrastructure and the IT system. The demonstrator clearly shows how different structures, whether machinery, logistic

systems, or human-machine interactions can be integrated in the existing concept – keyword: Brown Field.

This flexible system expansion is possible because of the development of manufacturer independent standards. The reconfiguration of the Industrie 4.0 production plant is essentially based on four standards. This includes the RFID tag descriptions, which defines the data structure and programming used in the product memories, the standard OPC UA communication, the dynamic safety concept, and the standardization of the hardware, which gives the docking station and the modules a common, basic mechanical function. Manufacturer-specific IT systems are also easily integrated into the production via uniform standards. Last minute product configuration during the production process is possible. This new layout lets the partner consortium show the productivity potential of the intelligent factory of tomorrow. Topics like standardization, modularization, product memory, and Plug&Produce are still highly relevant for achieving the goal of batch size 1 in the future.

Intelligent, modular – ready for use in industry: The Industrie 4.0 system from SmartFactory^{KL}



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.

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.

Flexible Transport Systems – FTS

2 The **ROBOT PLATFORM** by **Festo** is a self-navigating robot system that links the various production cells and manual assembly stations with a flexible, material transport solution. A WiFi connection to the manufacturing execution system (MES) ensures an optimal material flow.

Production Cell 2

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.

1f The **WEIGHING MODULE** by **Mettler Toledo** determines the weight of each product by means of a precision scale. The metrological quality control compares the product memory with the actual assembly status.

1g The module **QUALITY CONTROL** by **Lapp Kabel** 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.



↑ Flexible manual work station for manual assembly tasks

Maintenance and Repair

1h A **BRIDGE MODULE** supplied by **MiniTec** and **TE Connectivity** offers the possibility to replace any other module in the production process. A short program selection allows this module to eject each product at the appropriate production step and continue to a replacement manual assembly job. As a consequence, flexible failure-proof maintenance and variable degree of automation of the production plant is possible.

Manual assembly stations and worker assistance

4 A **MANUAL WORKSTATION** is also connected to the process via the robot platform, a system

created by **MiniTec**. Internet and communication systems provide optional support to the worker for various assembly tasks from an ergonomically perfect work station. Thanks to the Augmented Reality systems developed at **SmartFactory^{KL}**, an individual process step or even an entire production process can occur completely manually. Augmented Reality – the connection of real-time pictures with recommendations for actions – offers many advantages, especially for training processes and assembly with many variants. Through an integrated RFID reading and writing device, the employee can read out the current production progress of the product as well as the client-specific information. Augmented Reality Technologies support him with the implementation of the variable tasks. Mobile devices like tablets, smartphones, smartwatches, and smartglasses are useful in providing an appropriate mobile support to the worker.

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, TE Connectivity and Cisco, 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 also stands for a close integration of automation and IT systems. The guiding principle behind all this is the synchronization of real and digital worlds for the purpose of achieving transparency and computer-assisted optimization. Information about the production modules and products is digitally recorded in real-time and sent to the modular IT system. New database-oriented services for the production environment are developed and implemented on the basis of digitally available data. The following IT systems and vendors are integrated in the manufacturer-independent Industrie 4.0 production plant of **SmartFactory**^{KL}:

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 IT Infrastructure

Connected Factory Architecture from **Cisco** aims to link IT and automation technology by connecting

intelligent networks, server-architectures, and a unified communication architecture. This achieves the company requirements for a modern Industrie 4.0 environment and facilitates applications in the areas of preventive maintenance, multimedia remote-access to the units, and a remote maintenance concept. The current productivity can be derived from the digital images supplied by the **Cisco Asset Manager**.

7 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.

Moreover, **TÜV Süd** has drafted a design for a modular certification method for flexible production plant structures. Specifically, these safety and legal issues have not been thoroughly addressed in the past and represent a potential showstopper. The new certification methodology includes a specific timetable, which makes the practical advantages of Industrie 4.0 achievable.



8 IT Security

CodeMeter by **WIBU-SYSTEMS** provides the technology required to achieve comprehensive and strong IT security standards in Industrie 4.0 production facilities. It protects software components against unauthorized access and manipulation. Cryptographic keys, e.g. used for authentication in OPC UA, are stored and used securely on CmDongles. CodeMeter's license management capabilities allow fine-grained controls over software's features and configuration or confidential production data.

9 Manufacturing Execution System – MES und Digital Twin

The Manufacturing Execution System (MES) from **iTAC Software AG** forms the central data hub. The MES receives order data from the ERP system and assigns a serial number to the semi-finished product, which is to be married to the finished end product. The MES assigns work steps, receives feedback from the equipment about the completed steps and enters the successful work steps in the system (Track & Trace).

Information from the integration bus is sent to the MES, where the decision is made as to where to transport the product for further processing based on production plant topology and corresponding instructions are given to the flexible transport system. Key Performance Indicators (KPIs) are assessed using the production data generated and stored in the MES and can be read in real-time on the dashboard controls located on the line. Additionally, conclusions drawn in this way from production data facilitate the optimization of production process and preventive maintenance decisions. Clearly, the MES contributes greatly to a self-optimizing production system.

Aspects such as operational excellence, real-time transparency, predictive maintenance services, and quality assurance are visualized in the uniform and flexible production control center provided by **IBM**. Data from the various production modules is enriched and structured for storage in the Data Historian. Results derived from analysis of this data are used to avoid bottlenecks, waste, rework, and down time. Ultimately, the product, all modules, and even decisions out of the IT systems can be shown to the worker by a so called "Digital Twin" in real-time.

The Working Groups of the Network

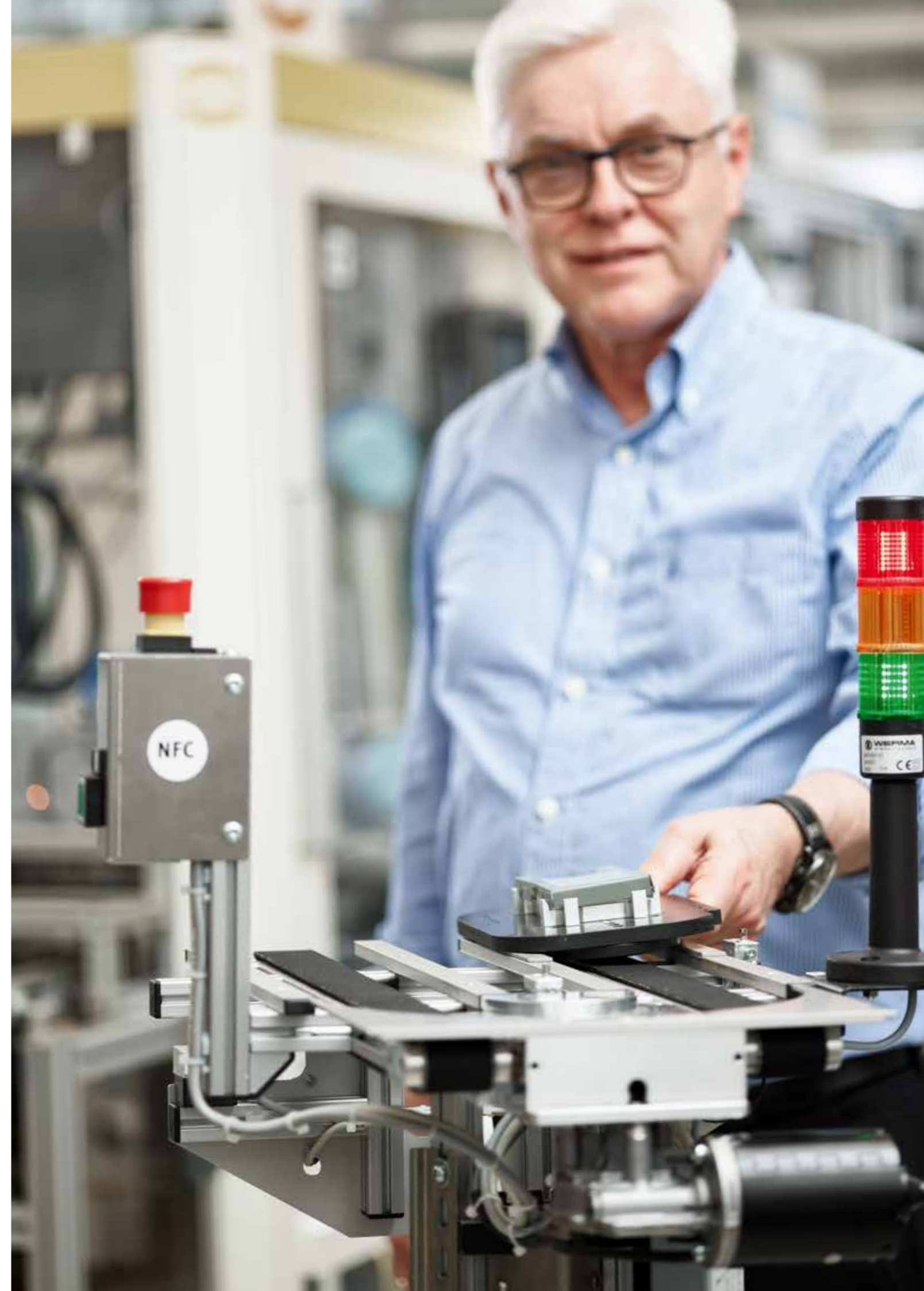
Members of the **SmartFactory**^{KL} are working on a variety of topics in various groups. This is where concepts, trends, visions, and ideas are developed and conceptually designed to pave the way for the next steps, integration and implementation in the demonstrator.

The **Safety** Working Group has already integrated a modular safety concept this year. It shows how to implement a modular safety concept using today's technologies. Machines can be inserted or removed from the production process without affecting the rest of the production plant. All processes continue to operate safely. Innovative, illuminated emergency stop buttons inform the operator when a machine is safely integrated into the rest of the plant.

The **Automation Systems** Working Group demonstrates Time Sensitive Networking (TSN) as an advanced development model for the integration of the concept into the production plant. TSN Ethernet is introduced in the demonstrator as a manufacturer-independent communication protocol. The industrial Ethernet protocol Sercos is used to demonstrate the real-time capability via the

L2 protocol. While simultaneously broadcasting best-effort traffic in the form of a video using a synchronized Sercos Motion Control Application, TSN delivers a solid real-time capability. The combination of OPC UA and TSN is regarded as the ideal machine-to-machine (M2M) communication standard for the future. TSN and OPC UA is expected to be the replacement for the Backbone communication within the manufacturer-independent Industrie 4.0 plant, and also for internal module communications.

The **Digital Factory** Working Group is creating a digital representation derived from the Industrie 4.0 production plant found in the **SmartFactory**^{KL} system architecture. **SmartFactory**^{KL} specifically references the so called "administration shell" of the Plattform Industrie 4.0. On the basis of existing standards with relevant objects and instance data from the engineering process, very diverse objects including the manufacturer-independent production modules are provided, enriched, managed, and used in concrete applications, for example, in the (re-) engineering of scalable production.



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.



Cisco (NASDAQ_ CSCO), the world-leading IT provider, helps companies seize tomorrow's business chances today. Unique opportunities are opened up by networking people, processes, data and more.

Current information on Cisco can be found at:
<http://blogs.cisco.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



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 18,700 employees in 61 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



iTAC Software AG, an independent company of the mechanical and plant engineering group Dürr, provides Internet-enabled information and communication technologies for the manufacturing industry and is one of the leading MES providers in Germany. The iTAC.MES.Suite is a cloud-based MES that is used worldwide by companies in industry sectors such as automotive manufacturers and suppliers, electronics/EMS/TC, medical technology, metal processing and energy. Additional services and solutions, such as the iTAC.IoT.Platform, enable the implementation of industry 4.0 requirements. iTAC's philosophy is connecting people, data and systems.

www.itac.de



The HARTING Technology Group specializes in the areas of electrical, electronic and optical connection, transmission and network technology, manufacturing, mechatronics and software creation and develops tailor-made solutions and products such as plug-in connectors for power supply and data transmission, for industries including mechanical engineering, factory automation, railway technology and wind energy plants.

www.harting.de



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www.ibm.com



Headquartered in Stuttgart, Germany, Lapp Kabel is a leading supplier of integrated solutions and branded products in the field of cable and connection technology. Lapp Kabel's portfolio includes standard and highly flexible cables, industrial connectors and screw technology, 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, 18 production sites and approx. 100 national partners worldwide. They employ 3,440 people.

www.lappkabel.de

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



Phoenix Contact is the world market leader for components, systems and solutions in the field of electrotechnology, electronics and automation. As an operator and manufacturer of modern production plants with a high degree of vertical integration as well as a supplier of automation products and the related connection and interface technology, PHOENIX CONTACT has a thorough knowledge of the requirements of Industrie 4.0. Because we aligned our business towards IT-powered automation at an early stage, we have many years of experience and contribute this to the committees for Industrie 4.0. With our in-house mechanical engineering section we plan, build and test the intelligent production of tomorrow.

www.phoenixcontact.de



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 ten 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



Pilz is a complete automation technology supplier. The company covers the whole of automation technology, from sensor technology to control and actuator technology. The product range also comprises relevant software tools, diagnostic and visualization systems and services. Complete system solutions are the result. Pilz solutions consist of both automation and safety functions. One example is the automation system PSS 4000, the central concept of which is to merge safety and automation.

www.pilz.de



The proALPHA group is the third largest provider of ERP for medium-sized manufacturing and trading companies in the DACH region. For 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.de



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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.de



Bosch Rexroth is an international leading provider of drive and control technologies. Regardless of the motion task that customers face anywhere in the world, they will always find a Bosch Rexroth team with the local experience and the appropriate know-how from a variety of industries and all drive and control technologies. This is what makes Bosch Rexroth a strong, reliable partner for Mobile Applications, Machinery Applications and Engineering, and Factory Automation. With a product portfolio that includes all technologies, as well as service and support solutions, Bosch Rexroth sees itself as a partner for the complete machine life cycle.

www.boschrexroth.com



TÜV SÜD provides quality, safety and sustainability with 24,000 employees at more than 800 locations worldwide and bundles consulting, training, inspection and certification services around Industrie 4.0. The TÜV SÜD experts have been involved in several significant research projects and have already completed initial certification processes according to international standards including IEC 62443. As partners of the Technologie-Initiative SmartFactory KL e.V., TÜV SÜD addresses modular certification based on the digital twin concept and the principle of module interoperability.

www.tuv-sud.com



Wibu-Systems is an innovative security technology leader in the global software licensing market. With CodeMeter®, a comprehensive, award-winning suite of hardware and software-based solutions for computers, embedded systems, mobile devices, PLCs, and microcontrollers, Wibu-Systems offers a highly secure, unique, and versatile technology. Software publishers and intelligent device manufacturers can safeguard the intellectual property of their applications against illicit and fraudulent use, reverse engineering, and tampering attacks, and generate new digital business models fully integrated with ERP, CRM, and e-commerce platforms.

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Technologie-Initiative SmartFactory KL e.V.

Trippstadter Straße 122
67663 Kaiserslautern, Germany

P +49 (0) 631 / 20575-3400

F +49 (0) 631 / 20575-3402

M info@smartfactory.de

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is a non-profit association registered in the register of associa-
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Christopher Arnoldi; Lapp Gruppe/Maiwolf



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