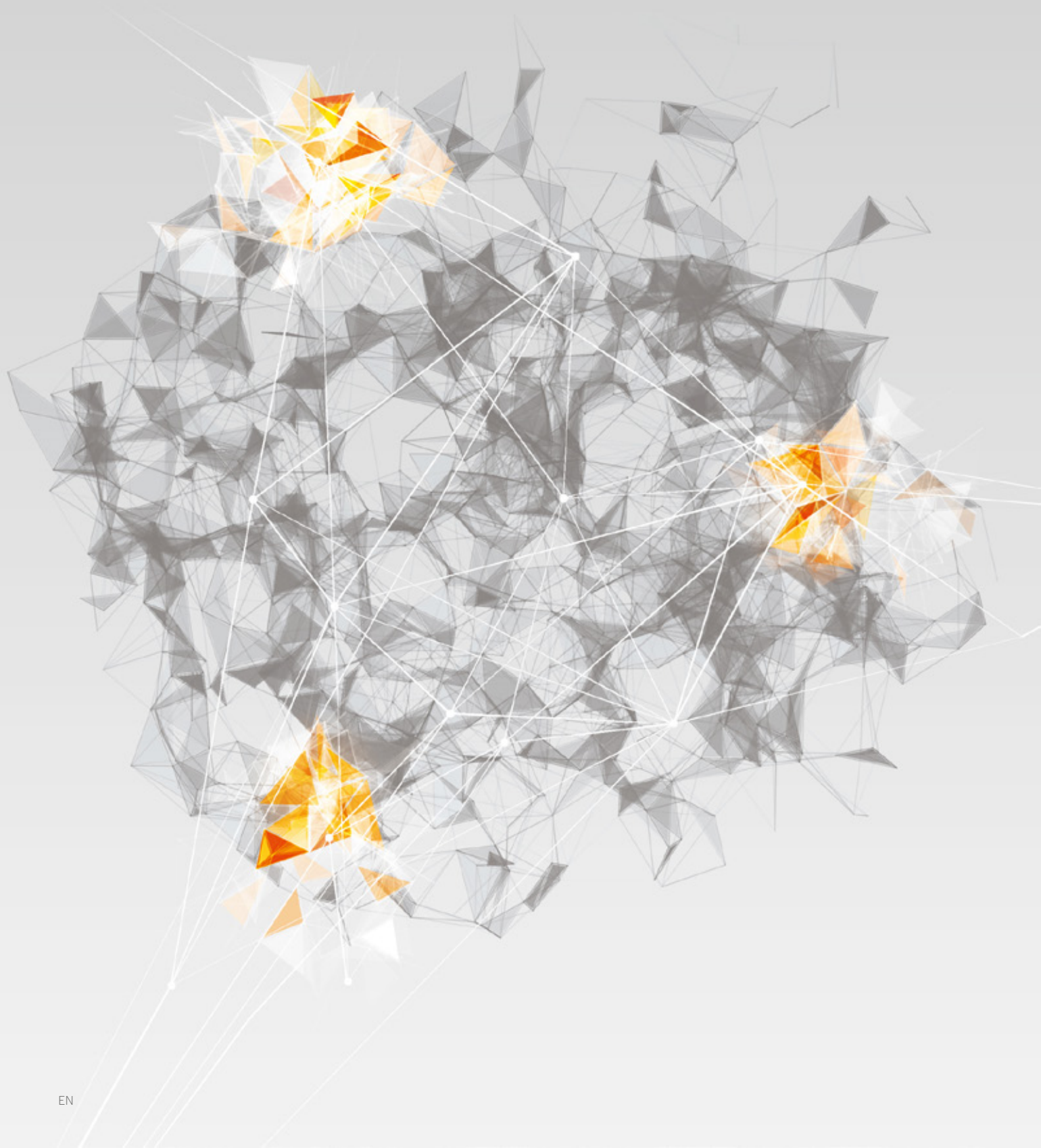


KUKA



Hello Industrie 4.0
_we go digital





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Hello Industrie 4.0

_we go digital

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Things are changing Here and now

The Internet of Things, Industrie 4.0 and Smart Production – even if the name varies internationally, the core idea remains the same. What is called for here is nothing less than a long-term transformation of our global perception of industrial production through the seamless connection of the digital and real worlds. As a thought leader and trailblazer for Industrie 4.0, KUKA is playing a decisive role in this shift towards networked, intelligent production. With the courage to change things.



Dr. Till Reuter
Chief Executive Officer
KUKA Aktiengesellschaft

–Rethinking the future

»Today we are setting the course for a revolution that will be all-embracing.«

Progress in society and technology has advanced at breakneck speed in the past years – and this covers virtually every area of everyday life and business. The Internet of Things is just around the corner. From refrigerators and streetlights to complex machines – every “thing” is then in the network, has its own sensors, can be detected and controlled, and is able to provide feedback.

Even today, almost every electronic device is able to communicate with the Internet. The digital world is an integral part of our lives and influences our desires and actions.

Digitization and the inexpensive availability of ever greater computing power have increased our ability to recognize and model complex relationships: for example in the fields of physics, chemistry, economics and ecology. The rapid developments this has triggered in the past years in the fields of biotechnology, genetics and nanotechnology, fabbing, robotics and artificial intelligence are

laying the foundation, in the context of a completely networked world, for a revolution that will be all-embracing. Fully digitally networked processes, innovative business models, and new processes and materials will make it possible to manufacture products in a manner that is far more flexible, energy-efficient, resource-saving and with a high level of customization.

Cloud computing and Big Data will give this process another significant boost. Systems that have the capacity to save, share and interpret millions – or even billions – of data records and to draw logical conclusions from them will be able to learn and develop further at lightning speed. We can already see this effect in the current evolution of intelligent personal assistants, such as Siri or Cortana. Feedback from millions of users enabled them in a short space of time to improve their capabilities considerably. And they continue to learn quickly – very, very quickly.

In a completely networked world, robotics and artificial intelligence are laying the foundation for this revolution.

Applied to the world of industrial production, the connection to the cloud and Big Data will open up entirely new production environments. This will initially be achieved by means of easily implemented app-based software expansions or cloud-based functions, such as asset management, condition monitoring, anomaly detection or predictive maintenance. The outcome, however, will be platforms that flexibly control and autonomously optimize production processes and adapt them to external influences. These cloud solutions will tap the full potential of the combination of comprehensive production data, innovative manufacturing processes, digital networking and responsive components. They will do so throughout the entire digital value creation chain.

New business models

Cloud-based services will change the approach to physical possession. This is being replaced by temporary access to goods or services. The best example: music streaming. What has already become an everyday situation in many consumer segments will also revolutionize the industrial environment over the next few years.

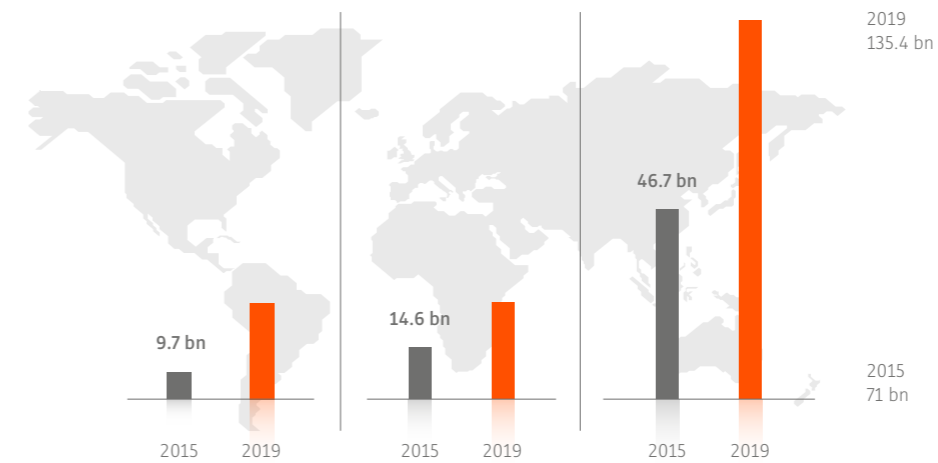


Connecting the world of industrial production with the cloud and Big Data will open up entirely new production environments.

It will be possible to order manufacturing processes and capacities at the click of a mouse. In “manufacturing as a service”, the systems themselves are not purchased. It is merely the performance of the machine that is paid for. What applies to complete production systems will, in the future, also hold true for individual elements within a manufacturing facility – for robots, for example. On the basis of “pay-per-use” models, it will not be the machine itself that is purchased, but its output.

Clouds integrate all these services into production processes and enable companies to react extremely flexibly to capacity requirements and goods flows. In the technology hub of Austin, Texas, KUKA is working with an experienced crew of interdisciplinary development engineers to achieve precisely that: the fusion of the IT sector with the leading expertise in the fields of mechatronics and industrial manufacturing processes. Our team in the USA will ensure that operational technologies such as robots and logistics machines are connected to the cloud, the web, mobile platforms and other modern IT technologies. This will make KUKA technologies even more user-friendly and provide new features in practical operation.

The digital revolution will also affect the machines themselves, however. They will become interoperable, increasingly sensitive, more intelligent, more autonomous, more mobile and ever easier to operate. We are also approaching a historic juncture in the relationship between humans and machines: namely the moment when a machine will be intelligent enough to understand our language and gestures and to follow our instructions. What is already clear is that this machine will be a robot. As the most flexible element in the production system, robots already gather data and exchange them with a wide range of different systems. No other component



Source: IDC Forecast Worldwide

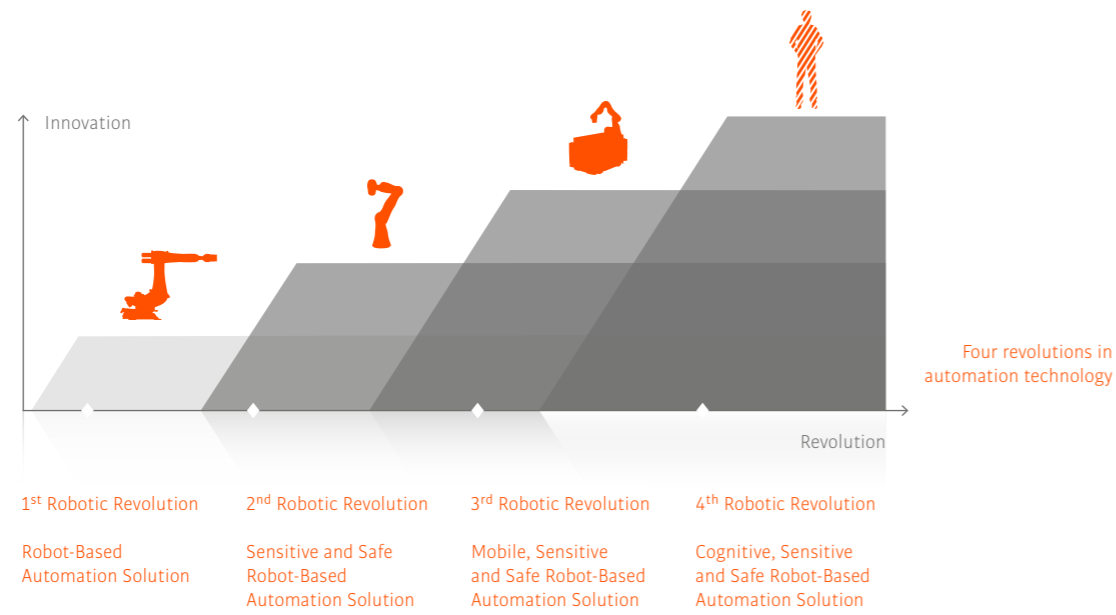
in the production process is currently capable of accomplishing this role. Initially designed merely as a universal machine to boost productivity, the robot is increasingly evolving into a servant and assistant in factories, supporting humans in their work. Because a robot is better at specific things – speed and precision – it provides humans with entirely new capabilities. As robots become increasingly intuitive to operate, so that everyone can understand them, it will soon also be possible to integrate them into unstructured work environments or have them carry out new instructions.

The world is changing.

The rapid advancement of robotics will permanently change the world, just as the Internet and IT have done. Today, robots are a key element of Industrie 4.0, providing answers, with new production methods, to the major questions of our times: shortage of resources, climate

change and the consequences of accelerating population growth combined with the aging of society in the industrial nations. If we consider a longer period of time, it is foreseeable that robots will also become smaller, more mobile, networked and cognitive, reflecting the development from the mainframe computer to the desktop computer (miniaturization), laptop (mobilization), tablet and smartphone (omnipresence). Endowed with these capabilities, they will accompany us in every area of our daily lives – both in the workplace and at home.

The International Data Corporation (IDC) forecasts a global increase in expenditure for robotics and associated services to 135.4 billion US dollars by the year 2019.



Future generations, “robotic natives”, will see robots as the state of the art, as a lifestyle, or quite simply as normal. These generations will certainly have no inhibitions regarding robots. They will have overcome the old human versus machine antagonism. They will see the capabilities of robots as universal, networkable services that can be requested via the Internet and flexibly adapted to the requirements and desires of the individual at the click of a mouse.

As the world’s leading brand for intelligent automation with robotics, we are driven by the goal of making living and working easier for people. At KUKA, added value results from the interdisciplinary interplay between a wide range of different fields of expertise. As far as the Internet of Things and the new production worlds of Industrie 4.0 are concerned, these include our technological expertise in the web, the cloud and mobile platforms. These areas merge with KUKA’s existing core competencies in mechatronics and automation. On this basis, we are already working with our customers today to create completely digitized manufacturing processes – intelligent production solutions which overcome the barriers existing between the digital world and the real world.

This exceptional customer added value is epitomized in what we call ›Orange Intelligenz‹.

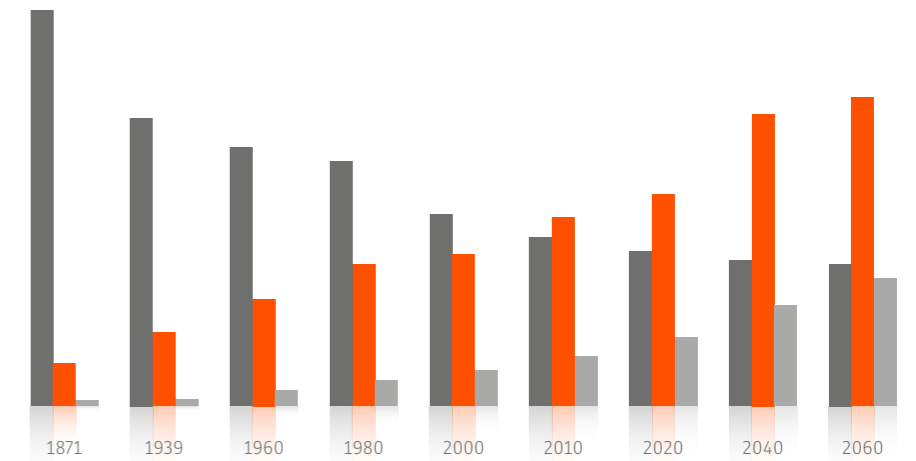
Rethinking the future

- Demographic change
- Customization
- Resource efficiency
- Fast availability



Demographic change

Is it possible to safeguard prosperity?



Source: German Federal Statistical Office

The threat of an overaging society in the leading industrial nations is an oft-postulated horror scenario. The fact is that in contrast to global population growth, society in the industrial nations is faced with falling birthrates and increasing life expectancy. In Germany in 2030, of 100,000 employees currently working in the manufacturing industry up to 20,000 will already have retired.

But is it necessary to conclude from this that the pensions and prosperity of coming generations are truly jeopardized? Or does it inevitably mean that the economy is going to run out of skilled workers? From a statistical viewpoint, this will only happen if we assume that the productivity of employees in the year 2030 will remain at today's levels.

In a country like Germany, where total industrial production accounts for around 23 percent of gross value added, this means that the prosperity of society can essentially be safeguarded in the long term by increasing industrial productivity.

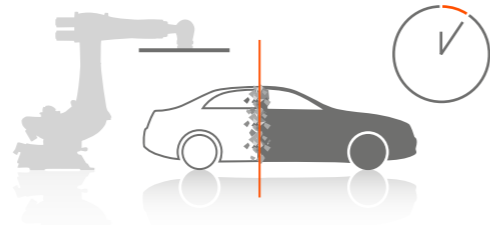
No-one can accurately predict the extent to which labor productivity will increase in the future. With more intelligent machines and the digitization of industrial manufacturing processes, however, the workers of the future will certainly be significantly more productive than all generations before them. New technologies, such as robots that collaborate with humans, will enable experienced older employees to make a longer active contribution in the workplace.

Industrie 4.0 thus has a key role to play in permanently assuring the prosperity of our modern society. This is despite what any demographic pyramids might indicate – quite simply because intelligent machines will be able to generate the required value creation.

In Germany in 2030, of 100,000 employees currently working in the manufacturing industry up to 20,000 will already have retired.

The megatrend of customization

Or the value of the individual



Customization, or individualization, is a megatrend shaping present-day society. It is leading to ever clearer differentiation of life philosophies, consumer behavior and self-presentation. Driven by the technological transformation of the media, the megatrend of customization is no longer restricted to the industrial nations, but has meanwhile taken hold worldwide – particularly in the emerging economies.

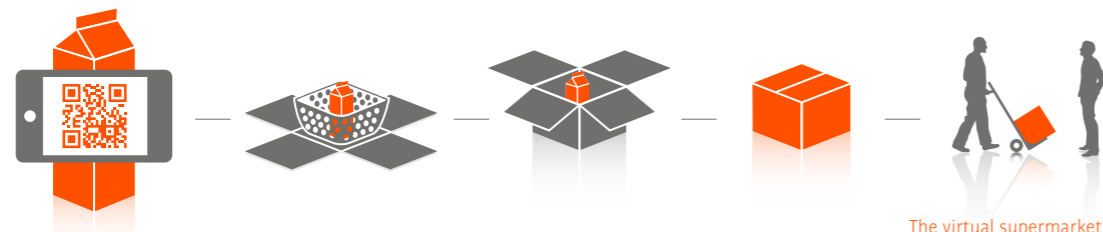
In the factory of the future, the time to market, which is often decisive for the sales success of a product, will be significantly shortened. Changing requirements and trends in increasingly volatile markets can be met with corresponding products much more quickly than previously.

As the availability and diversity of opportunities offered by the media increase, so too does the importance given to individuality in real life. It expresses itself in the development of language and in socialization in peer groups and is also enjoying massive market penetration with ever more specific purchasing patterns.

Industrie 4.0 is creating the basis for manufacturing high-quality one-off products with the profitability of series production. Traditional manufacturing is being replaced by highly flexible factories in which humans and machines work hand in hand. Products and goods can be adapted simply to personal tastes and requirements via the Internet.

The more a user's identity is reflected in a product, the more the user can identify with it. It is ultimately down to industry to give customers the feeling that the goods they receive were made specially for them.

Through Industrie 4.0, highly efficient manufacturing systems will play a key role in safeguarding production locations in industrial nations over the long term.



The virtual supermarket: The individuality of users is having an impact on markets as purchasing patterns become ever more specific.





The megatrend of resource efficiency

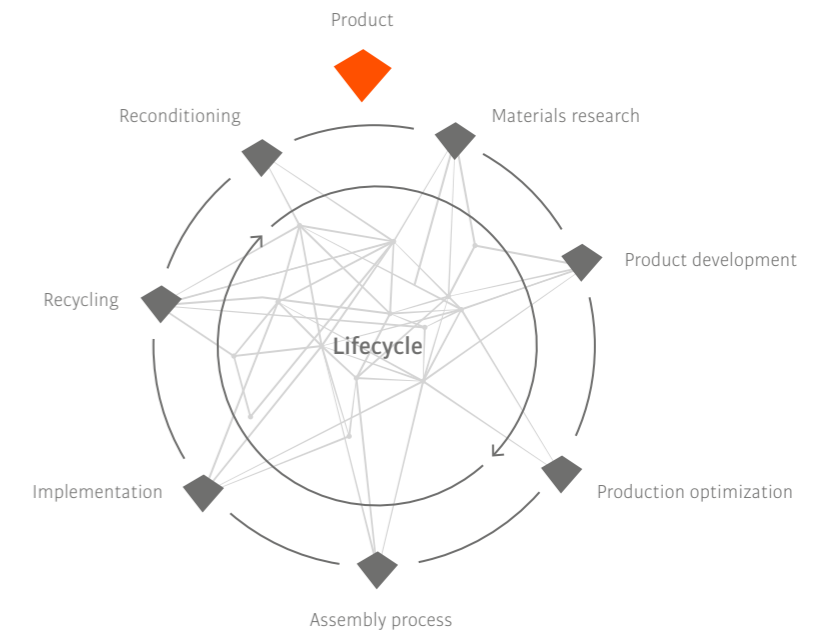
The limits to growth or the dawn of a new age

By 2030, the world population will have grown to 8.4 billion people. Elementary resources, such as land, energy, water and food, will be required – but there will also be 1.2 billion new consumers on the planet.

The consumption of natural resources has already been increasing for decades. Global consumption of raw materials has more than doubled in the past 30 years. By 2050, the world population will have grown to up to 10 billion people, who will be laying claim to more than 140 billion tonnes of minerals, ore, fossil fuels and biomass – assuming consumption patterns remain unchanged. Global climate change and shortages of substantial resources already clearly demonstrate, however, that our existing systems are reaching their limits as far as our planet is concerned. The need for sustainable action and sustainable manufacturing is thus more urgent than ever before.

There are several reasons for this: firstly, we are extremely dependent on the intelligent use of energy and raw materials, such as rare earths, in order to maintain the competitiveness of our highly industrialized business locations. Secondly, customers are increasingly demanding sustainable, fairly traded products.

As a result, Industrie 4.0 will not only revolutionize our production cycles with more intelligent technologies and more sustainable production processes. It can also help us to demonstrate our social, economical and ecological use



Flexible, intelligent and networked production as envisaged in Industrie 4.0 offers the opportunity of using raw materials more efficiently and more sustainably along the entire value creation chain.

of resources, as will be required to an increasing extent. This applies to every step – from extraction of the raw materials to production, assembly, distribution and use of the products, not forgetting disposal and recycling of the raw materials.

In order to meet the global challenges arising from the combination of a growing world population and limited resources as well as living up to our call for a “fair” world, we need to rethink our business and production systems. We need to learn to communicate openly and to consistently network our systems worldwide. Industrie 4.0, cloud technologies and Big Data are the building blocks that will enable us to shape this

new world – a global economy that uses raw materials more efficiently and more sustainably along the entire value chain and recycles them to the greatest extent possible for the sake of the planet.

An economy that accepts responsibility – for our planet and the people who live on it.

Fast availability

Speed determines the success of a product.

It has long since become clear to us that the digitization of the economy will have a similarly far-reaching impact on people to that of the Industrial Revolution. Amazon, eBay and others have already impressively demonstrated that the new business models of the digital world are able to change consumers' purchasing habits – and thus goods flows – permanently in our real world.

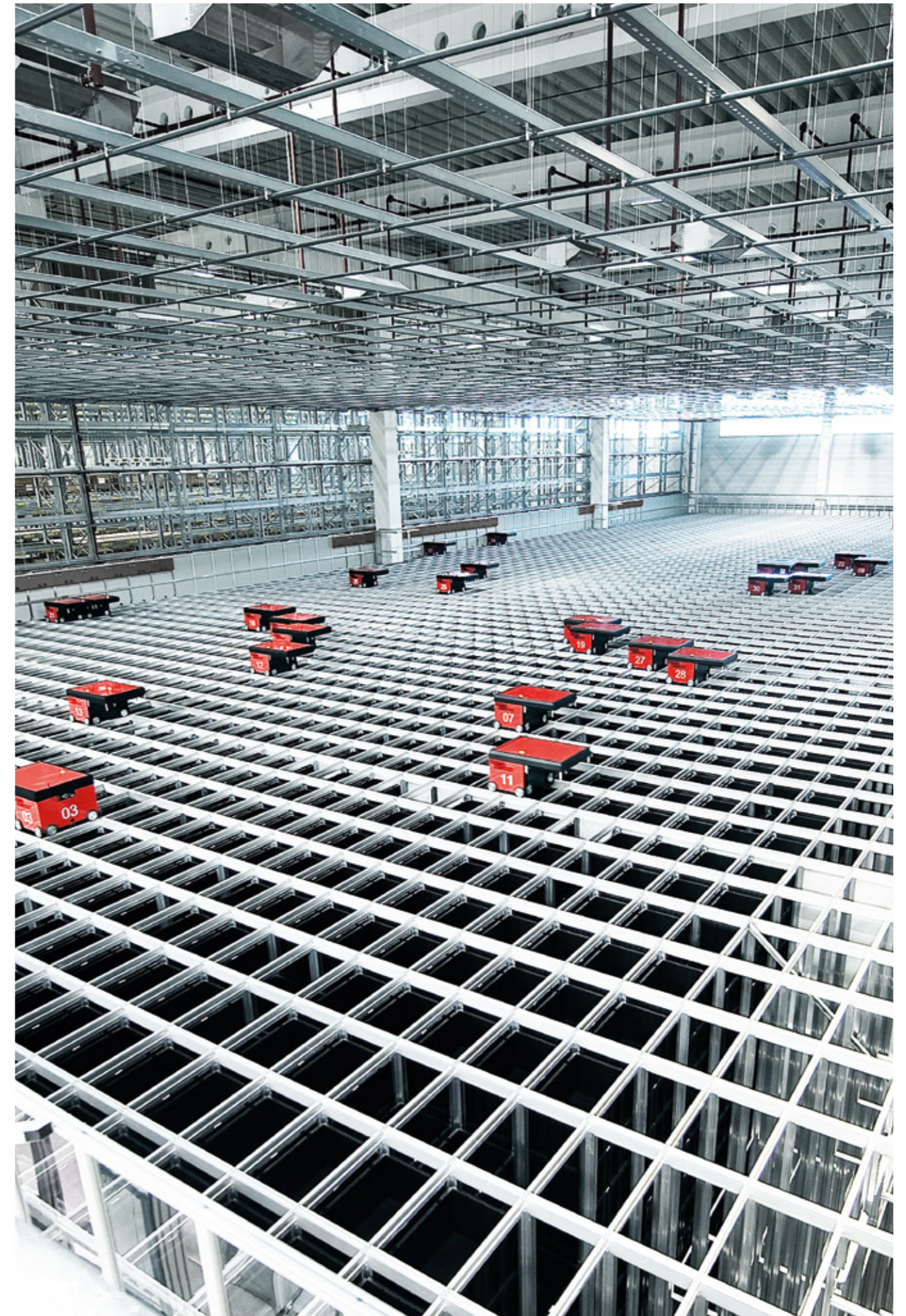
Whereas in the past purchase decisions were often primarily made on the basis of the lowest price, in the future it will be the product that is available most quickly and with a high level of customization that will be at the top of consumers' shopping lists. Customer orientation will increasingly become a deciding competitive factor for companies. In addition to the necessary flexibilization of production, this customer relationship will be heavily influenced by intelligent, fast and reliable logistics services – also from an economic point of view.

In this context, the significance of flexible stocks of goods and materials and the necessity of coordinating them along the entire value creation chain will increase. On the one hand, it will be necessary to ensure the reliability of supplies. On the other hand, there will be increasing pressure to avoid large warehouse inventories while still being able to deliver a wide range of goods and products quickly.

Companies have to rethink their entire approach: the industrial concept of “ever more of the same” will give way to the individual product – manufactured in small series and even batch size “one” by intelligent, universally deployable machines.

Thinking in industrial terms, this will entail new, more intelligent manufacturing, logistics and sales methods as well as structures that are already becoming possible with the integrated networking of production in smart factories. Short distances to the consumer will also be an important factor in achieving fast availability. Due to the high degree of automation in intelligent factories, production steps that are currently outsourced to low-wage countries for manual execution can be repatriated to high-wage countries. Irrespective of wage structures, intelligent automation allows cost-efficient and high-quality production in the vicinity of the consumers.

Due to the high degree of automation, production steps that are currently outsourced to low-wage countries can be repatriated to high-wage countries.





Dr. Christian Schlögel
CTO KUKA Group

—Establishing intelligent technologies

»What is called for here is no less than a sustainable transformation of our global perception of industrial production.«

The digital revolution is changing the world in ever shorter cycles. Even though we are currently only at the beginning of this development, it has already had a significant impact on our economy in the last decade, and it has radically changed some entire sectors. Companies that have failed to recognize the dynamics of the digital transformation and have held on to traditional business models and products have found themselves on the sidelines quicker than expected. Today, hardly anyone can remember the dominant brands of analog photography or the leading cell phone manufacturers at the turn of the millennium. They all became a footnote in history within the span of just a few years.

It took only eight years for smartphones to increase their market share from zero to almost 100 percent – young and new market players now determine how the world runs. It is quite evident that the digitization of our world brings with it enormous opportunities to benefit from these changes.

But this also harbors fundamental risks for all those who believe their business model or industry is not, or not yet, affected by the digital transformation.

And the pace is picking up. New technologies and the increasing fusion of IT and OT are shortening innovation cycles dramatically. Computing power is getting cheaper all the time and is now available virtualized in the cloud for just a few cents per hour. Open source models and components enable productivity in the software development sector on a scale that was previously unimaginable. The time span between digital fiction and reality in production is becoming increasingly shorter.

While the term “Industrie 4.0” was used in the context of a vision for the future just a few years ago, today it is obvious that we are already in the thick of the digital transformation with corobotics, autonomous mobile solutions, cloud and Edge Computing, and Big Data – and there is no way back.

New technologies and the increasing fusion of IT and OT are shortening innovation cycles dramatically.

The first shockwaves of the digital transformation are currently hitting the core industries of the leading industrial nations.

Innovative business models are threatening established market leaders and offering opportunities for those who have recognized and systematically exploited these new potentials. Whether we like it or not. It will not be the size or market position of a company that determines its future success, but rather its ability to quickly and flexibly adapt to constantly changing framework conditions.

As paradoxical as it may sound: digitization is both the cause and the key to the solution of the problem.

New technologies enable companies to work more efficiently and flexibly, while also accommodating customer wishes more quickly and intelligently. The factories of the future are not only about communication and collaboration between man & machine or machine & machine. These machines will also be capable of sharing knowledge, learning in swarms and autonomously adapting to various tasks. In an increasingly aging society, they will help us make up for the shortage of skilled workers by improving workplace ergonomics and acting as team players to assist and permanently relieve the human workers.

It was back in the 1990s that KUKA recognized the potential to be gained by combining IT with conventional automation technologies. The company was also the world's first robot manufacturer to develop open, interoperable and flexible systems on the basis of standardized mainstream technologies and to make them ready for the market. As a thought leader and global trailblazer for Industrie 4.0, it is therefore no wonder that KUKA is playing a decisive role in this shift towards networked, intelligent production. We see ourselves as an inte-

gral part of Industrie 4.0 and all its various aspects, and we are directly involved in the fourth industrial revolution with pioneering key technologies. With intelligent machines and new digital domains.

KUKA Intelligent Machines

Without even thinking about it, we routinely use smartphones, cloud services and the Internet. We rely on electronic assistants when parking vehicles and entrust them with tasks such as the energy management of houses or simple jobs like mowing the lawn. All these electronic assistants have one thing in common: they wouldn't even exist without robot-based automation technology. Not one of them can be manufactured purely manually. Robots are the most flexible and versatile machines that mankind has ever come up with.

This is why robots will remain at the very core of the digital supply chain in the long term. But their capabilities will undergo drastic changes – step by step, they will become intelligent machines, which:

- are constantly improving their ability to work directly with humans,
- master communication such as gesture or voice control,
- intuitively integrate into variable processes,
- operate in a mobile and autonomous manner, for example as AGVs or mobile robots,
- are capable of learning, share knowledge and act in swarms,
- become perceptive and are aware of their environment.

If we take a look at the future, it is already evident that robots will become smaller, more mobile, networked and cognitive. They will be increasingly able to act in an autonomous and task-oriented manner. Endowed with



smart skills, they will accompany us in every area of our daily lives and at all times. And they will permanently change the way we manufacture products, the way we work and the way we live.

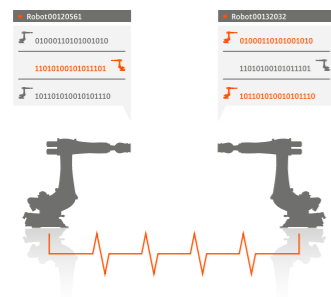
KUKA Digital Domains

When we talk about the future, the situation may sound paradoxical: in many areas of manufacturing, KUKA is already able to implement the networking of production and the digital world required by Industrie 4.0 – and has long since been creating automated production systems of this type worldwide. Until now, however, there has been one limitation: these highly efficient and flexible systems have always been specific individual solutions – self-contained systems that are individually adapted to specific customer requirements.

But that is changing: the progress of the deterministic Ethernet, based on the TSN standard in combination with the increasingly popular OPC-UA standard for machine-to-machine (M2M) communication is changing the OT structures in industry. The enormous potential and the significance of Industrie 4.0 in securing a company's own market position in a competitive world are being recognized to an increasing extent.

In addition to being an active driving force in the creation of these new standards, KUKA is also working on integrating the existing OT infrastructure into the new digital world of production. With edge computing as a consolidation hub currently waiting in the starting blocks, we will enable our customers to rethink the networking of machinery also in existing, heterogeneous IT landscapes and production environments. In this way, real-time edge computing opens up the potential to work with cloud architectures on the shop floor, providing a stepstone to cloud-based production.

The enormous potential and the significance of Industrie 4.0 in securing a company's own market position in a competitive world are being recognized to an increasing extent.



In the future, machines will also be capable of sharing knowledge, learning in swarms and autonomously adapting to various tasks.

If the machines are additionally combined with expanded sensor capabilities, the collection of sensor data will offer new opportunities for the intelligent use of the machinery or products. In the future, every machine and product will then have all the information required in the context of Industrie 4.0 at its disposal and will be able to process it in dynamic information networks:

- Identification (Who am I?)
- Location (Where am I?)
- Data storage (What do I know?)
- Computing power (What can I do?)
- Connectivity (Who can I communicate with?)

In Austin, Texas, USA, the heartland of Big Data and cloud computing, an experienced team at KUKA ATX is developing solutions based on cloud and edge computing that integrate KUKA products into the increasingly diverse landscape that is linked to the Internet. To create groundbreaking, intelligent and valuable new opportunities. But also to secure existing investments and transform them seamlessly into digital production with all its open standards.

At the same time, KUKA is a strong driving force in terms of smart platforms with its KUKA Connect solution.

The aim is to offer customers new “on-click” options through cloud-based software applications and services that allow them to leverage the existing infrastructure, i.e. logistics and production, to the next level of flexibility, efficiency and effectiveness.

A first step with which KUKA is demonstrating that the paradigm between OT and IT can be solved and that we are committed to offering our customers integrated solutions on the road to comprehensively networked digital production.

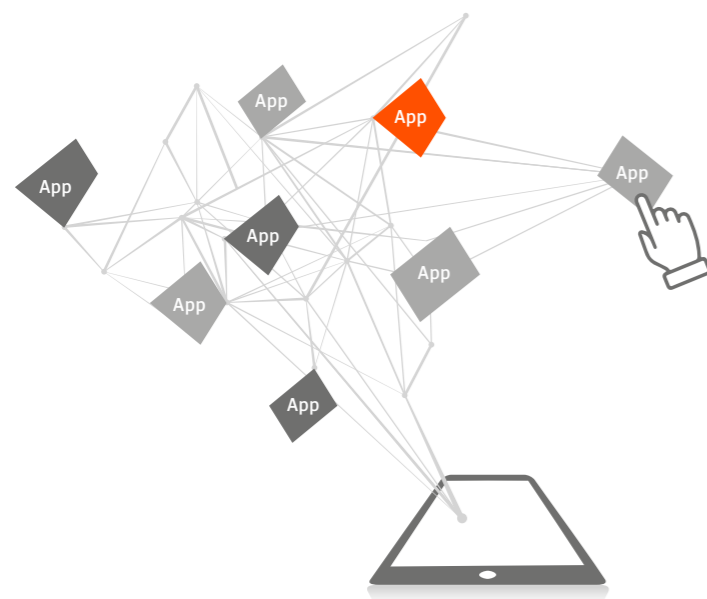
With groundbreaking intelligent products – for hardware and software.

For us, shaping the future of Industrie 4.0 means a clear commitment to a new world of Manufacturing Execution Systems, Logistic Execution Systems and cloud-based Engineering Suites. New tools that support a wide range of new approaches and business models in the digital supply chain. For instance, we fully expect that in the near future it will be possible to procure functions and applications via cloud services and marketplaces, or solutions and production capacity on demand through pay-per-use.

And KUKA will play a central role in this development. By intelligently merging expertise from the digital and real worlds.

This development is concentrated on applications in the fields of:

- Digital Asset Management
- Condition Based Monitoring
- Availability Management
- Maintenance Management
- Big Data Optimization
- Quality Management
- Predictive Maintenance



Establishing intelligent technologies

- KUKA Digital Domains
- The Internet of Robotics
- Real-time Edge Computing
- More intelligent machines
- Mobile robotics
- Mobility meets HRC
- Cobots in industry

KUKA Digital Domains

Building bridges between the worlds of OT and IT

Transcending all boundaries. The digital supply chain merges the major business processes of all parties involved – from the suppliers to the manufacturer and the end customer. With integrated networking, Industrie 4.0 will be able to overcome all current media discontinuity of the value chain. The primary potential lies in the acceleration and flexibilization of production and logistics processes, the reduced effort for data acquisition, and the optimization of data security and consistency. In addition to the main issues of Big Data, Security, HRC and Mobility, the Cloud plays a decisive role in every conceivable Industrie 4.0 scenario as a connection layer for horizontal and vertical integration.

The finished result will connect operational technologies such as robots, AGVs or logistics machines to the cloud, the web, mobile technologies and other modern IT infrastructures.



In practice, however, it is evident that the approach to Industrie 4.0 is defined by paradigms that differ greatly between Operational Technology (OT), the specialists from industry and Information Technology (IT), e.g. ERP and MES providers.

If Industrie 4.0 is to be successfully deployed in practice, it needs to be understood that OT is obviously not the same as IT. There are different approaches, different requirements and often even a different language. Let's take the German word "Sicherheit" as an example: in English, there is a clear distinction between "safety" in OT and "security" in IT. But in German, one and the same word describes two completely different requirements:

In the production world of OT, the term "Sicherheit" covers the full spectrum that starts with ensuring the availability and reliability of production systems and ends with the safety of the production environment for man and machine. Even though a tendency to rethink the issue is surfacing in industry, efficiency and safety in this context are very often represented by specific, closed systems individually adapted to the relevant customer requirements.

In an IT environment, "Sicherheit" in the sense of security generally pertains to the assurance of confidentiality, integrity and availability through targeted access control to data. And this in a world that is increasingly characterized by open standards and a high degree of system interoperability.

As a first mover, KUKA recognized these issues as far back as the 1990s and developed open, interoperable and modular systems based on standardized mainstream technologies, effectively initiating the convergence of IT and conventional automation technology.

For the smart factory of the future, KUKA therefore already has modular software architectures in its portfolio, prepared for the entire evolutionary process of Industrie 4.0. With products where all building blocks fit together and each individual one is agile enough to dock proactively onto the IT landscapes or standards of future production environments or to integrate them seamlessly. A groundbreaking concept and a solid base from which we can take a further important step. With KUKA Connect, Nebbiolo Technologies and Edge Computing, also known as Fog Computing, we are creating system-relevant layers and cloud platforms in order to seamlessly bridge the gap between proprietary OT in production and standardized data formats and new protocols in business and cloud IT.

The finished result will connect operational technologies such as robots, AGVs or logistics machines to the cloud, the web, mobile technologies and other modern IT infrastructures. We want to offer our customers real added value by supplementing our portfolio with tools for improved support, service, provisioning, deployment, installation and proactive maintenance.

And to make these as user-friendly and efficient as possible.



David Fuller
Chief Service Robotics Strategy and R&D Officer
KUKA Systems North America

The Internet of Robotics

Which was just a vision yesterday, now has a name: KUKA Connect.

KUKA is working to deliver a modular and digital software platform, KUKA Connect. Through easily implemented app-based software expansions, such as asset management and condition monitoring, we will be able to increase the intelligence of our robot systems throughout their entire lifecycle.

Step by step, KUKA Connect – controlled via a uniform user interface – exploits the full potential of combining comprehensive production data, novel manufacturing processes, flexible networking and responsive components. At the same time, KUKA Connect makes the digitization of manufacturing processes significantly easier through the intelligent integration of the latest technologies in electronics, mobile devices, mobility systems and communications infrastructure.

Given the rapid advancement in technology and the increased expectations and desires of consumers, manufacturers need to be able to incorporate new design processes while permanently improving their production performance and effectiveness at the same time. KUKA Connect is the first step towards establishing a simple and seamless link between Operational Technology (OT) and Informational Technologies (IT).



Through the unified software framework provided by KUKA Connect, KUKA robots are now able to leverage various services and applications through a single platform. KUKA Connect provides the opportunity to leverage Big Data analytics and cloud computing to predict and sustainably increase the productivity, quality and flexibility of manufacturing.

The KUKA Connect platform not only offers access to the machine data, but also has the intelligence to create meaningful representations, histories and statistics. KUKA Connect supports leading cloud, web and mobile technologies while providing a universal backbone to exchange all the data and information horizontally across various KUKA robot-based automation processes and solutions, connecting robots, people and services.

The most important economic benefits of the new KUKA Connect cloud platform at a glance:

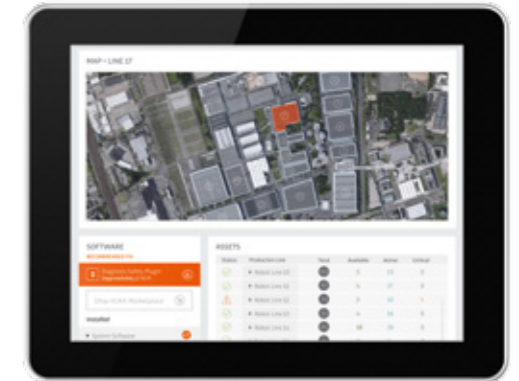
- Sustainably increase productivity
- Permanently decrease total cost of ownership
- Support the full lifecycle of robots across various applications

Built using open global standards, KUKA Connect is Big Data ready and enables integrators and partners to expand the platform with their own applications, services and add-ons. This provides customers with further added value in a wide variety of sectors – from automotive and aerospace to consumer electronics and general industry.

Designed for maximum freedom in the application, KUKA Connect is platform-agnostic and vertically scalable. Based on the newest back-end architectures, KUKA Connect enables a fast-reacting and easily operated web user interface that requires absolutely zero software to be installed and can be run on any device.

KUKA Connect is the gateway into a world of endless possibilities to increase KUKA robot efficiency in diverse areas:

- **Operation:** production optimization
- **Maintenance:** robot condition monitoring, maintenance planning and schedule, anomaly detection and predictive maintenance
- **Service:** remote management, field services, spare parts management and knowledge-based services
- **Resources:** energy optimization and management
- **Data:** static robot data and dynamic operating data



Real-time Edge Computing

Open connections beyond the cloud

Information Technology (IT) has made immense progress in recent years, particularly in regard to IoT, cloud computing and Industrie 4.0. For example, networking and security concepts have been redefined, with the introduction of Software Defined Networking (SDN), the evolution of cloud computing and virtualization, and rapid advances in data management, analytics and Big Data. In the meantime, industrial embedded systems and Operational Technologies (OT) have in many ways remained separate or even isolated. OT systems are still mostly based on specific and at times antiquated network protocols that are primarily geared towards local vertical networking. While it is true that Ethernet is gaining significance as the basic protocol for OT, it is often associated with non-standard modifications. The OT world has also not broadly adopted current wireless technologies.

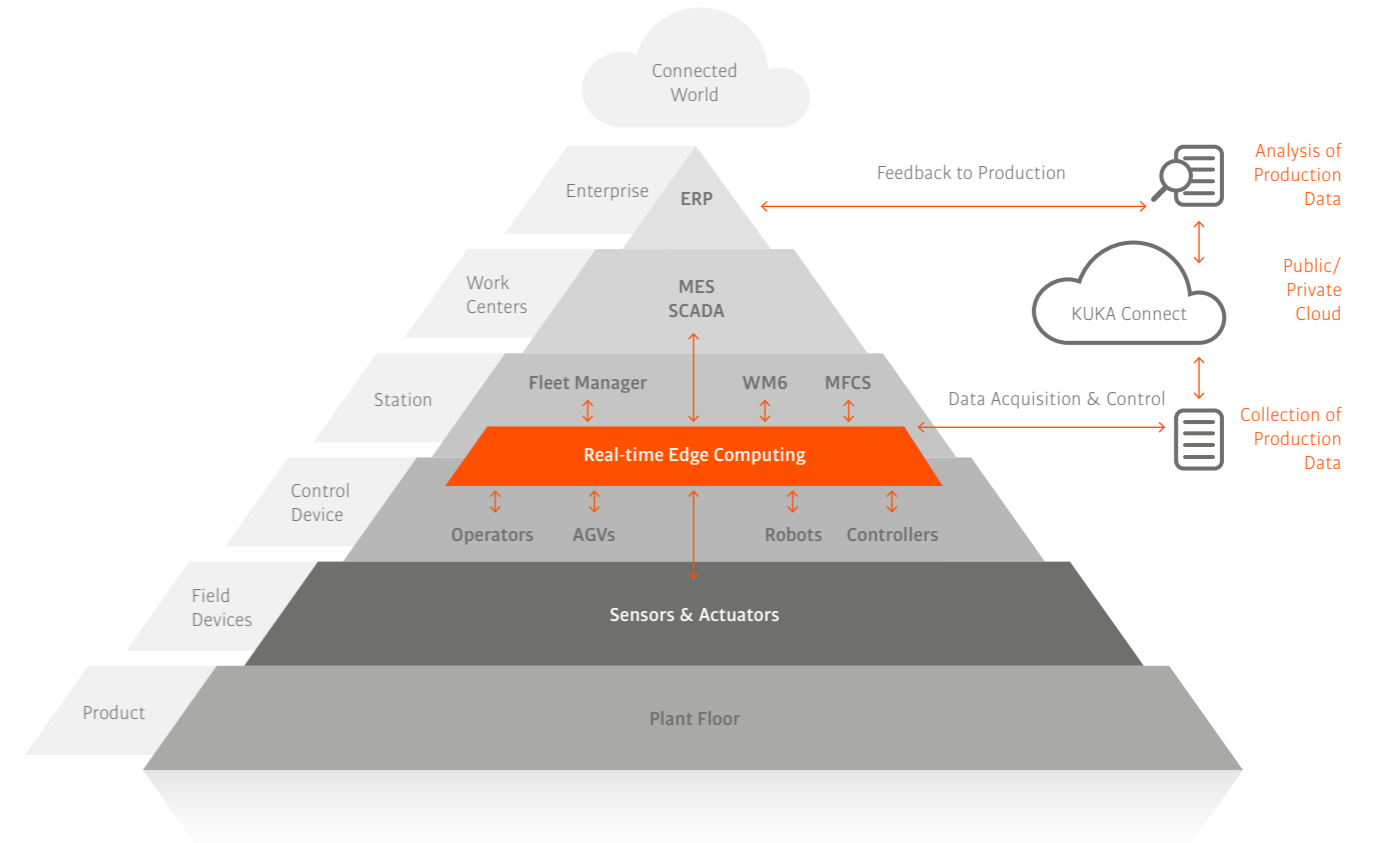
When integrating existing industrial automation systems into an intelligent and seamlessly networked production chain, we will almost always encounter one or more of the following challenges:

- The need to integrate proprietary network protocols.
- The necessity of restoring security when interfacing production systems.
- The rectification of limited data interoperability between the OT and IT functional layers.
- The incorporation of highly specialized and non-scalable computing and storage architectures.
- The use of vendor-specific programming languages at the control level.
- The rare application of modern best practices for the IT sector.
- The weak visibility into process metrics and non-optimal operational efficiency in terms of costs and flexibility.

As insurmountable as these barriers seem at first, they also lay bare the gigantic potential for optimization and flexibilization of the production processes.

Real-time edge computing

As a mediator positioned at the interface between OT and IT, real-time edge computing also known as fog computing is key to seamlessly converging these heterogeneous worlds. On the one hand, real-time edge computing is based on some of the technologies characterizing cloud computing, but with the pivotal difference that they are applied to compact and embedded computing systems. Such technologies include the virtualization of all resources, the automation of resource management, application lifecycle management and fully software-defined networking approaches.



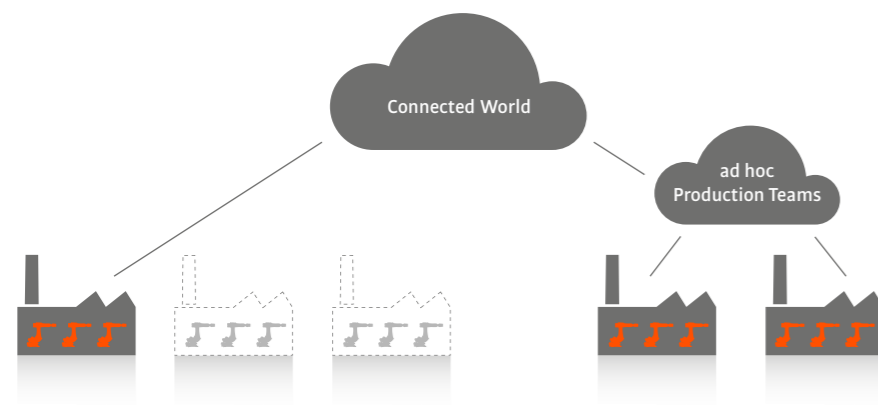
On the other hand, real-time edge computing is also able to effectively break through the “constraints of the cloud” by integrating the following functions:

- Hard real-time and deterministic behavior.
- Direct support of a wide set of networking technologies, including wireless and sensor networking, as well as legacy fieldbus networking typical of OT deployments.
- Support for interoperability with non-homogeneous data sources, and compact, streaming data analytics with real-time capability, along with networking, system and physical security and safety.

Through the close collaboration between KUKA Robotics, TTEch and Nebbiolo Technologies, we are now able to implement the perfect fusion of modern information technology and existing production infrastructure by means of real-time edge computing. Barrier-free networked digital production environments that allow both scalable computing power at the “edge of the network” and the complete virtualization of resources. Supporting real-time and non real-time computing. OT architectures that feature not only advanced networking and security but also modern middleware for data interoperability (including OPC UA), enabling edge storage and analytics. An architecture with which a high degree of convergence, unification and standardization can be achieved in terms of networking, security, data, computing and control – at a manageable cost.

The goal is to achieve an ideal link between modern information technology and existing production infrastructure.

For the task at hand, specific services will be retrieved from the cloud or individual robots networked on an ad hoc basis to form temporary production teams.



More intelligent machines

Because digitization needs a counterpart in the real world.

The new digital world is fast. Everyone talks to everyone else across all borders. We have to work on the assumption that Industrie 4.0 will have the same disruptive consequences for industrial production as Facebook, WhatsApp and other social media have had for interpersonal communication. In a similar way, the digital supply chain merges the major business processes of all parties involved – from the suppliers to the manufacturer and the end customer. From the perspective of manufacturers, the potential of a digitized value creation chain lies primarily in the acceleration of production and logistics processes, the reduction of effort for data acquisition and the optimization of data security and consistency. Against this backdrop, companies today are already making use of digital value chains to optimize individual production islands and processes within their organization. But does this really tap the full potential of Industrie 4.0? Probably not.

It is far more likely that in the factory of the future, the focus of thought and action will shift more to the human worker with his individual requirements, desires and capabilities. This applies equally in his role as consumer and as sought-after employee.

Whereas until now the primary focus was on mass production at the lowest possible unit costs, the industrial production of the future will be characterized by high-quality, highly customized products. At the same time, the increasing overaging of society in the industrial nations will force us to keep older, experienced employees in the workplace for longer. Just as a smartphone is simple and intuitive to operate, so too will we have to ensure that even highly complex machines such as robots can be configured, controlled and operated by employees intuitively and without special knowledge.

Industrie 4.0 ready

If we take a closer look at this upheaval, we see that it is actually a combination of several technological revolutions that are occurring almost simultaneously. Undisputed here is the role of digitization, which enables us to network production processes in a fully new dimension and to augment them with new knowledge and capabilities. In the real world, this digital revolution is coinciding with the next generation of intelligent machines. The optical appearance of some has hardly changed. At first glance they look like normal industrial robots, but they are now endowed with all the capabilities that characterize cyber-physical systems in the Internet of Things.

Others have acquired additional intelligence that enables them to save energy, control their motions with even greater precision, learn new functions more easily, and much more besides. KUKA quite simply calls robots with these capabilities: "Industrie 4.0 ready".

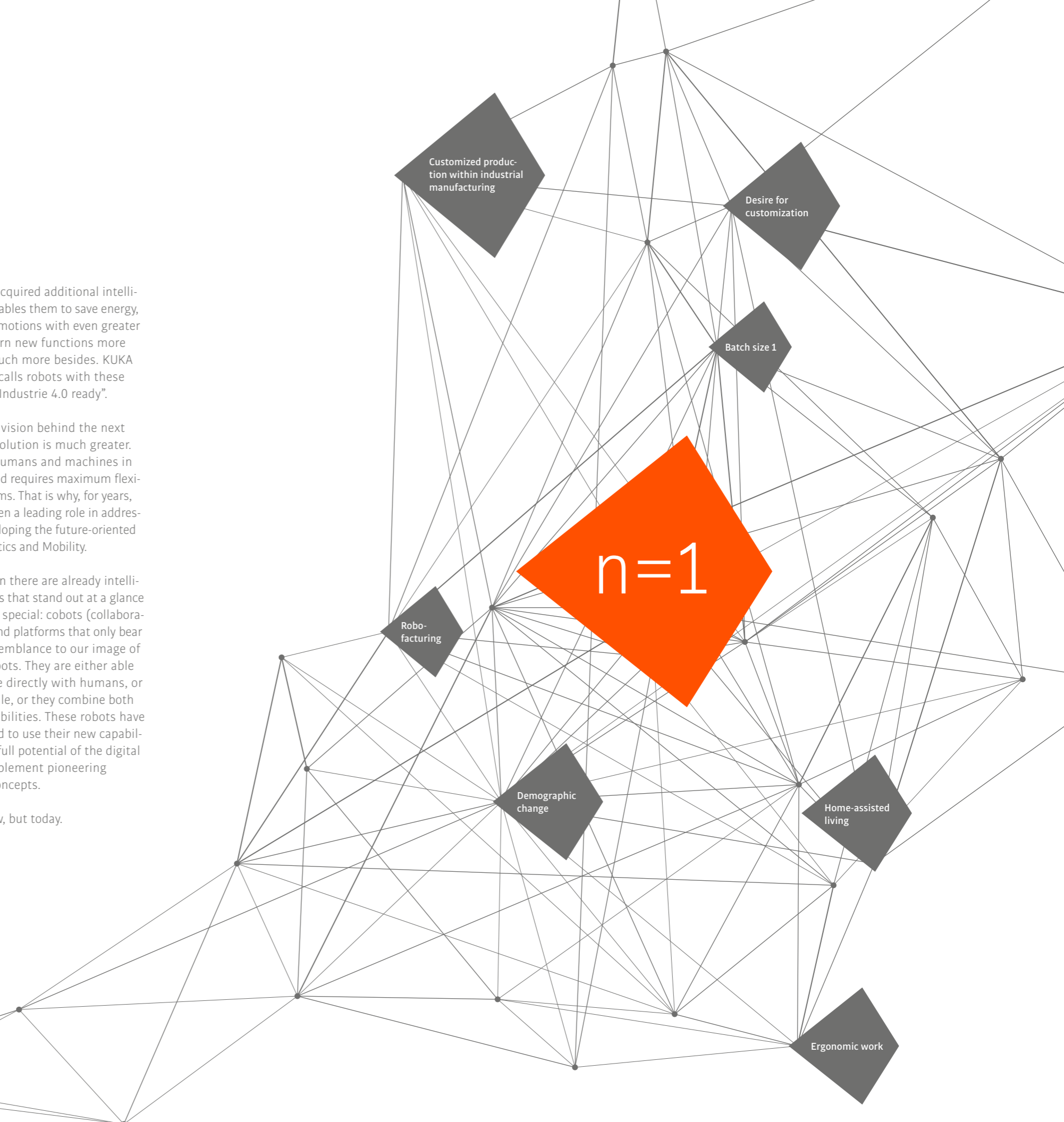
However, the vision behind the next industrial revolution is much greater. It networks humans and machines in production and requires maximum flexibility of systems. That is why, for years, KUKA has taken a leading role in addressing and developing the future-oriented fields of Cobotics and Mobility.

For this reason there are already intelligent machines that stand out at a glance as something special: cobots (collaborative robots) and platforms that only bear a passing resemblance to our image of industrial robots. They are either able to collaborate directly with humans, or they are mobile, or they combine both of these capabilities. These robots have been designed to use their new capabilities and the full potential of the digital factory to implement pioneering production concepts.

Not tomorrow, but today.



Industrie 4.0 is creating the basis for implementing the highest levels of customization – all the way down to batch size 1 – within industrial manufacturing.



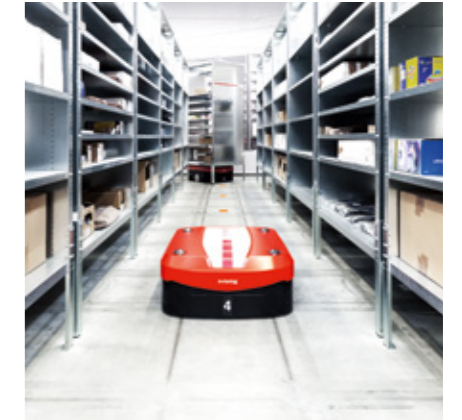


Mobile robotics

Freedom of movement
in every order of magnitude



Mobile robotics for the precision machining of XXL components.



Designed to be modular and multi-functional, CarryPick from Swisslog consists of mobile racks and automated guided vehicles for goods-to-person picking.

In the cyber-physical production world of IoT and Industrie 4.0, established structures are becoming a thing of the past. Machines and workpieces will autonomously adapt the production sequence to current constraints. In the case of production bottlenecks, they will independently divert to other production islands and actively request new tools, materials or modules. Static production lines that transport goods from A to B will be the exception rather than the norm in this world. Intelligent, mobile units acting in swarms and finding their destinations autonomously will be used instead of conveyor belts and herald the next evolutionary step in the flexibilization of industrial production with fully new concepts for moving products, workpieces or entire production units, or repositioning them in different locations. One example is robots on mobile platforms that can move autonomously in order to transport things or to machine workpieces. If necessary, finding their own way around – without floor markings, induction loops or magnets. They align themselves with the workpiece with millimeter precision. Alternatively, they turn customary sequences upside

down: for example the robot moves to the workpiece, rather than the other way round – or large workpieces are stationary and the machining robot moves freely around the object. Mobile automation solutions from KUKA show today what the future holds in store for highly flexible, digitally networked production.

KMP omniMove

The KMP omniMove permits unrestricted maneuverability in every direction and rotation about its own axis. The vehicle can be navigated freely via its omnidirectional wheels, without reorienting the wheels, and steered by remote control in any direction, even in the tightest of spaces. The logistics area required is up to 50 percent less than for conventionally-steered wheels and a larger production area can be used. KUKA omniMove vehicles for internal logistics effortlessly lift payloads of up to 100 tonnes and, with ten different vehicle variants, offer numerous customer-specific options packages to cover a wide range of requirements, including autonomous navigation and fleet management.

Mobility meets HRC.

How robots are opening up new doors.

They can move, feel, collaborate with humans, tend machines, transport materials and tools, and much more besides. Mobile robots are able not only to react intelligently to their surroundings, but also to change their place of use. The KUKA spectrum ranges from lightweight robots that can be moved manually to fully self-navigating systems, such as the KMR iiwa. Their ability to interact with people, machines or workpieces in a location-independent manner means that the application potential of this new generation of mobile robotics is virtually boundless. Essentially, there are as many potential applications as there are ideas for such applications. Mobile robots can already perform logistics tasks independently, collaborate directly with humans or quickly take on new tasks at different workstations. Even deployment in offices or service departments is conceivable.

Mobile robots suitable for industrial applications are breaking down the existing boundaries for robotics in the production environment. These machines are equipped with SLAM navigation, dispensing entirely with the need for static floor markings, induction loops and magnets for defining the paths. They can independently draft maps of their surroundings and also share this knowledge with other units in the fleet. Anything that has been located by one unit in the swarm is instantly available to every other unit. This results in a universally networked, shared "motion and route plan" that allows the coordinated execution of all robot motions. If the production environment in the factory or shop changes, the mobile robots can be adapted to the new situation in the shortest possible time.

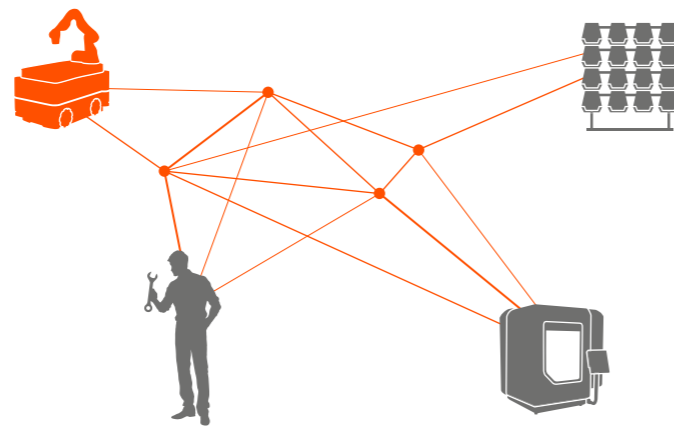


KUKA flexFELLOW
The ideal combinability of manual and automatic tasks means that production can be optimally adapted to the required capacity utilization.



KUKA Mobile Robotics iiwa
The combination of mobile platform and intelligent, sensitive work assistant opens up a wide range of potential applications.

Rack storage
Thanks to its innovative navigation system, the KMR iiwa operates autonomously and is able, for example, to set down machined workpieces or independently fetch required components.



Operator
The operator is relieved of monotonous, non-ergonomic tasks and can concentrate on important processing steps.

Machine tool
The KMR iiwa takes over the tending of machine tools and relieves the human worker of strenuous and tiring tasks.

Cobots in industry

Machines expand capabilities of humans.



EN ISO 13849
The safety functions of the LBR iiwa meet the requirements of Performance Level “d” with structure category 3. This enables safe human-robot collaboration.

With the LBR iiwa in 2014, KUKA laid the foundation for an entirely new relationship between humans and robots in industrial environments: direct and safe collaboration – without any safety enclosure. As a component of the smart factory, the LBR iiwa is able to learn from its human colleagues thanks to its sensitive technology. Connected to the cloud, it can autonomously check, optimize and document the results of its work. The feedback provided by the robot to the networked factory ensures maximum transparency and highly flexible coordination within the production processes.

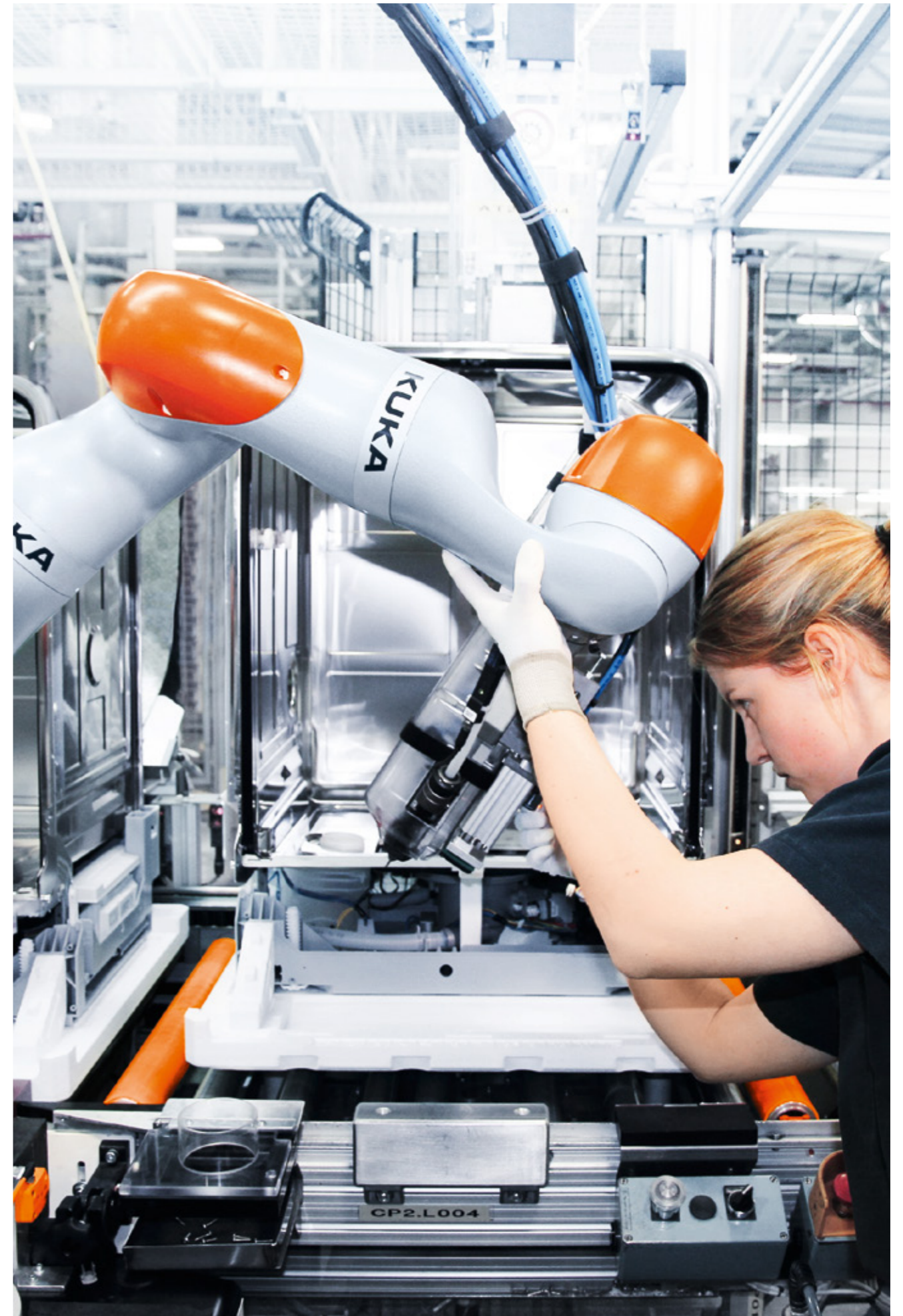
Even today, human-robot collaboration still seems like a vision of the future to many. This is despite the fact that intelligent cobots such as the LBR iiwa have long since begun to automate entirely new areas: with their sensitive capabilities they assemble transmissions, insert plugs and tend machines and logistics systems. They are able to detect work-piece positioning tolerances, work with non-rigid parts, open doors on machines, recognize component types and perform an infinite number of other tasks. In the context of this robot class, the term “universally applicable” needs redefining. The range of possible applications in the factory of the future is virtually infinite. Cobots currently working in industry prove one thing:

collaboration between humans and robots works – even in the harsh environment of day-to-day production.

This is also necessary: in a time of technological transformation towards digitized production, characterized by ever shorter product cycles in manufacturing and ever greater diversity of variants, the challenges facing the production of the future are enormous. This applies in equal measure to human workers and robots. Genuine teamwork between human and machine opens up an opportunity to support the worker, make his work easier and extend his human capabilities in the long term.

LBR iiwa

With the LBR iiwa, the cobot for industry, a service-proven, universally applicable robotic colleague is now available. Moreover, it proves that the visions of Industrie 4.0 can be implemented in reality. Robots are already working hand in hand with humans and expanding their range of capabilities, enabling them to work more efficiently and ergonomically, and with greater precision and concentration.





Larry Drake
CEO KUKA Systems North America

– Implementing networked production

»Ultimately, what will be of decisive importance is the ability to adapt the new possibilities of our digital world to the real requirements of manufacturing.«

Highly dynamic and flexible factories with fully networked systems and access to the cloud will, without a doubt, form the backbone of our global digital society. Whether this development towards the IoT and Industrie 4.0 is driven by the transformation of society or by technological progress in robotics and artificial intelligence, Big Data and the definition of new standards – it is advancing at breathtaking speed in all dimensions.

In this time of upheaval, it is important to address the decisive technical and corporate challenges in order to safeguard existing competitive advantages and to create new ones. In the context of digitization, what companies are expecting above all is advantages that can be calculated directly: lower procurement costs, higher productivity and increased market share.

In actual fact, however, these points only cover part of the challenges. In the future, many markets will be characterized to a previously unimagined extent

by extremely fast technical innovation cycles and integration of the customer into the configuration or individualization of the products. Already now, in the electronics market, no-one is interested in last year's technical highlight. At the same time, with e-mobility, intelligent vehicles and new business models, such as car-sharing and Uber, the automotive industry is undergoing a radical transformation in all areas. This list could easily be extended to other branches of industry.

For our customers, accommodating these shifting paradigms competitively and cost-effectively in production will mean extremely high requirements on the flexibility and efficiency of their processes in the future. The important thing is that the opportunities arising from intelligent production networking are sensibly implemented in the real manufacturing process. This means that both the economic and manufacturing aspects must be fully taken into account.

In the context of digitization, what companies are expecting above all is advantages that can be calculated directly: lower procurement costs, higher productivity and increased market share.

KUKA has extensive expertise and innovative prowess in both worlds – the digital and real production worlds. In concrete terms: based on our many years of process expertise, we not only know what our customers need, but also precisely how these technologies and processes are implemented and how they are used in practice for manufacturing. We are one of the very few companies in the world that are able to offer customers comprehensive support in every area along the road leading to Industrie 4.0. It does not matter how far along this road a company is or what speed of transformation is conducive to value creation in its specific environment or branch of industry. As an experienced industrial partner, we become involved in the production processes as early as the development phase, thereby enabling optimal utilization of the entire potential of intelligent, networked automation solutions – throughout the entire manufacturing process. We are aided here not only by our leading role as driver and thought leader in the development of key technologies for Industrie 4.0, but also by our in-depth knowledge of

how a wide range of different processes and technologies are used in production. These include spot welding, arc welding, laser welding and laser cutting, adhesive bonding, sealing, drilling, milling, deburring, assembly, inspection and many others besides.

Our history as a pioneer in industrial production stretches back well over 50 years – with milestones such as the invention of the first 6-axis industrial robot in 1976 and, more recently, the first series-produced sensitive industrial robot: the LBR iiwa. Throughout this history, we have always been characterized by our readiness to overcome existing boundaries in the pursuit of progress.

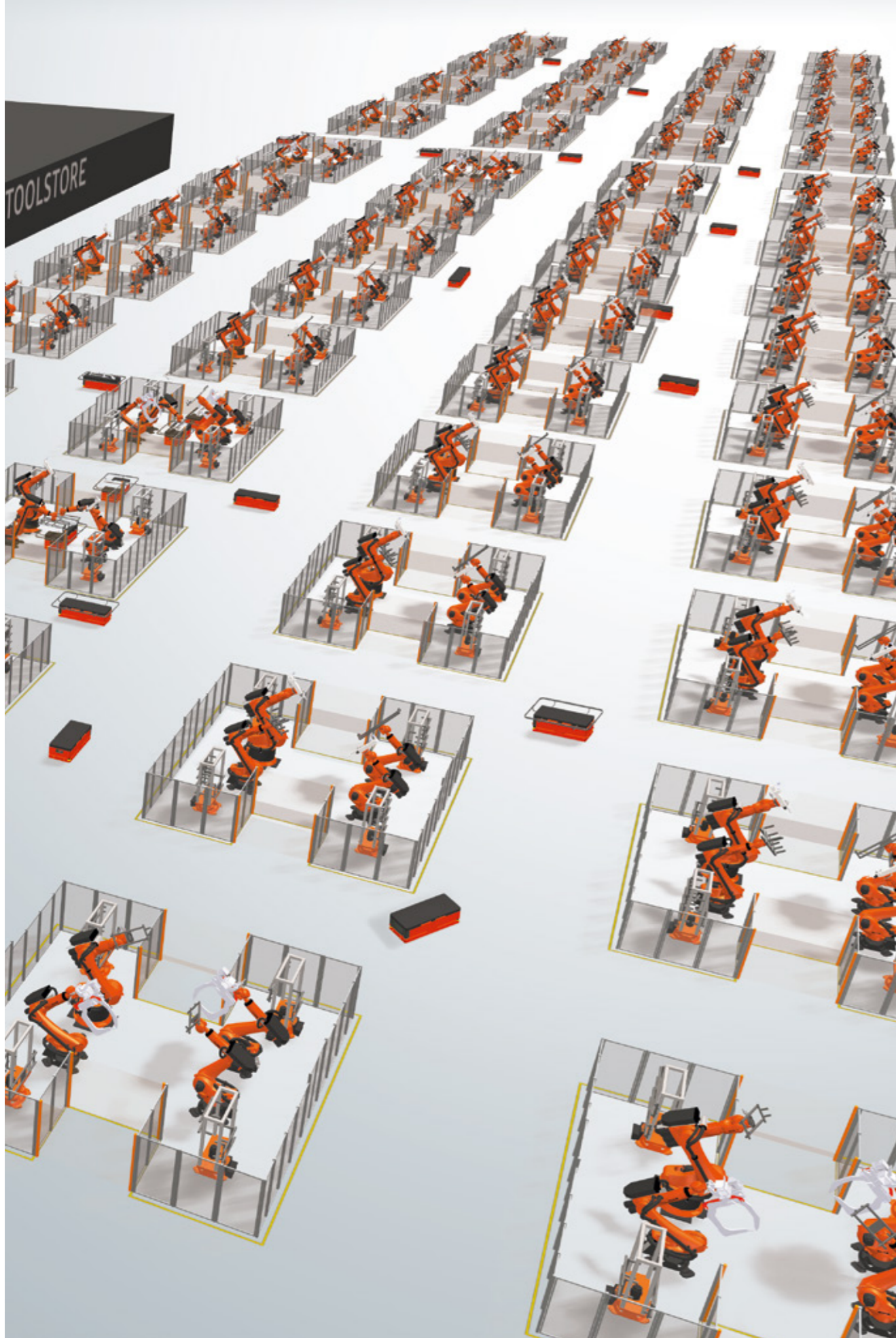
We ultimately create pioneering production solutions together with our customers. Intelligent production worlds that demonstrate that Industrie 4.0 has already started to become reality.



Companies today are already making use of digital value creation chains to optimize individual production islands and processes within their organization. In the factory of tomorrow, the digital supply chain will also encompass global procedures across company boundaries, controlling them largely autonomously.

Implementing networked production

- Matrix production
- Greater dynamism due to self-organizing value chains
- KUKA Toledo Production Operations: harnessing the power of IoT for Jeep® Wrangler
- ASM Assembly Systems: intelligent human-robot collaboration in the electronics industry
- From science fiction to reality

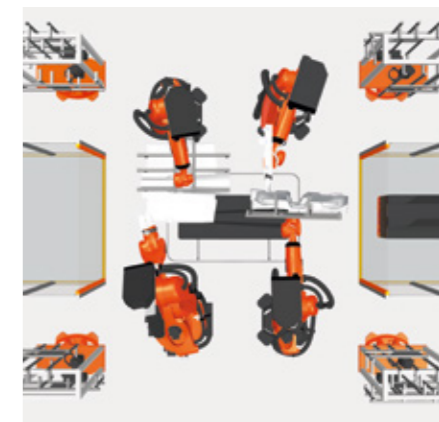


Matrix production

Highly flexible production is becoming reality.

Economic, social, technological and ecological megatrends such as globalization, urbanization, digitization and sustainability are radically changing the industrial landscape of the future. This poses new challenges for manufacturing industry. Industry is responding to these processes of change and to the increasing competitive pressure with shorter product cycles and a more differentiated product portfolio.

Versatile solutions are required to cushion workload peaks and resource bottlenecks in the age of Industrie 4.0. Matrix production may become a decisive competitive factor through configurable production cells, the transfer of parts and tools using automated guided vehicles (AGVs) and the separation of logistics from production.



The production cell for easy conversion.
Four robots handle and join the parts. Tool magazines in the cells enable provision of the required tools. This enables adaptation of the cell during the cycle time.

_Matrix production

Increasing customization is changing production. Volatile markets are making the cost-effective production of small batch sizes ever more important. Increasingly, the challenge is to produce an ever greater number of different variants and models of a product in variable quantities – one example being the increased degree of customization in the automotive industry. In the future, the matrix production concept will enable extremely versatile production on an industrial scale and networked throughout the entire process chain. The system can automatically convert itself “on the fly” to changing product types. This is achieved without wait times and without lost production time. It will thus become possible to implement the manufacture of highly customized series without limitations in the context of industrial mass production.

Matrix production is based on categorized, standardized production cells that can be arranged in virtually any number in a grid layout. All cells are equipped with process-neutral equipment and product-specific basic functions. Inside the cells, there are turntables for the setdown of parts, tool locations and robots which perform the relevant process. These production cells can be individually expanded with process-specific equipment. Welding, adhesive bonding, punching, brazing and clinching: virtually any process can be integrated.

Workpieces and tools are transported by automated guided vehicles (AGVs), which navigate to the individual cells using a SLAM navigation algorithm. A robot picks up the workpieces on arrival in the cell. These workpieces are then machined using intelligent robotic applications, such as jigless bodyshop technology. One robot holds one part while the second robot holds the other part. Both parts are locked together to form a unit which is then welded by the third robot – the so-called process robot. The workpieces are stored in the warehouse. The dedicated tools, on the other hand, are located in the tool store.

The autonomously navigating AGVs can pick up and transport the different workpieces and tools using individually configurable load handling attachments. Logistics processes and production are separated from one another in matrix production. This concept means that with variable parts logistics the system is always able to respond flexibly to peaks and to divert to other cells, involve additional cells or remove cells from the process. The value chain is not interrupted because the logistics processes are logically linked to production by means of software.

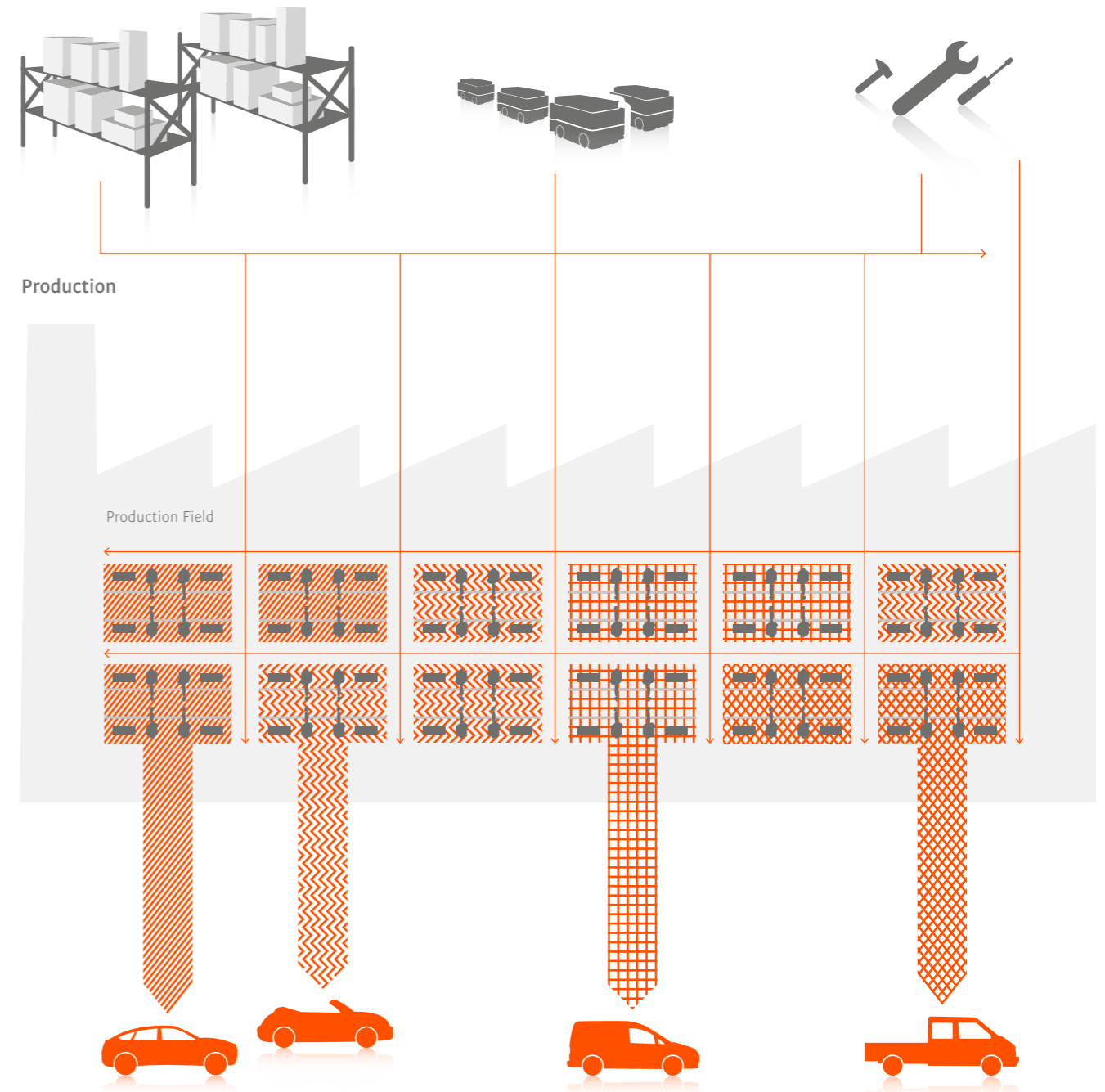
With the concept of highly flexible matrix production, KUKA is systematically fulfilling the requirements of Industrie 4.0 in industrial manufacturing.

Logistics

All components relevant for production are stored in the warehouse. They are fetched by AGVs and transported to the production cell.

The AGV pool is, so to speak, the parking garage of the production facility. All automated guided vehicles wait here until they are required. Workpieces and tools are transported to the basic cells by AGVs, which navigate to the individual cells using a navigation algorithm.

The dedicated tools and process equipment are located in the tool store. They are transported by AGVs to the cell in which the technology, tool or production equipment is required.





Greater dynamism due to self-organizing value chains

The logistics and distribution center of a European retail chain

Now more than ever before, modern industrial and commercial enterprises are dependent on highly automated and dynamic logistics processes. As long as the flows of goods and data are kept separate, however, the increase in efficiency is subject to natural limits. To overcome these, the KUKA Group's logistics expert, Swisslog, is pursuing a clear goal: the systematic fusion of all physical goods transport processes with digital information streams in order to fulfill the preconditions for self-organizing value chains.

For example, one of Europe's most modern logistics and distribution centers has been set up over the past two years. From the summer of 2016 onwards, a European retail chain will be supplying about 1,000 branches and numerous online shops around Europe from its extremely efficient omnichannel warehouse.



CycloneCarrier:
reliable shuttle system
for the highly
dynamic storage
of small parts.

_Intralogistics in a European company



The key to unlocking the world of self-controlling processes is data streams that are made intelligently usable. With a wide range of state-of-the-art automation components for pallets, hanging goods and small parts, a European retail chain is already optimally equipped to achieve this goal. The lynchpin of the modern logistics solutions is Swisslog's own warehouse management and control software. It forms the intelligent link between the high-bay and small parts warehouses, the AutoStore system comprising 80 robotic vehicles, the lifting and conveyor components as well as the cross-belt sorting system and the customer's merchandise management system (ERP).

The digital process chain can provide all information about the physical goods movements in real time. The warehouse management system is in constant communication with the merchandise management system. It is possible to check, for example, that all goods ordered via online shops or by the branches are actually in stock at the time of ordering. If there is a risk of stock shortages, the European fashion retailer can respond quickly, for instance by removing the missing items without delay from the list of available articles.

Already today, a large proportion of Swisslog logistics components in the system are equipped with autonomous control and drive units. In the sense of a cyber-physical system, they can be used at any time in the decentrally organized network structures of future IoT worlds.

This Industrie 4.0 approach is based on direct peer-to-peer communication between individual warehouse components. Rack feeders that use artificial intelligence to exchange information about the current location and destination of a transport unit eliminate the delays that resulted until now from communication with the central control unit. Theoretically, individual components of the overall Swisslog system are capable of independently implementing measures to optimize entire logistics processes. An important start has already been made: the combination of high-performance data warehouse technologies and intelligent algorithms for data evaluation already offers Swisslog customers the opportunity to make use of performance-oriented value-added services such as condition monitoring. The condition monitoring tool is an integral modular component of the Swisslog system.

It provides a real-time overview of energy consumption and overall warehouse performance – and warns the service technicians of impending critical states in the system.

The prediction of faults – long before they actually occur – is the next step addressed by Swisslog with an optimization solution. The "Crystal Ball" solution focuses on long-term analyses of the data. This enables system operation with fully automatic performance optimization.

The CycloneCarrier was designed for sectors where high throughput rates and excellent availability are essential.



Harnessing the power of IoT for Jeep® Wrangler KUKA Toledo Production Operations

KUKA already reached the first milestones in the digital supply chain a decade ago. In 2006, a new body-in-white plant was built for Jeep® Wrangler body shells. This manufacturing solution, consisting of highly networked systems and architectures, was ahead of its time in every respect. Until then, the efficient production of large numbers of units and a wide range of models and variants on the same production line had always been considered impossible.

KUKA Toledo Production Operations, or “KTPO” for short, proved the contrary. This plant, which was pioneering in terms of networking and process control, enabled a quantum leap in productivity – combined with unprecedented flexibility.



KTPO is one of four production facilities that are grouped together at the Toledo Supplier Park, an operator model that remains unparalleled in North America.



_Harnessing the power of IoT for Jeep® Wrangler

A vehicle body – of whatever model and whatever version – comes off the production line every 77 seconds. Every day. Reliably, for the last ten years. To achieve this, KUKA linked the plant's 259 robots and 60,000 other devices with powerful back-end monitoring systems and a master data management system. This was essentially the development of "IoT in a Box" which has evolved dynamically and continuously ever since.

For years, the plant has been one of the most efficient body-in-white lines in the US automotive industry. So far, at a rate of nearly one a minute, around one and a half million bodies-in-white for the Jeep® Wrangler have rolled off the line – the same line, that is, irrespective of whether they are for the classic two-door model or for the four-door "Unlimited" series.

The Jeep® Wrangler is a success story – in terms of both production and demand. In order to keep up effortlessly with the increasing production figures, KTPO made use of an intelligent control system to enable non-stop output of body shells in two-shift operation.

"KTPO reliably produces top-quality vehicle bodies," emphasizes KTPO Managing Director Jake Ladouceur. The operator model at KTPO is also pioneering. In the four production facilities at the "Toledo Supplier Park", several suppliers take on responsibility for the manufacture of entire preliminary stages in their own production shops. Chrysler itself is responsible for painting and final assembly.

What began with the networking of production processes via back-end monitoring systems, has meanwhile developed into an intelligent lifecycle management platform as part of Industrie 4.0. It has become a fully digitized solution which – linked to production – controls and monitors the entire value chain in real time, from receipt of materials to the actual production processes and goods dispatch, as well as identifying weak points and optimizing capacity utilization. Day in, day out, KTPO impressively demonstrates that KUKA is operating a body-in-white production facility that can meet the most exacting requirements of the global automotive industry in terms of quality and efficiency.



At KUKA Toledo Production Operations (KTPO), part of the KUKA Group, body shells are produced for all models of the Jeep® Wrangler series which is sold worldwide.





Intelligent human-robot collaboration in the electronics industry

ASM Assembly Systems in the SMT Center of Competence

Where fences are no longer required between robots and humans, the way is paved for entirely new and highly productive approaches to industrial manufacturing. KUKA laid the foundation for this with the development of the first robot approved for human-robot collaboration – the LBR iiwa (intelligent industrial work assistant). Its built-in sensor system allows the seamless integration and division of tasks between human and machine – with considerable advantages in terms of manufacturing efficiency and flexibility.

An application at ASM Assembly Systems, one of the world's leading suppliers of manufacturing solutions for the electronics industry, demonstrates how networked production enables the optimization of SMT lines.



As a pre-setup operation, the LBR iiwa takes a component reel from the SIPLACE Tower.

Equipped with custom-tailored grippers, the LBR iiwa is able to flexibly handle all kinds of tape reels.

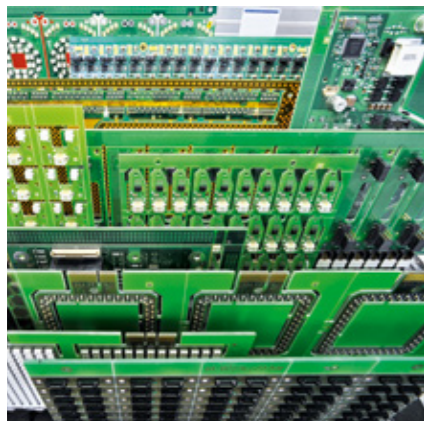
_Intelligent human-robot collaboration in the SMT Center of Competence

The premiere of the manufacturing innovation for the electronics industry set new standards. At its headquarters in Munich, ASM Assembly Systems, one of the world's leading suppliers of manufacturing solutions for the electronics industry, demonstrated two different variants of intelligent human-robot collaboration: with the LBR iiwa as a stationary variant in the pre-setup area and, mounted on an autonomous mobile platform KMR iiwa during ongoing operations in a SIPLACE SMT line. In the pre-setup area of an SMT line, the component tables have to be supplied with component reels. With the aid of the SIPLACE Material Setup Assistant, it is determined which component reels are required on the tables. This assistant sends the appropriate request to the SIPLACE Material Manager, which automatically releases the component reels from the SIPLACE Tower. The robot takes component reels from the SIPLACE Tower and places them on the component trolley in the desired order – human and robot interact directly, without a safety fence. The concept achieves two key objectives simultaneously: not only is the high quality of the products assured at all times thanks to the use of robots but productivity is also increased. Equipped

with a custom-tailored gripper, the robot is able to pick up the component reels sensitively in the pre-setup area of the SMT line – even though the reels have different diameters and the sides of the reels are of varying thickness and flexibility. In the placement process on the running line, the SIPLACE Line Monitor informs the operator which component reel in which slot will run out next. It sends this request to the SIPLACE Material Manager, which automatically releases the reels from the SIPLACE Tower. The KMR iiwa now travels to the SIPLACE Tower. There it feels along the lower level and left side of the shaft as well as the depth of the shaft. By moving downwards, it determines the height of the tape reel and then loads tape reels one by one onto the mobile platform. Finally, the robot transports all of the component reels to the SMT line and hands them over to the operator at the correct location and in the correct order.

The robotic automation for SMT lines demonstrates the potential in terms of avoiding errors, lightening the workload for human operators and simplifying tasks in the pre-setup area. The mobile robot is able to move freely and safely in the work environment of the human operators.

The great diversity of products in the electronics sector necessitates production solutions offering utmost flexibility.



Whether stationary or self-navigating, always the right solution: the LBR iiwa from KUKA.



The mobile LBR iiwa autonomously finds its way to the SMT placement line.



From science fiction to reality

Robotic riveting

For almost a century, ever since aircraft have been made primarily of metal, the task of riveting together fuselages has been manual labor. It's exacting work, repetitive, stressful on the body – a leading cause of job-related injuries.

It's a logical task to automate, but automated riveting is a recent development for aerospace, still used in a limited way. That's about to change.



_Robotic riveting

The future is taking shape in a building in Anacortes, Washington, near Seattle, temporary home of the FAUB project. FAUB, which stands for Fuselage Automated Upright Build, is a robotic system for automatic riveting being developed by KUKA Systems for Boeing. It has the potential to change how aircraft are assembled. The pairs of robots are equipped with multi-function end effectors from KUKA's new subsidiary, ALEMA Automation. They will build up much of the fuselage for both current 777 twin-engine jetliners and their successors, the next generation 777X family. The robots will drill and fill more than 60,000 fasteners per airframe. FAUB is the largest automated assembly system ever built for aircraft production, designed for one of the world's largest commercial airliners.

"The importance of the project to KUKA and the aerospace industry cannot be stressed enough," emphasizes Larry Drake, President of KUKA Systems North America. "It's a bold step forward in automating aircraft assembly and KUKA's largest project ever for the aerospace sector."

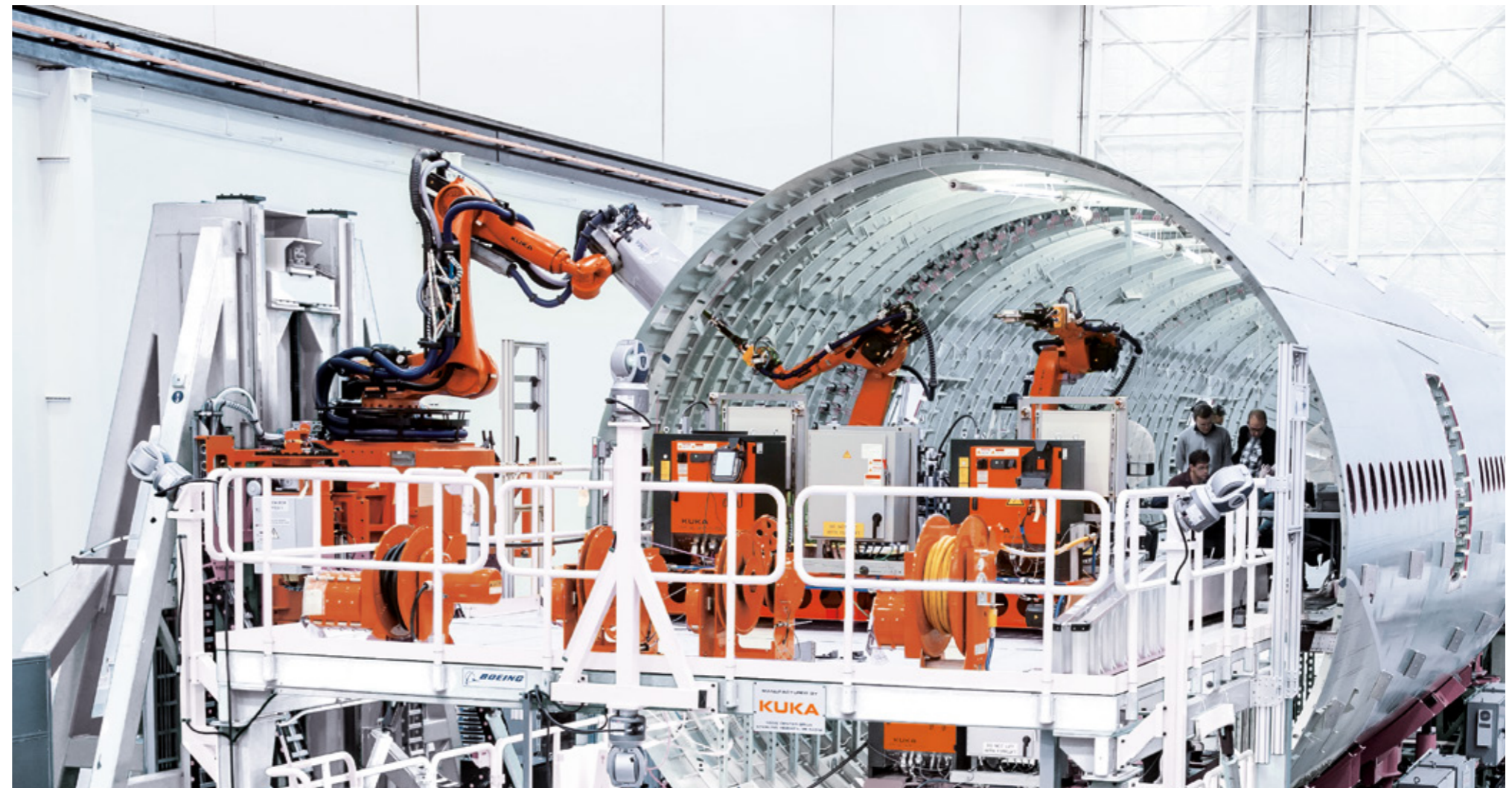
As a reference project for KUKA in the aerospace industry, FAUB establishes the company in this sector and allows it to position itself as an outstanding developer of advanced assembly concepts. "This project has captured the attention of the aerospace industry," enthuses Robert Reno, head of the Aerospace Group at KUKA Systems. "This is partly due to the large scope of the project and the technological competence we are demonstrating, and partly, of course, due to the fact that Boeing is a global customer that is known for its innovative capacity. This is a technological partnership that will last for many years," says Reno with confidence.

Rivets typically have a head like a screw and a narrower shaft. Installing them to hold two pieces of sheet metal together requires two robots working in tandem. One drives the rivet through a drilled hole from the outside, against the resistance provided by the robot on the inside. This means the end of the shaft is flattened, giving the rivet a head on both sides of the metal for a tight, strong joint. These robotic teams move along the aircraft hull, joining sheet metal together to build up sections of the fuselage. The exterior robots are mounted on a KUKA omniMove mobile platform, comprising an eight-meter-long unit, thus making the robots mobile.

"With this concept, the project has pushed back the frontiers in manufacturing," explains Randy Woolridge, Boeing Integrated Project Team Manager at KUKA Systems. "Various work steps that are currently performed separately in production have been uniquely combined."

When aircraft riveting is not done manually, it is usually performed in large stationary machines. The work pieces thus produced are then brought to the aircraft. With the robots, it is precisely the opposite approach that is adopted. The robots navigate autonomously on the mobile platforms and move along the fuselage layout to where they are to work. "KUKA was the only supplier to propose this concept. In this way, all work steps, from drilling and filling to the insertion and hammering of the rivets, are carried out in one place. Robotic riveting is extremely precise, with repeatable quality.

"The robot platforms can be put on the floor in any position, and as long as they have power and pneumatic



feeds in place, they can position themselves and do the job precisely as required to build up the fuselage," says Kevin Reilly, Group Manager of the Aerospace Group. The KUKA engineers involved in the FAUB project also had to think ahead to the future. The new manufacturing process is to be used not only for production of the current Boeing 777 aircraft, but also for the

successor generation. The innovative FAUB project was unveiled to the public in time for last year's Farnborough Air Show in Great Britain.

"This project has made KUKA a trendsetter in this sector," declares Reilly. "For our technology team that developed this solution, the task initially sounded like something from the realm of science

fiction. Now it has become reality. We are naturally immensely proud that Boeing put their faith in us to bring about this revolution in aerospace production."



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