

KUKA



Hello Industrie 4.0
_we connect you





The digital transformation is now.
Let us connect you.

The added value of integrated, globally interconnected value chains is acknowledged throughout the world nowadays. Companies are opening up to the digital transformation in order to successfully compete on the markets of the future. As a thought leader and trailblazer for Industrie 4.0, KUKA supplies intelligent solutions for maximizing the flexibility of the entire process chain – from consultancy and conceptual design through to the complete implementation of individual requirements.

With the expertise to help you step successfully into the future world of production – here and now.



Dr. Till Reuter
Chief Executive Officer
KUKA Aktiengesellschaft



»It is time for us to help
business to fully exploit the
potential of Industrie 4.0.«

A collaborative approach is required in order to leverage the entire potential of Industrie 4.0.

One thing is for sure: Industrie 4.0 has arrived in industry worldwide. Transformation towards a globally networked and integrated economy is taking place at all levels. Almost half the German companies from the manufacturing sector are already employing Industrie 4.0 applications. Most of them are focusing on optimizing individual processes from an economic perspective and increasing the output. Every second company is investing in digitization to make production more flexible. Another 20 percent of the companies are planning to implement digitization. The desire is for this to be achieved quickly and in accordance with individual customer requirements. The primary focus here is on the proven success factors of the economy: greater efficiency, greater productivity and higher speed.

Some people still regard this development anxiously. However, the opportunities of the digital transformation stem from us challenging traditional thinking. The digital world is not waiting for us. It is developing at a breathtaking pace – and anyone who wants to be on the winning side must clearly take a leading role. The integrated networking of production is an important and correct milestone on this road. But we must also make sure that our supply chains and our business models keep pace with this new era. Moreover, it is important that Industrie 4.0 does not remain the sole preserve of large corporations.

Every company should have the opportunity to participate in this technological revolution. No matter

what sector they come from or how big they are. Industrie 4.0 solutions must therefore be tailored in a wide range of different dimensions and for varying goals and target groups. It is ultimately not about convincing industry of an abstract model of digital networking but rather about technology and tools that enable companies to generate quite specific added value in their competitive environment. In this connection, we also consider the abstract search for “the one right Industrie 4.0 platform” to be of little value. KUKA has very deliberately opted for a different approach. An approach that focuses on the goal-driven analysis of our customers’ requirements. An integrative concept in which suppliers, partners and specialists for external expertise are actively incorporated in the digital strategy of our customers.

KUKA’s key added value lies in the capability of seamlessly uniting expertise from the digital and real worlds.

The digital transformation necessitates a radical change in thinking on the part of all those involved. The world in which everything is interconnected will become not just more interactive and flexible but also more complex. Any action in the value chain will trigger a reaction at another point. And that will also permanently change the way we work and how we set about finding solutions. For this reason, KUKA is setting a clear course by infusing the principal thematic areas of Industrie 4.0 with its own expertise.

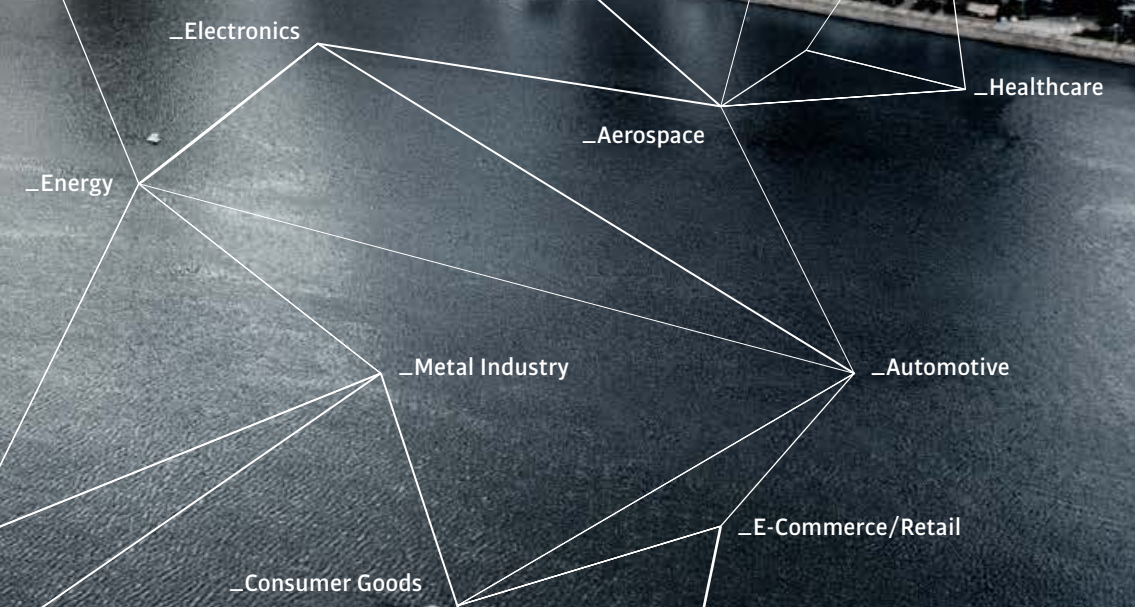


Our “Intelligent Machines” and “Digital Domains” make for a seamless connection between the real and digital worlds. And this can be scaled to any conceivable degree in the value chain between the shopfloor and the cloud. One specific example might be the intelligent networking and flexibilization of individual production processes. It may also be a matter of connecting complex production systems and integrating them into an existing IT infrastructure or of implementing entirely new business models with comprehensive interfacing to the cloud, Big Data or predictive analytics tools.

We know from countless projects that the full potential of Industrie 4.0 does not unfold until solution concepts holistically encompass the issues facing companies with a high level of competence in all customer-specific topic clusters.

We have pooled specialists from a broad range of fields in a dynamic, interdisciplinary Industrie 4.0 accelerator unit. Our aim is to reveal to our customers at the outset of the planning phase all added value that they stand to gain from digitization. And then to accompany them with our project expertise. In this way, companies also obtain direct access to KUKA’s global ecosystem. A network of highly qualified partners, integrators and suppliers from all areas of the digitized value chain.

Global. Dynamic. Fast-growing.
KUKA addresses the global
growth markets with holistic solutions.



Automotive

On the data superhighway to the future

The automotive industry is undergoing an epochal change. In the age of e-mobility, intelligent vehicles or completely new mobility services, the industry is facing far-reaching changes. From development through to production and logistics.

So, the time is ripe for decisive technical and entrepreneurial challenges to be faced. This is the only way that existing competitive advantages can be secured, or new ones established. As a world market leader, we have already been the strategic partner for all important manufacturers for decades now. This is because even today, KUKA delivers scalable concepts and solutions for the smart factory of tomorrow.

In the automotive industry, new market conditions are leading to structural changes of wide-reaching import. The focus is on the need for vehicles which customers all over the world find exciting, at the same time as keeping pace with the growing trends and technical development in an extremely flexible way. Irrespective of whether we are talking about new powertrain concepts, intelligent driver assist systems or totally innovative mobility solutions in the individual case – what is crucial when it comes to sales success is that the time between the initial concept and market launch must be kept short, and sustainably so. This is a requirement that can only be met in the long term with intelligently networked value chains. Consequently, the market is demanding flexible, robot-supported automation

that is capable of coping with the fast-paced change of time. Together with our customers, we are already implementing agile, intelligent production solutions today which will turn these dynamic and reactive worlds of production into reality.

Seamless integration into the existing ecosystem

These solutions are providing a key impetus for future-oriented production concepts. As a driver and pioneer in Industrie 4.0 and the Internet of Things, we are developing hardware and software solutions which achieve maximum variability, availability and greater throughput. Intelligent components for a fully digitized value chain which can be integrated seamlessly into existing ecosystems.

Now is the time to address the decisive technical and entrepreneurial challenges in order to develop and establish new competitive advantages, expand existing ones and maintain these in the long term.



Maximum availability for greater throughput, plannable ROI

Customer-specific human-robot collaboration for the smart factory

Agile, networked Industrie 4.0 solutions towards a fully digitized value chain



Metal industry

In the crucible of the data revolution

Trains pass safely through the transport systems of global cities. Modern agricultural machinery ensures that billions of people can be fed, while highly developed construction machinery forms the foundation of today's infrastructure. The metal industry makes life as we know it possible.

For our customers in these central processing sectors, it is important to manufacture large and complex machines which are processed to perfection down to the smallest detail. This is a challenge that robotic automation solutions were practically made for. And we supply intelligent, networked concepts for this.

Our many years of experience mean we are highly familiar with the challenging tasks faced by the metal industries. We are familiar with the demanding production conditions and have already worked together with customers from the metal industry to implement numerous solutions enabling sustainable, efficient production. With our broad portfolio of industrial robots adapted to the exacting requirements of the metal industry of tomorrow, we supply the entire spectrum from robots right up to cells and complete systems. Many of our robot models are produced in special versions, such as for particularly hot or wet environments.

which work with pin-point accuracy today. Innovative software technologies such as KUKA.ArcTech, KUKA.SeamTech or ROBOTstar System Software allow fast configuration and evaluation of welds and data. In this way, even during production we ensure that the ultimate quality check is carried out, and we are already supplying the technologies to link this to the cloud today.

Companies in the metal industry operate in a fiercely competitive environment. International competitors are creating price pressure. An increasing shortage of skilled labor and demographic change are leading to personnel bottlenecks. As a result, new robot-based automation solutions are needed to optimally support skilled workers in the workplace and provide supplementary assistance at decisive points – even in cramped or hazardous environments. We stand beside our customers in developing tailor-made and safe human-robot collaboration solutions together.

—Robot-based automation concepts from KUKA enable smooth, safe collaboration between humans and machines.

In spite of the difficult production conditions and extreme time pressure, the greatest possible freedom from defects is required. The customer wants to be able to rely on the product 100%. KUKA combines all of this expertise within the company in order to already supply groundbreaking Industrie 4.0 solutions

Optimal complement to and relief for skilled workers

Greater effectiveness and a lower error rate

Development of holistic HRC solutions for customer-specific applications

Energy

On the side of the energy visionaries

Automation partner for key technologies in e-mobility and renewable energy

The latest battery manufacturing processes

Climate change is one of the greatest global challenges. Irrespective of whether the subject is e-mobility or the use of renewable energies – the mass availability of high-performance energy storage systems is the central element in the success of the shift in energy policy.

As a key technology for the future, the energy market offers gigantic growth and innovation potential, although it is also crucial for complex technological and economical challenges to be resolved in the entire production process. Against this backdrop, we are acting as partners to manufacturers and investors as well as other technology providers to jointly implement future-oriented automation concepts which will make the shift in energy policy a successful model in both ecological and commercial terms.

Comprehensive documentation of production processes

Energy storage systems form the critical interface between energy production and energy consumption. At present, the solutions available for this are still cost intensive to produce and subject to significant technological change. Researchers are looking at a blend of in-situ energy storage systems, pumped storage systems and decentralized battery back-ups as an appropriate solution for storing energy from solar installations. At the same time, work is being carried out worldwide on compact battery concepts with high energy density in the e-mobility sector – which is decisive for the overall concept of the shift in energy policy. In this environment, KUKA is involved with innovative joining techniques for materials such as copper and aluminum

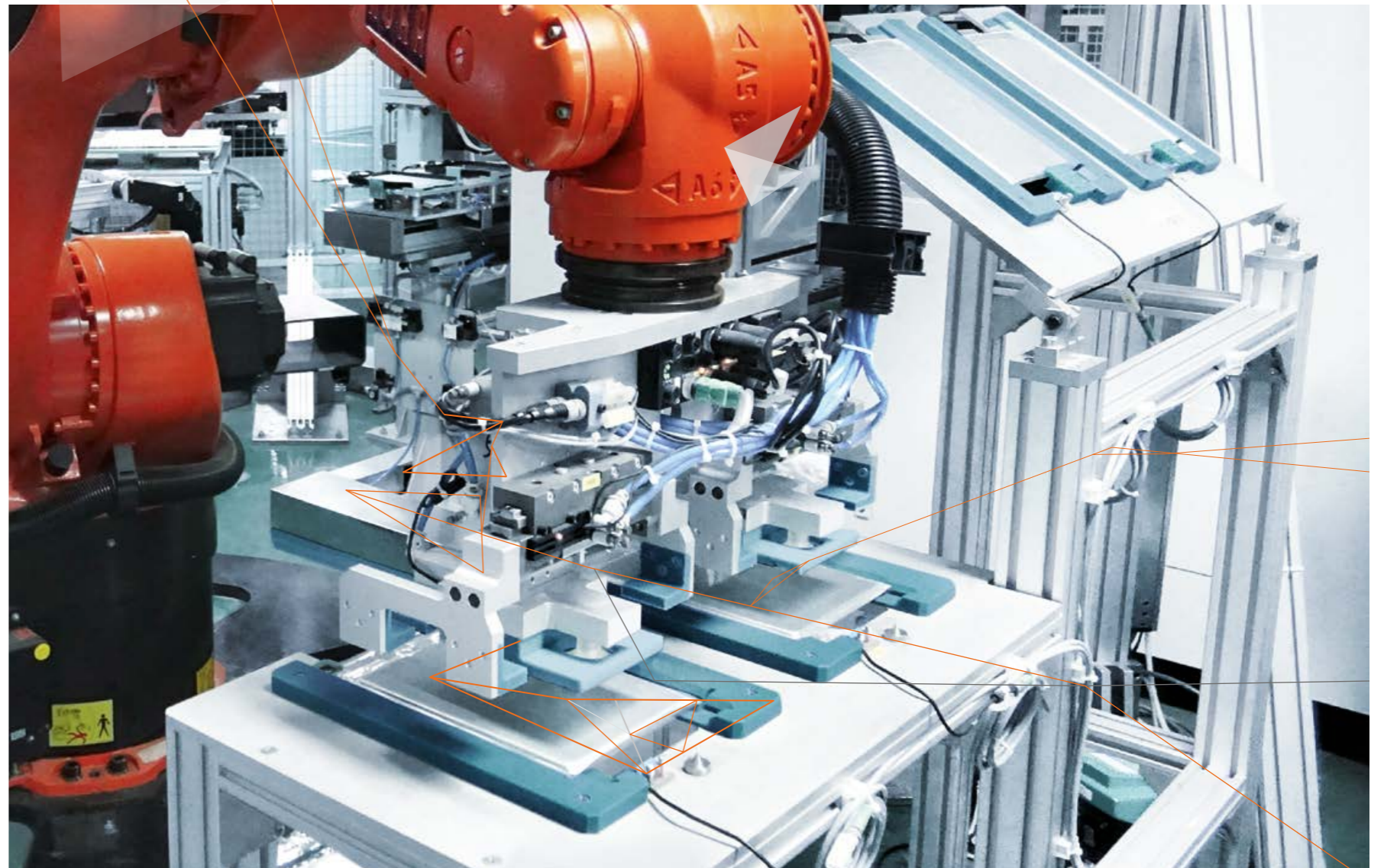
which are hard to connect, as well as in the development of intelligent, flexible automation concepts that permit economical mass production – even for a large number of variants and shapes.

A partner for individual automation solutions

As part of this, we combine the knowledge and experience of various technical disciplines to search for and implement holistic solutions – whether for the materials used, the module design, the connecting technology or final production. At the same time, our intelligent and networked automation processes, for example in battery production and

assembly, ensure comprehensive documentation of the production processes. This is an important factor in ensuring safe operation of high-energy storage systems during everyday use.

Intelligent high-tech solutions from KUKA thus make an important contribution towards making the energy transition a global success story.



Electronics

Technical innovation setting the pace

“Who is interested in yesterday’s technical highlights today?” This sentence sums up the electronics sector. The market is hungry for innovations and the immediate availability of the latest products. The Internet of Things is just around the corner and will increase the pressure on companies many times over through a multitude of new product ideas. As a result, changes will form part of everyday survival training.

Enormously shortened lifecycles accompanied by tough price wars will present manufacturers with a herculean task, however: they will have to produce and deliver massive quantities of premium products within an extremely short time and with maximum reliability. KUKA knows where the crunch points of the industry are and is working with customers to develop automation solutions that are extremely flexible.

More intensive media usage, individualization and fast product lifecycles lead to greater performance and lower costs. To enable smart products to be produced quickly and successfully for this fast-paced world, KUKA is, among other things, developing ready2_use packages together with its customers specifically for this area. These are innovative automation solutions that deliver numerous commercial benefits to the customer. The preconfigured robot packages simplify installation and commissioning, increase output, and make production more modular.

Thought leader and trailblazer for Industrie 4.0

In our TechCenters, we are working globally on the latest technologies and future scenarios. As a result, we are always capable of developing modular, robot-based automation solutions and concepts together with the customer – developments which are increasingly able to accomplish the specific tasks right out of the box. Together with our partners and customers, we develop concepts for automation and application solutions, carry out feasibility studies, work on demos and on-site product tests.

As a thought leader and trailblazer for Industrie 4.0, we enable our customers to respond directly to market changes and to match the requirements of consumers at any time. This is true, for example, with our KR 3 AGILUS – developed specially for assembly and handling of small parts. This lightweight robot has the agility and dynamism to accomplish an extremely wide range of tasks in small, compact and cost-effective production cells. The result: top performance, maximum output and extreme precision with very short cycle times.

Our flexible automation solutions such as “ready2_use” enable our partners to meet the ever-changing requirements of the market optimally at all times.

Consistent quality thanks to high precision

The product cycle of electronics products in the industry is less than 6 months

Flexible automation solutions and smart manufacturing

High availability and thus ideal for 24/7 production

Forecast sales revenues in the smart entertainment segment in Germany from 2014 to 2020

Year	Revenues in millions of euros
2014	58.73
2015s	81.52
2016p	124.65
2017p	196.82
2018p	288.72
2019p	375.33
2020p	442.02

Source: Statista (Digital Market Outlook) © Statista 2015. *All forecast values are marked with a p.



Aerospace

Perfection at new heights

Without question, aircraft are the backbone of our global, mobile society. The requirement profile for a modern aircraft is the equivalent of “squaring the circle”: designed for a decades-long product lifecycle, it must be capable of adapting chameleon-like to the fast-paced changes of technological developments, ecological requirements, customer expectations and safety standards.

Implementing this variability in production on a competitive basis creates extremely demanding requirements in terms of the flexibility, efficiency and transparency of all processes in the value chain. This is a challenge that can only be met economically in the long term by the comprehensive intelligent networking of all components over the entire lifecycle of an aircraft.

Today, a modern transport aircraft comprises about five million individual components that are produced by thousands of supply companies and input in the production sequence at precisely the right time. Thus, the aviation industry generates products with a simply mind-boggling range of variants. At present, there are more than 1,500 airlines which order specifically adapted versions. Adding the suppliers, sub-suppliers and maintenance providers to this makes the result an extremely multi-faceted supply chain. A closely intermeshed sequence of working steps in which the quality of every individual part and every process can determine the reliability and safety of the produced aircraft. Within this complex sequence, knowledge of details, no matter how small, is an important commodity. Today, it is a standard feature of the aircraft industry for all components that are essential for operation, such as the jet engines and control systems, to be monitored by sensors. The increasing digitized networking of production processes down to the levels

of subassembly, parts or raw material suppliers will lead to remarkable improvements in knowledge about potential weak points in an aircraft.

From virtual simulation through to automated production

Even though it may sound like science fiction – with digitized production processes, we will not only be able to produce with greater flexibility and efficiency, but also detect problems long before they have effects on the practical functional capability of an aircraft.

As a result, the path for the aviation industry towards the uncompromising digitization of all processes is pre-ordained. The development and design of aircraft has long since been verified and supported by virtual simulations in almost every area. This applies to physical/technical properties just as much as to the definition of all processes that are relevant to production. Our joint

work together with manufacturers starts right from the design and development phase so as to optimally design components and assemblies for automation over the entire production process.

As a result, we make a decisive contribution to creating future-oriented products in the aviation industry. At the same time, we provide for a humane working environment and support companies in coping with the lack of skilled workers.

—Our automation solutions with a wide variety of specialized end effectors can be seamlessly integrated into the networked production lines of the aviation industry.

E-Commerce/Retail

Smart automation of unpredictable processes

Flexible and scalable systems provide dependable responses to market volatility



Data analysis tools and artificial intelligence provide transparency and provide predictive calculations of supply chain events

Intelligent and mobile robotics is revolutionizing intralogistics

Electronic commerce is setting new standards and challenging brick-and-mortar retailers. Fast delivery, maximum variety of products and absolute price transparency combined with seamless logistics are convincing advantages for online consumers. Smooth logistics necessitates digitization of the supply chain and the implementation of automation solutions in warehouses.

Business models in e-commerce demand highly flexible supply chains with a holistic approach which permit the seamless integration of retail, finance and logistics processes into one transparent entity. Against this backdrop, solutions in e-commerce have to meet many demands simultaneously. These range from the interests of exclusively online retailers through to classic retail outlets and the distribution service provider or brand-name manufacturer.

Mobile end devices, Internet research with a purchase option and exchange via social media have now become part and parcel of the buying process. As a result, it is almost certain that the commercial significance of e-commerce will increase further in coming years. Even conservative estimates for the year 2020 predict online sales in excess of 4 trillion US dollars. The boundaries between online shopping and brick-and-mortar retailers are becoming more blurred and entering into a long-term symbiosis. Whereas we are currently still busy mapping the intermeshing of internal and external logistics processes in real time, the trend is moving towards predictive analytics of the available mass of data. This means that we are using digital information intelligently enough to allow the next consumer action to be predicted accurately.

Digitization is creating intelligent intralogistics

In the future ever more powerful forecasting tools will be available to the retail sector which will be capable of predicting consumer behavior more accurately and will allow targeted advertising. Smart purchasing may require only two clicks by the consumer, but it is based on extremely complex and heterogeneous logistics networks – characterized by a large number of data interfaces and an interchange between automated and manual activities, for example in the storage and picking of goods. The latest automation technologies from Swisslog are already providing the e-commerce and retail sectors with networked software and robot-based logistics concepts that precisely serve the nerve centers of the logistics chain – for instance, technologies based

on the goods-to-person principle. Human-machine collaborations such as the AutoPiQ order picking technology from Swisslog are capable of opening up areas to automation that were previously an exclusively manual domain. Particularly forward-looking: even today Swisslog can already seamlessly depict the transitions between the requirements in brick-and-mortar retailing and e-commerce in hybrid systems. They are capable of both order picking for pallets and single-item shipments from a warehouse.

—Industrie 4.0 solutions from KUKA optimize the throughput of goods, minimize downtime and ensure both transparency and high-speed responses throughout the entire supply chain.

Consumer goods

Customization requires production expertise.

In actual fact, there is no such thing as “the” consumer goods market. Rather, there are dozens of them. No other market segment is as fragmented as the consumer goods segment. And scarcely any other market is facing such diverse challenges in coping with the future. However, they all have one thing in common: modern production concepts and logistics should support them in making their offerings even more flexible and suitable for customers, through to complete customization of mass-market products.

Any company that intends to survive in this challenging sector in the long term really has no other choice: only consistently digitized processes and highly flexible, automated production and logistic systems will be capable of efficiently bringing these customer-driven business models to a position of economic success. Solutions from KUKA take account of the entire value chain from manufacture through to packaging, logistics, sales and distribution.

A look at the large shopping malls and supermarkets leaves no room for doubt: there is a massive variety of products in the consumer goods industry. Foodstuffs, clothing, personal hygiene products, cleaning products – in each segment, the offering is characterized by a large number of categories, sub-categories, packaging sizes and types as well as different brands. In addition to the variety of items available, volatile parameters in the business models are key factors in the success of the consumer goods industry – for example, global and regional trends, political influences, new technological drivers, social taste and changes in values through to economic crises and natural events. At the same time, it is apparent that the number of product variants is continuing to increase because of the trend towards increasingly customized products.

Using digitization to mass-produce unique products

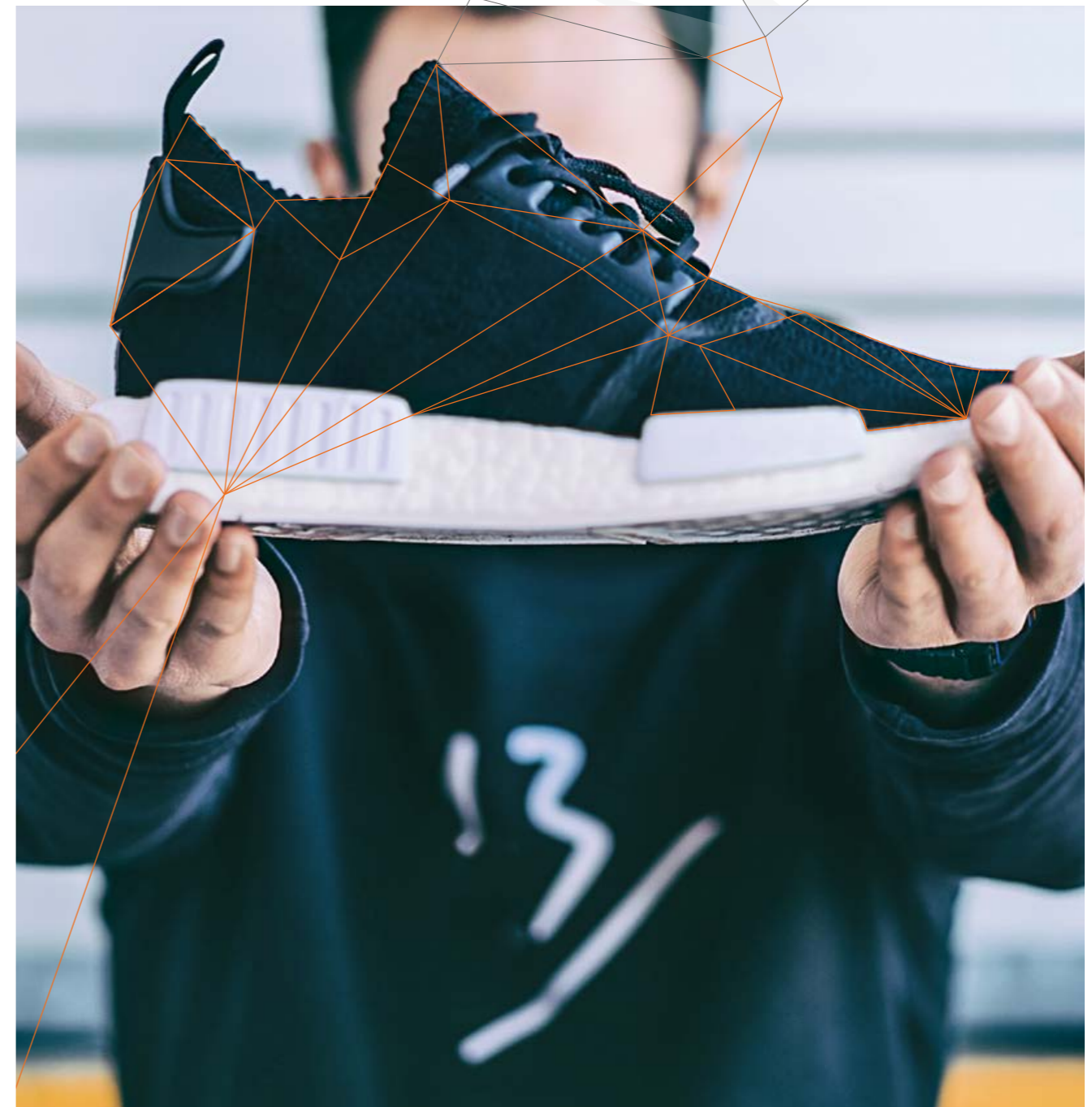
In view of the enormous dynamics in the consumer goods market, every future strategy for automation solutions must be capable of responding to new conditions efficiently and functionally. Here, KUKA offers digital concepts and technologies for agile control of integrated value chains. Intelligent analysis procedures use real-time data to precisely predict customer behavior and market movements. It is not an exaggeration to say: any company that does not digitize will be punished by the market. KUKA offers customers a tailored solution for each sector – in the area of Industrie 4.0 automation, this is achieved through the networking of the shop floor with data analytics tools, which enable us to better gauge the end users and their responses.

...Digital production permits business models that are individually adapted to customers and optimum control of the entire process sequence.

Digitization and automation open up decisive potential for efficiency gains and cost reductions

Transparency of all production and supply processes

Establishment of planning and analysis instruments





Intelligent robots support treatments

Optimization of material flows and safe medication management

Development of future technology for a digitized healthcare system

Healthcare

Digital intelligence for perfect patient care

Healthcare systems are coming under pressure from two sides: firstly, there is an obligation to keep costs down for running clinics, patient care and medication. Secondly, the quality demands for healthcare are rising in parallel to the aging of society.

However, quite apart from the financial challenges and necessary efficiency increases in processes, what is ultimately important is the ongoing treatment success and patient welfare. With this goal in mind, we are creating modern automation systems for our customers which, for example, permit material flow, 100% traceability and safe medication management during and after hospital stays.

The challenge of allowing everyone to enjoy the best possible healthcare into old age is reaching its limits in existing systems. This is because the costs of healthcare systems are rising at the same time as demand on them is growing due to the ever aging population. In Germany, the number of people over the age of 67 will increase by 40 percent to about 22 million by 2040. As age increases, so does the intensity of care – and thus the cost for healthcare systems.

A whole series of technologies and concepts from the environment of Industrie 4.0 can make a decisive contribution to breaking the “ever more expensive” trend and reducing the load placed on our healthcare systems. This includes the use of robot-supported automation solutions as assistants during treatment and aftercare as well as digital process optimization and intelligent monitoring technologies.

With networked systems towards proactive healthcare

Beyond this, a comprehensive view of healthcare provision is crucial. This is why KUKA is working together with customers to produce integrated solutions beginning with prevention and continuing to hospital stays, rehabilitation and the sector of ambient assisted living. Health data continuously gathered from people by means of sensors as well as the networking of medical databases will make it possible to establish a proactive healthcare system. This means, for example, that routine examinations and hospital stays for observation can be avoided.

...The healthcare system will benefit from automation solutions in the form of increased, logistical efficiency and treatment methods improved by robotics.

Holistic. Intelligent. Interconnected.
KUKA identifies three key areas that
open the door to tomorrow's production.

_Consulting

_Digital Domains

_Intelligent Machines





Dr. Christian Schlögel
Chief Technology Officer
KUKA Aktiengesellschaft



»Those who act quickly and
with foresight will have a handle
on the future.«

The digitized world is incredibly fast.

Holistic. Intelligent. Interconnected.

At times, products that were all the rage just yesterday are considered boring or old-fashioned at the blink of an eye. For gadgets this may be the case within days, for clothing it may be weeks, for a car perhaps months or years. And of course we expect products that highlight our particular style and status, not just off-the-shelf products. It is no surprise that we can configure our cereal online, and we expect this high level of personalization and customization in virtually every aspect of our personal and professional life.

For how long do people deem products or services exciting? At what point do we become ambivalent to them, bored or even get annoyed by them? There are probably no generalized answers to these questions. But they reveal the factor that is key to sustainable economic success: empathy for the market, adaptability and speed in implementation. In the coming years, it is estimated that about 50 billion devices and 4 billion people will be networked. Even today it is clear that this provides the foundation for numerous new services and products which will dramatically change the world as we know it today. And just like in all previous revolutions, the fourth industrial revolution will be a blessing and a curse at the same time. Those with

their finger on the pulse will succeed, and those who miss the boat will lose out. Hyperconnectivity will enable new forms of production, spur many new business models such as the shared economy, and the data will allow us to make clear predictions. No matter whether we are talking about consumer behavior or the failure of a component in a machine.

Prosumers, consumers with more professional demands on the product or who may even directly impact the added value of a product as co-designers, will challenge manufacturing and logistics in a completely new way. Many analysts even go so far as to predict that, in the end, the best business model will win, and not the best technology. Even though we do not entirely agree with this opinion, it certainly points out that, in essence, it is about bringing products and services to market maturity as quickly and simply as possible. Speed in all of its forms is the decisive argument of our time.

Production and logistics at the center of the storm

The trend towards personal or individualized products is already clearly noticeable in many manufacturing sectors. It is highly likely that the variants of industrially manufactured products will proliferate explosively in the coming years. And quantities will remain constant or increase slightly at the same time. But it would be wrong to think that optimizing production and logistics processes and making them more flexible will suffice. In the course of digitization, all communication within the value chain will be restructured. Customer contact, communication channels, distribution channels – everything will change. In order to remain successful and address all of these aspects, companies must take a holistic look at the possibilities, opportunities and challenges of Industrie 4.0. When implemented properly, Industrie 4.0 is a tremendous opportunity. For example, it is entirely realistic to assume that the combination of a fast time-to-customer and the high demand for personalization renders it necessary to produce closer to the consumer, or even to include the consumer in the product design as a co-producer. Intelligent automation with reduced manual effort presents an opportunity to reshore outsourced or relocated production.

Programmed for dynamism – Focus 4.0

KUKA recognized the importance of the fourth industrial revolution many years ago and has strategically aligned itself systematically to these new challenges and topics. As a result, it is of no surprise that KUKA is amongst the world's leading companies in this future-oriented segment as one of the drivers of Industrie 4.0. We firmly believe that digitization will sustainably and irrevocably transform the global economy. Even if the technological cycles shorten, this topic will be the decisive factor for industry over the next decades. And that has consequences for the direction of our own business as well. The world is fast-paced, and this is sure to only increase in the future. To be successful, it is important to adapt swiftly. That applies both to our customers and to KUKA itself. This is why we have been making changes over the past years and will continue to do so in the future.

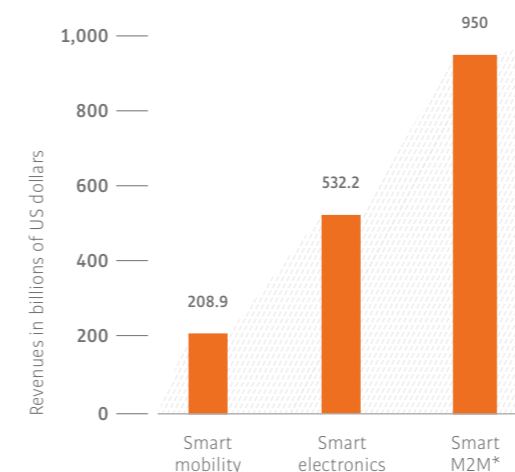
First, we started using networked and more flexible production in our own factories and our own robot production. Next, we recognized early on that our concept of approaching Industrie 4.0 in a holistic manner can only be implemented with proprietary expertise in edge computing, our own IT hubs and our own cloud platforms. For this reason, we moved quickly and decisively to enhance our OT portfolio with IT expertise. We call this new overall competence of OT and IT simply "Digital Domains". Hidden behind this humble name is a core competence for seamless and integrated digital networking of industrial production environments. A marriage between the real (OT) and digital (IT) worlds. This involves basic knowledge that gives us a decisive edge even when seamlessly integrating our OT systems in existing or third-party IT infrastructures. We are now making this accumulated in-house expertise available to our customers within the KUKA manufacturing ecosystem.

Industrie 4.0 and IoT taken a step further

The digital revolution is here. The combination of Industrie 4.0 and the Internet of Things probably offers the greatest opportunity for the economy to realign for a stronger future. In our opinion, the existing consultancy sector is not capable of addressing this complex issue holistically. Contradictory statements or isolated viewpoints from the individual disciplines reinforce the uncertainty in companies and inhibit the investment propensity necessary for Industrie 4.0. But the technical groundwork has long been established. Today, KUKA is implementing complex Industrie 4.0 scenarios in virtually every industry and to vastly different degrees. In our opinion, the actual risk is that companies will miss their window of opportunity for transformation and that they will eventually be outdone by more agile competitors.

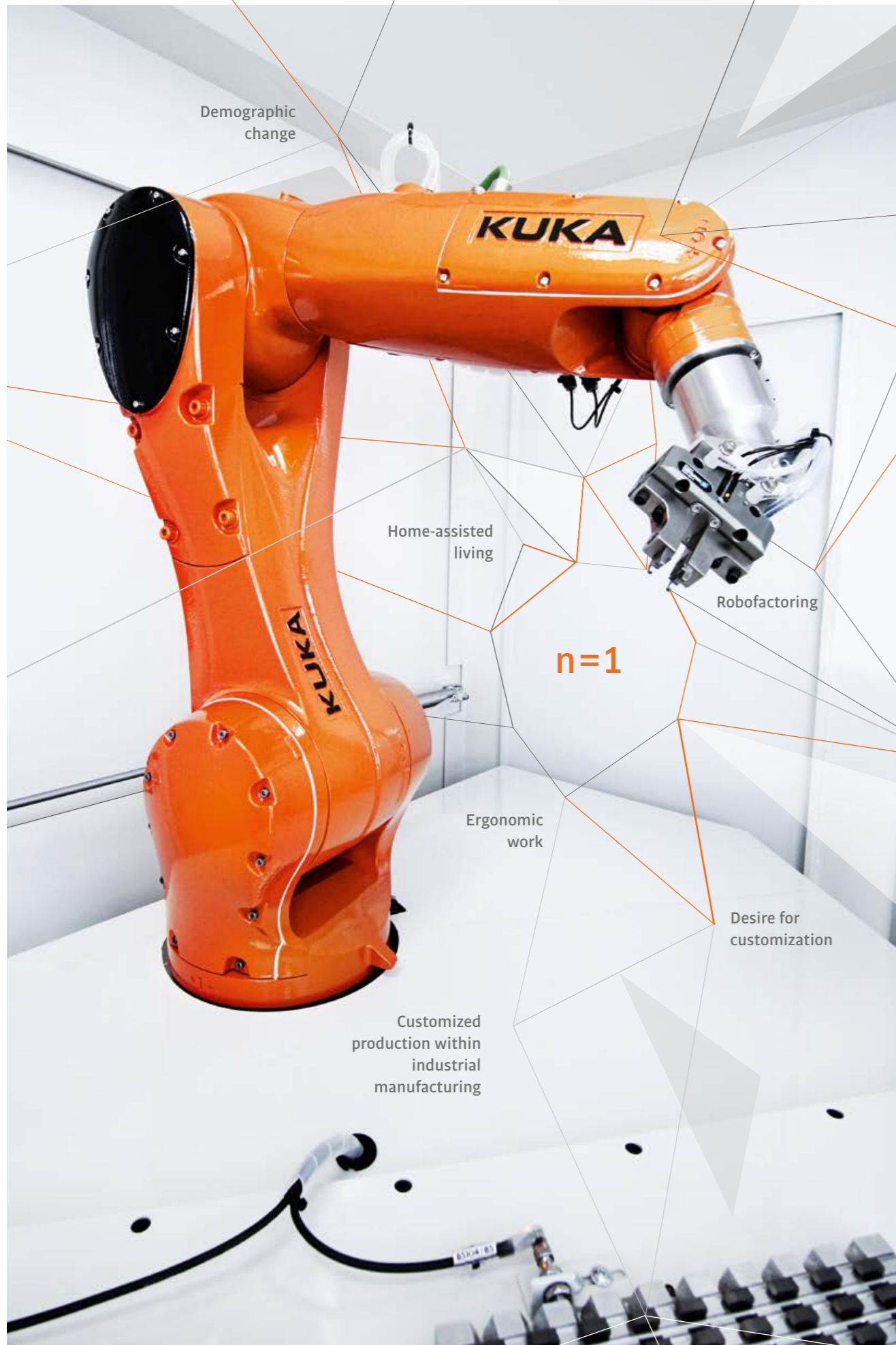
KUKA has therefore asked the question of how we can use our own knowledge and our advanced global ecosystem, which includes relationships with research institutions, specialists, industry experts and much more, to significantly facilitate access to Industrie 4.0 for our customers. To make it safer, more needs-driven and above all easier. Our answer is very simple – we offer our customers direct access to our network of expertise. No matter whether you require validation for new digital business models, seek an exchange of experience in your industry, are looking to consult with Big Data specialists or if you require expertise for a specific manufacturing or logistics process – the KUKA ecosystem offers competent answers to all your questions.

Forecast global sales revenues with networked devices by sector in 2020



Source: University of Jyväskylä © Statista 2016

*M2M stands for "Machine to Machine" (excluding PCs, laptops and smartphones).



Intelligent machines

Interoperable systems for tomorrow's production

Unimaginable only a few years ago, but already entirely normal today: devices of all kinds – whether autonomous lawnmowers, thermostats, lamps, cars or simply kitchen appliances – nowadays, almost everything is capable of contacting other gadgets or data sources via the Internet. Now, it is time to make industrial production more agile, more intelligent and more efficient along the same lines. This is done by endowing machines with the ability to develop themselves in an evolutionary way in a diverse range of forms and configurations. Among other things, they possess the capability of communicating with other systems via the cloud – with production, workpieces or other machines.

Intelligent machines which support humans cleverly, powerfully and safely during their everyday work are a reality. Not in the humanlike form as Isaac Asimov forecast in the 1950s: this is where reality departs from fiction. Machines that join, assemble, transport and so on do not have to look like people. To all intents and purposes, they only have to accomplish three things: they must carry out their task as efficiently as possible, be able to adapt to new framework conditions as quickly as possible and, in the future, be capable of sharing

this knowledge with processes and systems in an intelligent way. These are parameters that are required for success in the networked world of IoT and Industrie 4.0. At the same time, they take on a range of different guises. We know them as 3D printers, CNC machines or indeed as robots – probably the most generic and versatile machine which human beings have ever thought up.

The backbone of the fourth industrial revolution – intelligent robots

KUKA recognized the potential of networked and open automation systems back in the 1990s. For example, in 1998 we introduced the world's first interoperable, web-capable industrial robot onto the market. Possibly, it was those machines which provided the impulse for the evolution which we currently know as Industrie 4.0, or the fourth industrial revolution. It is a fact that no robot today has any future unless it is capable of being integrated into complex, networked production systems on the basis of standardized mainstream technologies. And robots are continuing to develop further. In a variety of forms and configurations, they are conquering areas which were still closed to them only a

few years back. Wherever the journey takes us – in the future too, intelligent robots will form the sturdy backbone of industrial production. They will not only be tethered within cells as we knew them in the past, but provided with new intelligence, apps that are simple to integrate and give them new capabilities at a click, or cloud-based functions which turn them into active players in the flexible, autonomously operating smart factory. In contrast to Isaac Asimov's visions, this is not science fiction, but actual, progressive reality.

Cobots in industry

Your robot colleague shares the work.

In 1978, the cult band Kraftwerk released a legendary piece of music under the visionary-sounding title “The Man-Machine”. Today, this vision has become reality. With sensitive robot colleagues, “cobots” for short, KUKA is demonstrating that human-robot collaboration can be implemented today.

Sensitive cobots have the sense of touch required for the cyber-physical world of tomorrow’s production, in which IoT and Industrie 4.0 will replace familiar structures. With their integrated sensors, they make it possible to automate delicate assembly tasks in the first place – ranging from assembling automotive transmissions through to inserting rubber plugs or handling flexible parts. If unexpected contact is made, cobots for example reduce their speed and thus the kinetic energy to an extent which prevents injury. When people and robots can work safely together, many conventional safety precautions become superfluous. Additional costs which would normally be required for safety technology and protective fences can be dispensed with. Workers and robots can share the same workspace without any concerns. In this way, expensive feed systems and production floor space can be saved.

Without doubt, cobots will play a key role in Industrie 4.0 – not only directly as part of modern production, but as data gatherers which can communicate all relevant information to IT systems in real time if required. Information that can be processed immediately and sent back to production. Knowledge that can be used for optimizing production successively or autonomously. At present, no other component in the production process is capable of carrying out this supporting role as well as modern robotic systems.

Human beings remain at the center of production

The crucial point is to achieve open communication and simple integration. This makes cobots virtuosos for modern, networked production and logistics which will link together automation solutions with services and databases within the foreseeable future. However, a factory staffed by robots alone will remain an illusion, even in the smart factory. People will remain the central focus. However, robots will make people’s jobs less arduous, will support people and give them entirely new capabilities.

This means the workers and logistics experts will be able to carry out their jobs even more efficiently, with greater concentration and, above all, more ergonomically. This aspect is becoming increasingly important, especially in a society that is aging to an ever increasing extent – worldwide. An ever smaller number of people in employment will have to generate the entire productive output for the social systems. It will only be possible to meet this challenge by employing the available workforce in a much more productive way than in all previous generations. With cobots in different payload categories, KUKA already offers central, key technologies for a wide variety of tasks involving cooperation between humans and machines: collaborative robots, mobile assistance systems, autonomously controlled vehicles and intelligent, digitized automation solutions which reduce the burden on humans in a variety of ways.





KMP omniMove
 Maneuvering huge components simple and safely on site: the KMP omniMove at the Airbus plant in Hamburg

Mobile robotics

The path is the goal.

Future production and logistics will have to expand like a spring. This means flexibility is called for, not only for accelerated manufacturing but also for customized products. Guaranteeing this flexibility will require significantly greater mobility – irrespective of whether the mobility concepts involved are episodic, periodic or permanent. For this reason, KUKA is laying the groundwork for this technology – with platforms that move autonomously and intelligently to transport items or process workpieces. Or with platforms that find their own way if required, align themselves with workpieces with millimeter precision or respond adaptively to changing conditions in demanding logistics and production sequences through autonomous behavior.

Our mobile automation solutions provide the basis for the highly flexible production world of Industrie 4.0, in which rigid, assembly line concepts are consigned to history, and the future belongs to productivity spaces which can be continuously optimized. Even complete production units can be repositioned somewhere else on an ad hoc basis. This new type of mobility sounds like science fiction. But at KUKA, it is science fact. This means we are providing the blueprint for mobile automation solutions with which every industrial company can gear up for the flexible, digitally networked world of production.

Maximum autonomy for mobile robots and platforms

KUKA Navigation Solution knows the destination and the best way to get there. This navigation solution responds spontaneously to obstacles and modifications, and coordinates all known vehicles in the system. Fully in line with Industrie 4.0, its software ensures planning and implementation of orders in a coordinated way – even in conjunction with higher-level control systems. It registers data from safety laser scanners and radar sensors, and uses the SLAM method (simultaneous localization and mapping) to create a detailed map of the surroundings. By means of this map, the platform can respond to changes in the surroundings which are a matter of course in a flexible logistics system. It's good to know that the software, which is not dependent on a hardware platform, can be used for different kinematic systems. It enables any motion principles to be handled – and of course also holonomic vehicles with Mecanum wheels, such as the KMP omniMove.

These vehicles offer unrestricted maneuverability in every direction, including rotating the robot about its own axis. As a freely scalable modular system, it can be precisely adapted to the specific requirements in terms of size, length and width. With its omnidirectional wheels, the vehicle can be used even

in the most cramped conditions. This means the logistics area can be reduced by up to 50%, allowing more space to be used for production. In addition, KMP omniMove vehicles effortlessly cope with loads of up to 100 metric tons. It could not be more mobile.

Infallible sense of orientation: mobile automation solutions from KUKA find the way to their destination with unerring certainty even within highly complex production environments. With or without heavy loads.



KMR QUANTEC
 Intelligent robotics right where it is needed: the mobile industrial robot KMR QUANTEC stands for precision transport of even the heaviest components.



KMP 1500
 Maximum flexibility, unlimited mobility, autonomous navigation: the omnidirectional mobile transport platform KMP 1500 makes for smart production environments.

KUKA flexMOVER
 Automated guided vehicle for the smart factory: the KUKA flexMOVER is the flexible helper for all requirements, from the distribution of materials through to integration in complex assembly systems.



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

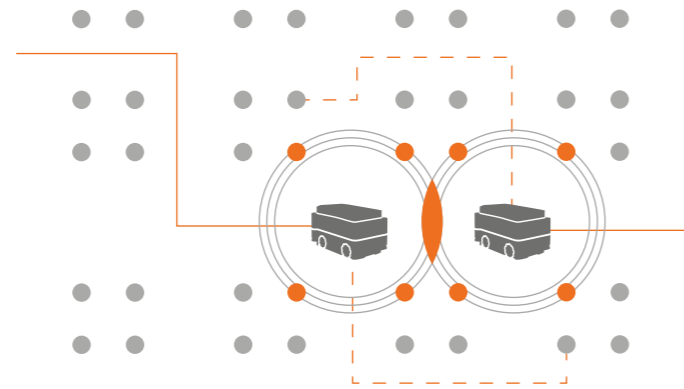
Humans and machines together

Unlocking scope for flexibility

Robots are establishing themselves in more and more fields. According to the International Federation of Robotics (IFR), the number of industrial robots used worldwide will increase to about 2.6 million units by 2019. One of the driving factors is human-robot collaboration (HRC) made possible through innovative technology. KUKA is laying the groundwork for this with the LBR iiwa, the first industrially applicable, HRC-capable robot. Its sensitive sensors permit seamless integration – without any safety fence – and a division of labor between human and machine. The human being controls and monitors production, the robot supplements the human’s capabilities and carries out an extremely wide range of tasks as an “Intelligent Industrial Work Assistant (iiwa)”. The option of interacting with people, machines or workpieces irrespective of location means that there is a practically unlimited range of applications for this new generation of mobile robotics. With its numerous possible applications, the LBR iiwa is symbolic of the reality of Industrie 4.0.

Added value through individual “ready2_use” solutions

However, sometimes even maximum flexibility alone is not enough. Fast-paced branches of industry such as electronics or plastics require solutions and applications that are ready for immediate use and easy to integrate. To meet the need for fast availability, KUKA has cooperated with some system partners to develop ready2_use solutions that can be implemented by customers “out-of-the-box”.



KUKA Navigation Solution
Intelligent orientation, positioning, response. KUKA Navigation Solution knows the destination and the best way to get there – every time.

Industry requirements occupy a central role in the strategic orientation and definition of these solution packages. As a result, these packages have been developed jointly with customers and specialists, and are tailor-made to the specific tasks.

ready2_use packages are combinations of KUKA software and hardware components which can be put into use immediately. In this way, the appropriate package can be assembled by KUKA and the integrator to precisely match the customer’s automation experience.



KUKA flexFELLOW
From manual to automated in 10 minutes: the KUKA flexFELLOW assists the operator flexibly and adaptably with a wide variety of tools that can be changed in a minute.



Safe and troublefree: KUKA HRC technologies make for relaxed interaction between humans and machines



KMR iiwa
An intelligent lightweight: the KMR iiwa combines the strengths of the sensitive lightweight robot LBR iiwa with a mobile, autonomously navigating platform.

KUKA Digital Domains

Smart transformation to the digital world



KUKA exercises a major influence on a key aspect of Industrie 4.0 by converging the necessary competencies from the digital and real worlds of machinery and system engineering. Aside from its role as proactive driver of manufacturer and industry-independent standards, KUKA is particularly engaged in creating essential platforms as a link between real production and the relevant digital structures.

In doing so, we create the prerequisites for an open, comprehensive architecture and a structure that provides constant user access on any end device to the customer's own production data. This structure will allow components and processes to be analyzed, managed and, if necessary, even reconfigured with virtually unlimited computing power – a platform that scales know-how and unlocks access to whole new markets and regions over the Internet.

Today, KUKA can master the key challenges arising from the integration of existing industrial automation systems into a smart and consistently networked production chain. KUKA lets customers focus on their core competencies because the platform technology is available for every component, in every sector and market, thanks to open standardized interfaces.

KUKA Digital Domains

Technical concept

Shopfloor / edge

As a first mover, KUKA has developed open, interoperable and modular architecture layers and platforms for tomorrow's smart factory that ensure efficient convergence of traditional automation engineering with cloud technologies.

Accordingly, every data transfer begins with a production component or process, whose control and sensor system communicates with peripheral equipment via specific protocols and bus systems. The edge provides the communication interface between the cell network (operation technology, OT) and overarching IT (information technology) network. Data are already consolidated, compressed, and encrypted in the local edge hardware before being transferred to the cloud.

A trend can be identified across all cloud providers in which typical cloud functions, like event processing, are shifted to the edge to increase closeness to the process and enable a more direct and faster reaction in real time. Ultimately this will lead to increasing centralization of control and regulation tasks in the cloud, instead of distributing them to various automation devices in decentralized locations.

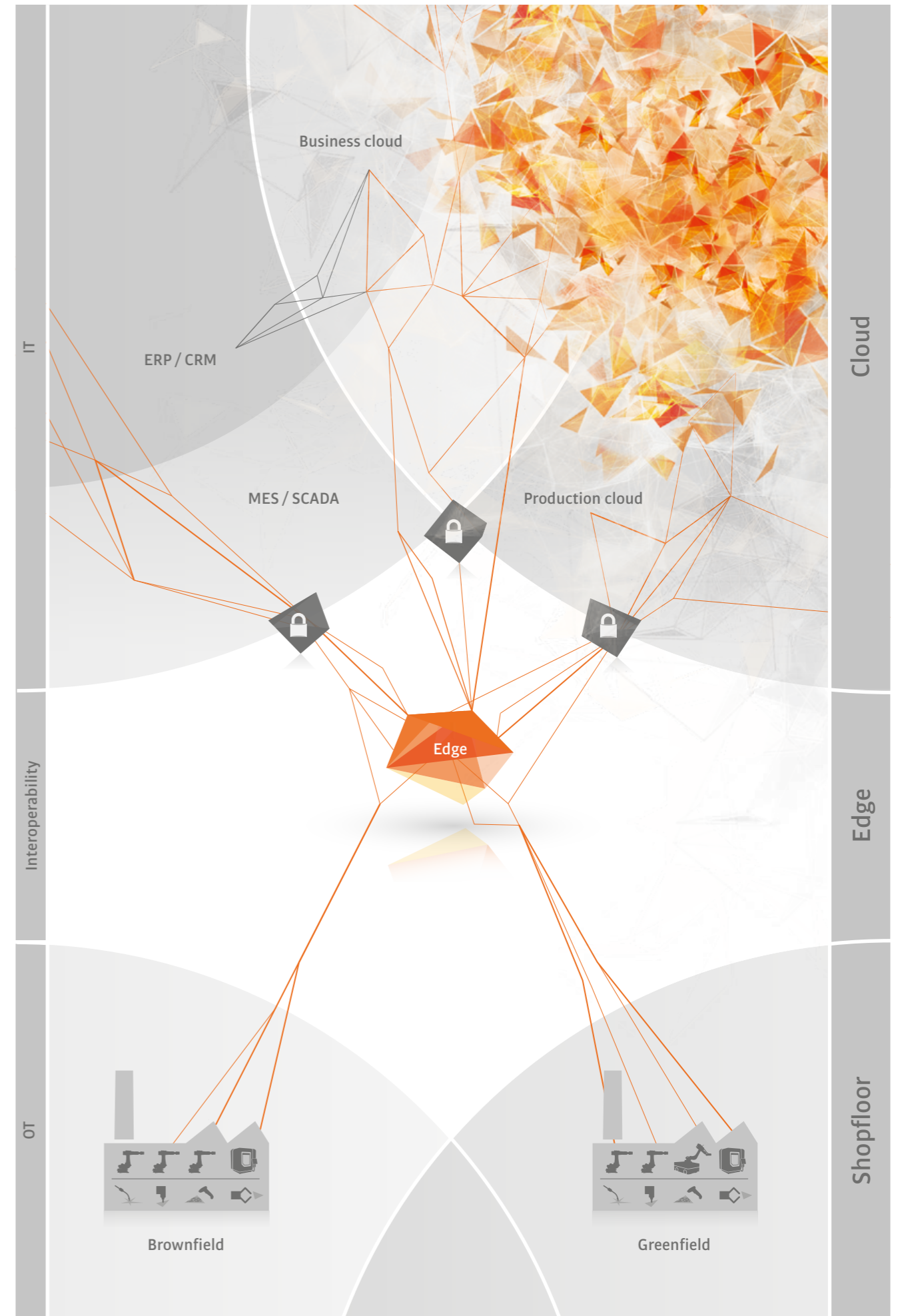
The edge is thus the crucial layer for connecting real "things" on the shopfloor to the virtually infinite computing and storage capacity in the cloud. They can also be incorporated into the new digital world of Industrie 4.0 via the integration of edge gateways in existing "brownfield" production plants. By contrast, when planning new "greenfield" plants, the edge permits completely new control architectures in which an edge with high computing and real-time powers acts as the central cell controller.

As the edge layer interacts between things and the cloud, components are relieved of requirements placed on cloud communication, such as security, computing power, memory requirements, etc., while at the same time being enhanced by previously lacking cloud-compatible communication protocols.

These services are directly integrated into compact and, more importantly, securely embedded computer systems in the production environment for cross-cell and cross-component availability.

For end consumers and thus cell and system operators, it is important that data accessibility to their processes is enabled through minimally invasive edge integration. KUKA therefore strongly advocates the standardization and openness of interfaces to allow all production "things" to communicate with the cloud via the same edge. To this end, KUKA sits on established committees and promotes OPC UA as a standardized communication protocol.

Deep dive: the company is also pushing ahead with TSN (Time Sensitive Networking) expansion for deterministic real-time communication via OPC UA and AMQP (Advanced Message Queue Protocol) for OPC UA cloud communication. And, of course, KUKA draws on its many years' experience in remote maintenance of products at the edge and has recently extended its expertise through participation in the Silicon Valley startup, Nebbiolo.



The cloud layer – public, private, on the Internet or on premises

The Internet of Things platform (IoT platform) – included in the term “cloud” – is the next station for data sets after the edge. But what is it actually all about?

Since all things in production will be communicating with the edge via standardized protocols in the future, these data are now sent to the cloud. In this context, the cloud is a computer infrastructure made available by providers such as Microsoft or Amazon in the form of “Infrastructure as a Service” (IaaS). The IoT platform in turn describes a platform on one of these cloud infrastructures – “Platform as a Service” (PaaS). Good to know: KUKA subsidiary connyun’s IoT platform is cloud-agnostic and can therefore run on any infrastructure. The customer can therefore freely choose whether this should be a private cloud, a public cloud (“anywhere” on the Internet) or on the customer’s premises.

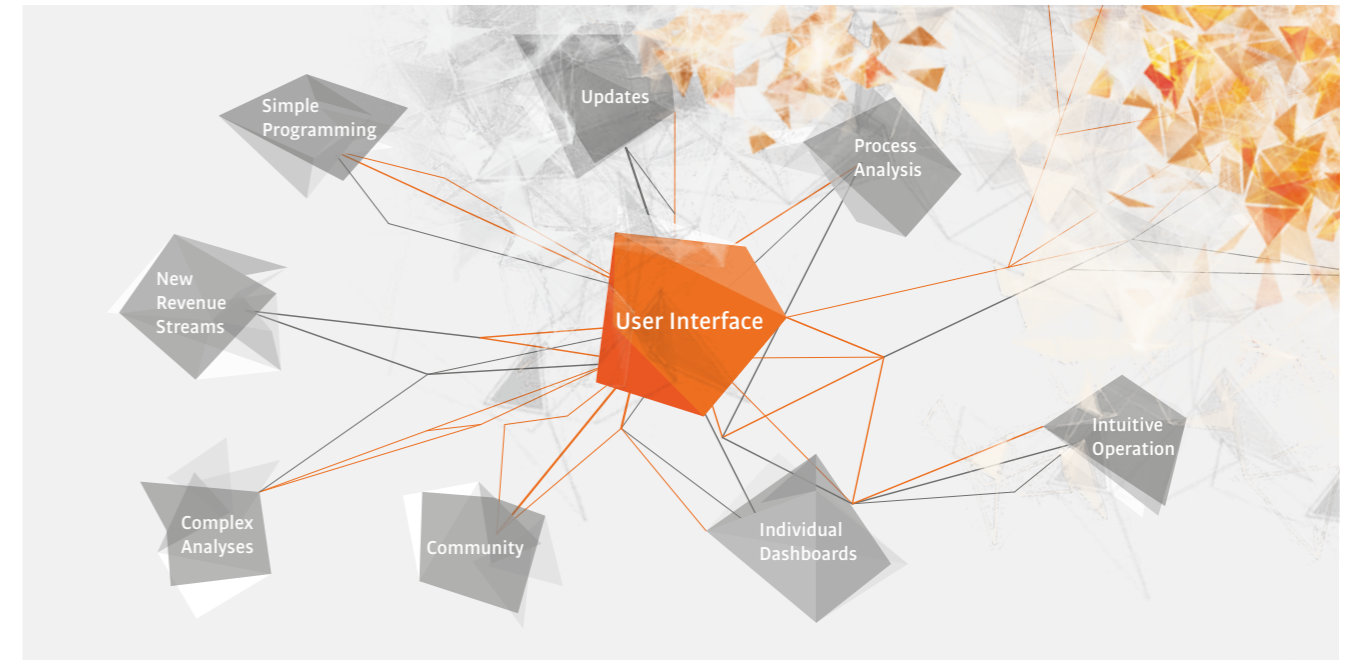
So-called micro services run on this platform, like for instance authentication, role concepts, Big Data storage and processing, etc. It also enables features such as artificial intelligence, predictive maintenance and event analytics. The IoT platform allows system operators to process the data from their producing things and to adapt processes on the basis of insights derived from the results.

KUKA tailors its IoT platform developments to the requirements of MSEs in the mechanical and systems engineering industry. After all, the platform is available to enterprises from all sectors and can be used across all markets. Partners can thus focus entirely on their core competencies and can access established micro services via KUKA’s IoT platform. In addition, our partners and third-party providers of services for programming and optimizing individual components or processes can also be integrated. A community based on partnership thus evolves, driving the optimization of components, processes and production operations via a shared technical platform.

Business cloud – production meets business intelligence.

The IoT platform manages thing-related data processing and evaluation. However, modern production systems also need a uniform, structured approach to comprehensive value chain and maintenance processes.

And that is exactly what the business cloud makes possible. It provides access, for example, to all historically captured data for process and component analysis – such as the lifecycle or maintenance information of individual robots. As a result, processes can be launched and run digitally.



Thanks to the standardized IoT platform link to the customer’s business cloud, all databases – of KUKA and its partners alike – can be incorporated into the analyses and quality assurance processes via this interface.

Like many other customers, KUKA also operates its own business cloud. The system offers customers an integral experience with KUKA across all points of contact. In the future, our robot, cell and system-specific data will additionally be available to our community partners on the IoT platform for improving production efficiency.

The KUKA Marketplace including the App Store will also be operated via the system. In practical terms, this means that the growing number of apps and generated know-how can be marketed worldwide through this store – by a simple mouse-click. The benefit for customers: KUKA takes on the responsibility for developing and operating the infrastructure and places the process expertise available on the market at the community’s disposal in the form of applications.

UI, HMI & app layer – the basis for intelligent applications and human-machine interfaces

Human-machine interfaces (HMIs) allow customers to access IoT platform data and analysis results and to take the required operator control actions. The interface between the cloud and HMI end devices is also implemented by means of open and documented APIs – known in this case as RESTful APIs. Community partners and other customers can thus program their own applications for any end devices and evaluate data supplied via the edge in line with their requirements.

Applications may have a very compact design and be used for highly specialized and possibly component-specific tasks. However, it is equally possible for complex applications with a wide-ranging scope of functions to be implemented. In practice, requirements vary enormously depending on the sector, individual production solutions and corporate structures. Virtually no bounds are set – everything is covered from recording operating hours to optimizing the energy consumption of process sequences.

KUKA already possesses wide-ranging expertise and specialized staff in the field of app development, as has already been required for many years for the local operation of components such as robots. This is reflected, for example, in the style guide for programming user interfaces, which supports the intuitive operation of all HMIs. The so-called RESTful APIs allow our partners in the KUKA Manufacturing Ecosystem to implement the apps they need, designed exactly in accordance with their own ideas. Companies can thus not only access their own production data, but also have them analyzed and evaluated via the established micro services from KUKA and other third-party providers.

In the future, companies from all sectors, such as system integrators, process, hardware and software manufacturers, OEMs and start-ups will enhance their products, and especially their services, with relevant apps. This scenario is made possible by the KUKA Marketplace with its App Store: programmed best practice solutions can be bought and downloaded here, thereby giving the creators the opportunity to market their know-how on a global scale. KUKA provides customers with a structured platform and broad community that offers all the relevant tools for quickly and efficiently integrating Industrie 4.0 solutions into the value chain in a dynamically growing ecosystem.

KUKA Connect

The smart KUKA robot

Full transparency of in-production data through the intelligent connection of various layers. KUKA has not only introduced this model, but also puts it into practice. The company has created and launched the product KUKA Connect fully in keeping with the slogan "Practice what you preach". Today, it already allows customers to access and evaluate the usage and consumption-related data of their robots – from any end device, anywhere and at any time.

KUKA Connect is based on the layer model already described. If the Nebbiolo box (edge) is integrated into a production cell, it automatically identifies the connected robots. The harvested data are evaluated in the cloud via the existing micro services in accordance with the customer's requirements. This enables system operators to directly view the status and condition of their robots.

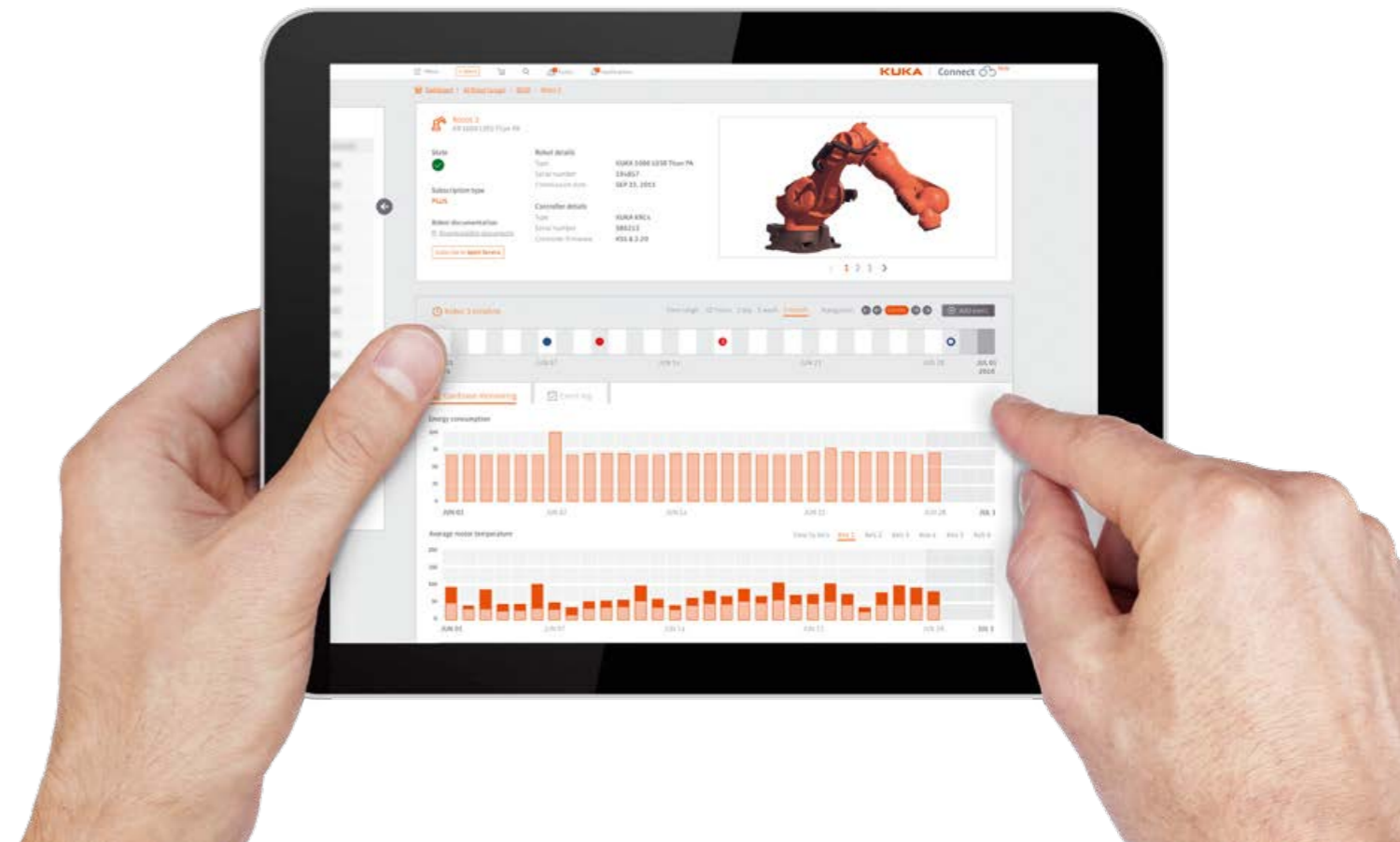
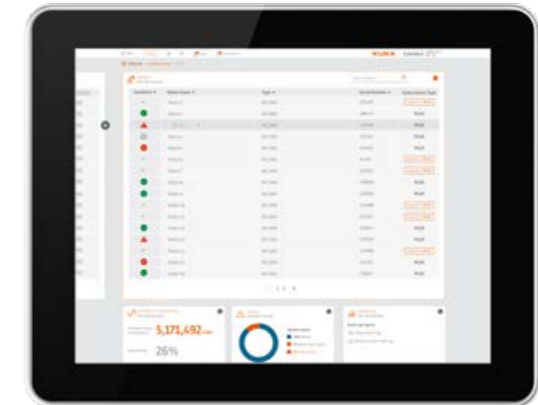
By incorporating the data, KUKA also offers practical services for the robots. For example, if a number of robots are deployed in a system, KUKA Connect automatically calculates optimized maintenance cycles for them. The responsible technicians are immediately notified of any service work required and the entire history of each individual robot is saved and made accessible.

The award-winning knowledge database "KUKA Xpert" is also integrated into the user interface – without the need for any complicated installation work. This makes the many years of expertise acquired by our service specialists accessible worldwide and at all times. Up-to-date documentation and specifications, work instructions and demo videos, help in locating the right spare parts and troubleshooting based on qualified solution proposals – after more than ten years in field operation, KUKA Xpert has become a valuable companion for its users.

These services substantially reduce the management requirements for operating the robots. Thanks to KUKA Connect, laboriously compiled, redundant or even contradictory documentation is now a thing of the past. Customers can access long-term analyses of their robot systems and can draw conclusions as to their incorporation in the process.

For this purpose, KUKA provides the necessary infrastructure for its products and customers. For enterprises such as system suppliers or line operators, KUKA Connect opens up wide-ranging possibilities for integrating KUKA robots into their concepts and operating them in their systems even more easily.

- Operation: production optimization
- Maintenance: robot condition and 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



KUKA SmartProduction

For seamless transparency
across all processes

Production lines consist of numerous sensors, actuators, network components, and lots more. Virtually all these integrated “things” are potentially valuable information providers, since processes depend on the interaction of various components and peripheral properties. If the aim is to use data not only to optimize individual components, but also to increase process quality, they must be intelligently processed and visualized together. KUKA SmartProduction gives system operators access to the information of process-relevant machines for evaluation – in compliance, of course, with the highest security standards and clear data association.

KUKA SmartProduction ensures easy, seamless, and manufacturer-independent cross-sector linkage of all production machines in the cloud. Designed for maximum freedom, KUKA SmartProduction can be deployed across different hardware and software landscapes. KUKA solution’s standardized interfaces and future-proof architecture make it the ideal IoT platform for enterprises in all markets and sectors.

KUKA SmartProduction enables all enterprises to consistently digitize whole cells and production lines. It creates an interoperable network, in which micro services and Big Data analyses can be used to analyze and lastingly improve manufacturing efficiency, quality, and flexibility. With our open platform we offer component manufacturers, system integrators, and machine operators an additional channel for value-added services and applications for the manufacturing industry.

At the end of the day, the question remains: what does the future hold for medium-sized engineering enterprises? With KUKA SmartProduction, KUKA paves the way for enterprises across all sectors to position themselves in the digital world. The challenge and chance for those enterprises is to seize the opportunities while not losing touch with own core competencies.

KUKA invites you, too, to become an important part of KUKA SmartProduction.



Clear. Competent. Comprehensive. The KUKA Consulting approach for Industrie 4.0

Let's be clear on one point before we even begin to talk about Industrie 4.0 solutions: Industrie 4.0 is not a product or service as is often mistakenly assumed. Neither is it a specific technique, model, or method that can be simply bought and used. Industrie 4.0 definitely concerns the product portfolio of established machinery and system builders, their market differentiation and positioning. All in all, it concerns the entire enterprise. Close examination already shows that virtually all corporate areas are affected one way or another by the subject and are already engaged in developing measures for future viability.


This diversity offers huge potential to create a cross-departmental dynamic through interdisciplinary initiatives that unite the enterprise on the transformation path. Compartmentalized projects and mentality have no place in a world of digital opportunity.

So, to summarize – Industrie 4.0 is complex and integrative in equal parts. Yet, if everyone is already doing Industrie 4.0, how can we pull the strings together without dampening initiatives? On the contrary, how do we boost their synergies? We enjoy a distinct status in the market through our KUKA Consulting approach, based on our long-standing industrial know-how and specialists to specifically foster and demand the relevant Industrie 4.0 skills. In doing so, we abide by our hands-on mentality, because successful Industrie 4.0 consultants earn their laurels on the shopfloor and not in steering committees.

We have been pairing this know-how with Industrie 4.0 approaches and associated technologies now for several years. This ongoing development of our core competencies makes us the ideal project partner for digitizing production and entire business processes in enterprises of all sizes and in all sectors. The Industrie 4.0 accelerator team complements this existing expertise through targeted partnerships with established specialists. Experts from precisely those areas vital to promote cross-company Industrie 4.0 measures, to initiate their targeted implementation and, if required, to provide support.

The KUKA Consulting approach is based on a modular, field-tested procedure which always focuses on the customer's individual added value. We develop solutions according to customer requirements in three phases. An important aspect is that various Industrie 4.0 solutions from KUKA and our partners are first trialed as prototypes to validate their relevance and effective added value at short notice within a customer context. Not Industrie 4.0 for the sake of digitization, but Industrie 4.0 as an opportunity for the integral development of individual components, processes, systems, or indeed entire corporate areas.

The intrinsic flexibility of the KUKA approach means that phases can be adjusted to specific and changing needs and the pros and cons of particular initiatives weighed before taking decisions. The scope of a project and the involvement of further partners is thus defined by the customer in the course of the cooperation. KUKA supports the customer throughout as a sparring partner with sound experience and process know-how. Along with our team of experts from the respective disciplines, we can bring structure to the complexity of our customers' specific challenges, plan defined steps, and put them into practice as required.



»Industrie 4.0 consulting
starts on the shopfloor,
not in steering committees.«

Rohitashwa Pant
Industrie 4.0 Accelerator
KUKA Aktiengesellschaft

The KUKA 3-phase model

Your path to measurable results

KUKA has a firm grasp of the challenges posed by engineering, process, cell and system automation, and the incorporation of logistics solutions. We also complement this know-how with experts from areas vital to Industrie 4.0, such as IT security, Big Data Analytics, and business model innovations. Enterprises can access this expertise via KUKA Consulting, easing their entry into a world of constant transformation and already producing practical results in just a few weeks' time. We devise customized solutions in three separate phases for maximum optimization potential to achieve the set targets. Customers obtain optimal, comprehensive guidance from KUKA Consulting whether their goal is to increase plant efficiency, reduce total cost of ownership (TCO), or automate a specific process for future viability.

Phase 1: Explore

During the Explore Phase we engage with the customer's relevant stakeholders to get a full picture of the customer's expectations, requirements, and goals. The procedure, the necessary project scopes and resources are specified in the course of workshops and interviews. At the same time, we define with the customer key areas for action in the fields of process design, technology deployment, production and cell layouts, organization, and IT structure. The relevant digitization aspects are highlighted, which can be capitalized on through Industrie 4.0. We define the projects with maximum enhancement potential and so-called quick wins, while always applying established standards, lean management specifications, and manufacturing principles.

At the end of the around three-week phase the customer receives a customized Industrie 4.0 maturity evaluation, a draft of areas for action and recommendations and, frequently, also a first Proof of Concept (PoC) in the customer's own production environment. At this point, the expert consulting models to be specifically applied in the follow-up phases are also defined.

Phase 2: Design & Prototype

The areas for action from the preceding analysis are now dealt with and practically implemented at the beginning of the Design & Prototype Phase. The customer can choose which projects and starting points are to be launched initially or even in parallel. We draw on our experience and incorporate various specialist areas which must be taken into account when implementing Industrie 4.0 measures into the project procedure. These include optimization, digitization and simulation of production processes, IT architecture, and the relevant security setups. The immense potential of Industrie 4.0 for extending and adjusting the customer's own business models is also explored and addressed with the customer. The Proof of Concept can also be developed into a prototype based on the customer's requirements and then used as a test and evaluation environment for downstream installations. As the result of the Design & Prototype Phase the customer obtains a specific test setup (process, cells, components), as the decision-making basis for implementation of further projects along with the process documentation and analysis. The key aspect of this phase is to draft with the customer an Industrie 4.0 solution that

fully satisfies their needs and expectations in short iteration cycles. The scalability and user friendliness of the solution in the enterprise is thus ensured.

Phase 3: Pilot

After the Explore and Design & Prototype Phases, implementation of specific medium- to long-term projects is launched. Based on collective insights, technologies and solution modules are now specifically implemented and entire system areas further optimized in this way. Applying the KUKA Consulting approach we address the customer's objectives through Industrie 4.0-focused automation solutions, individual potentials through digital services or innovative business models. The Pilot Phase acts as a springboard for various projects that comprehensively secure the customer's enterprise for the digital future. Increased efficiency, accessibility and analysis of process data, reduced cycle times, or the creation of integrated system concepts are all practical examples of added value. The customer obtains them in the initial phases of KUKA Consulting – respectively customized to their objectives. All in all, the KUKA Consulting approach offers a coordinated start to your journey into the digital future.





KUKA Consulting

Keeping an eye on the big picture

We have to broaden our view, break down compartmentalization, and foster interoperability if we want to make the most of Industrie 4.0. In technical terms this means cross-domain data management, data harvesting via proprietary interfaces, end-to-end management of cyber-physical security and creating integrated administration, communication and logistics structures. To achieve increased productivity, we have to abandon established structures and rethink every aspect of our business models.

KUKA offers customers access to the necessary competencies to steer enterprises quickly, simply and dynamically towards Industrie 4.0 while taking their specific needs into account.

In doing so, four structural areas are particularly influential and relevant to the evaluation of the measures required for the digitization process.

1. Enterprise resources (including the digital skills of employees and production automation)
2. Organizational structure (including goals and strategic alignment and organic internal organization)
3. Information systems (including horizontal and vertical integration as well as data delivery, processing, storage, and transfer)
4. Corporate culture (including focus on customer benefit, collaboration, and ongoing qualification)

Industrie 4.0 maturity

The technological maturity of production environments and their components is crucial for the customer's procedure and development towards Industrie 4.0. As every enterprise has its own current status of smart products and defines its own Industrie 4.0 goals and, for example, general IT structures, customers need an individual approach of their own. This status can be analyzed for each customer and then incorporated into the overall process.

Based on this analysis phase by our consulting partner UNITY, we find out how confident employees are in handling IT systems (resources), whether and if so, how cross-site information exchange works (organization structure) and whether all employees are involved in production optimization (corporate culture). Once the enterprise's Industrie 4.0 maturity rating has been established, a digitization procedure can be defined for the customer and efficiently implemented. An important aspect of this procedure is that the right areas for examination within the enterprise are selected from the outset. This makes it possible to take reliable stock of the current status and to derive appropriate goals.

Smart Processes & Logistics

Process chains in modern production and logistics systems offer further starting points for optimization by integrating (real-time) data, for example. In-depth industry and technical know-how is essential for the analysis and development of “smart” processes. KUKA Consulting’s Smart Processes & Logistics solution area provides the relevant experts from production processes, system design (lean management, for example) to entire (production) logistics setups and thus pools all the relevant skills. This facilitates our customers’ entry into a comprehensive digital transformation and makes the process as smart and pragmatic as possible.

No matter whether existing systems or the development of new concepts, all areas can benefit from Industrie 4.0-based technologies and developments. Along with our consulting ecosystem partners we identify the main potential in our customers’ systems within a few weeks. And we achieve measurable results in minimal timeframes simply by performing minor additions and adjustments to existing processes. By applying our partner NeoNex’s “Planning smart assembly lines” module, all the relevant steps from analysis and verification to ordering the relevant system modules for implementation can be completed within twelve weeks, for example.

Digitization in production and warehouse logistics has already reached a very advanced stage. Material flow analyses, condition monitoring, or digital shadowing for 3D system visualization are already firm fixtures in the Swisslog portfolio. Yet which of these measures take customers to the next crucial level? In this case, too, KUKA Consulting opts for joint, structured specification of optimization possibilities and offers the necessary solution expertise with the right partners.

Digital Factory & Prototyping

Many enterprises are very cautious when it comes to implementing Industrie 4.0 projects, considering them to be too expensive and time-consuming, and offering only uncertain outcome and benefit, etc. Precisely in the case of complex Industrie 4.0 challenges and tasks, it is vital to approach matters in a structured manner: Via its ecosystem partner Zühlke, KUKA offers all-important access to proven design-thinking components. One of the main elements of design thinking is a clearly structured process in recurrent loops. Prototyping begins as early as possible and insights are recapitulated time and again. This process provides the customer with fast results, enabling sound decision-making for next steps and follow-up projects.

The benefits of the model are plain: Empathy for the needs of users leads to the development of solutions that are actually needed. Thanks to fast, efficient prototyping, we do not beat about the bush, but try things out as quickly as possible, together with a cross-disciplinary team. Any mistakes are made together to learn from them – all of this taking place within a set budget. This is the fastest route to innovation.

IT Architecture and Security Consulting

Increased networking of machines and industrial systems generates new threat scenarios for manufacturing and digitized companies. Yet even individual “smart” components may be targeted by cyber criminals. So it is good to know that KUKA can come to the rescue. With the security consulting of our project partner Giesecke & Devrient, we offer line operators and component manufacturers tailored threat and risk analyses that they can use to assess the current security situation. This permits initiation of targeted measures. Backed by a security analysis based on proven approaches in the IT industry, the procedure is adapted to the circumstances and individual features of industrial systems and their specific requirements. KUKA and its consulting partners support customers in setting up secure component and system networking.

New complex issues related to IT architecture in general arise in the wake of digitization and Industrie 4.0:

- Safeguarding the security and interaction of the various layers
- Sustainable development in relation to scaling & connectivity
- Integration of existing systems and infrastructure
- Solution combinations incorporating business processes, technology, connectivity, and Big Data

Here too, KUKA offers the right advice on these issues and devises integrated solutions together with customers.

Business Model Innovations

Innovative products and solutions arising from Industrie 4.0 approaches call for a new mindset on value creation and absorption. Not only technologies change, but also how customers and other stakeholders in the extended ecosystem interact. Consolidating market position in the age of digital change hinges on setting yourself apart from the crowd with services, tapping new sales channels, or establishing new payment models. Along with its solution partner BMI Lab, KUKA enables enterprises to transcend

inured practices. The procedure of the St. Gallen University Institute for Technology Management spin-off unlocks hitherto dormant potential and methodically develops new business models. Highly innovative business ideas are devised in the course of a two-day workshop based on the St. Gallen method.

KUKA and BMI Lab help enterprises to directly translate the insights gained from all consulting approach stages into new business model templates and ripen them to market maturity as quickly and inexpensively as possible.



Envisioned. Done. Delivered.

KUKA offers tailor-made HRC systems and IT solutions that equip customers for Industrie 4.0.





Frank Klingemann
CEO KUKA Systems GmbH
Market Owner Automotive



»Our experts develop customized solutions to make sure new business models are successful.«

Industry and business, characterized by market trends

New challenges between consumer behavior and business models

Industry and business are influenced by market trends. Mobility, digitalization, and sustainability change consumer behavior and in turn the value chain. This poses industry with the challenge of uncertain future development, requiring it to react flexibly to changing market demands. We can offer our customers this flexibility, giving them the scope to create new business models.

Our new production concepts pick up on this and combine our experience with new technologies. KUKA has been implementing operator models in the automotive industry for many years, paving the way towards cost-effective, scalable and smart factories, and supporting the production of more than two million car bodies.

Human-robot collaboration, connectivity, and future-oriented hardware and software solutions smooth our partners' way to help them satisfy customers' requirements. In the e-mobility sector, for example, we offer an extensive solution portfolio from adaptable body construction and battery module production to e-drivetrain assembly systems. E-mobility is far more than just a new type of drive, it is actually an established aspect of how we will be mobile in the future. The paradigm change from ownership to mobility consumption forms the basis for new business models.

These market trends can be identified in various forms in all industries, not only in the automotive sector. Our experts develop customized solutions to make sure your new business models are successful. KUKA already provides solutions today for future service-based business models with networking and flexibility as enablers. Backed by data transparency and consistency on the shopfloor, digital services can increase customer added value by improving cycle times or availability, for example.

„To round up, the transparency and connectivity created by our Industrie 4.0 solutions facilitate our customers' progress towards globalization and individualization of their production.“



»e-mobility is far more than just a new drive type, it's an established aspect of how we will be mobile in the future.«

Frank Klingemann

Effective KUKA software for optimizing production

Starting a new era with detailed data analytics

A supply chain is as fast as its slowest link – this insight is law in the era of Industrie 4.0. After all, in a networked manufacturing operation, a delayed process has a severe impact on the speed of production.

That is why companies are interested in successively optimizing their cycle times. They are supported in doing so by an intelligent analytics tool for the factory of tomorrow – KUKA SmartProduction_management.

Industrie 4.0 needs speed. Everything needs to become faster and more effective – over the entire value chain. However, this requires the production dynamics to keep pace without compromising quality. That this can already be accomplished today is demonstrated by a joint project of KUKA and a well-known transmission manufacturer. This company is a leading supplier of drive train components and systems for the automotive industry and is the only tier 1 supplier worldwide to design, develop and manufacture complete all-wheel drive systems in-house. The interest of automotive manufacturers is correspondingly high. In order to cope with the great demand from the industry, the company focused on optimizing its processes at an early stage and scrutinized its system in the USA together with the strategy experts from KUKA. All procedures were analyzed and the results used as a basis for formulating targeted suggestions for improvement. The analysis was carried out using the Industrie 4.0 tool

KUKA SmartProduction_management, which is capable of examining the performance of an entire system down to the smallest detail. It communicates with the individual stations and collates the results. The outcome was extremely satisfactory: 500,000 data points were acquired on a daily basis and investigated directly from the system. This scanning in turn allowed highly relevant conclusions to be drawn regarding availability, cycle times and daily output. Ultimately it proved possible to network a total of 18 stations using KUKA SmartProduction_management – manual workplaces as well as joining, measuring and assembly stations. Over a period of six weeks, KUKA's data analysts were able to isolate problematic stations and propose specific improvements on the basis of the production data. For example, this included the exchange of worn holding points for measuring pinions and the installation of shock absorbers on the counterweight to accelerate positioning of the pneumatic cylinders.

These optimizations enabled the global acting transmission manufacturer to significantly improve the cycle time of the overall production system. KUKA SmartProduction_management is to remain networked with the system in the future too in order to allow the processes to be continuously analyzed and corrected if necessary.





The KR titan on a linear unit in a perfect workflow with the KR AGILUS

KUKA SmartProduction Augsburg Step by step to production of the future

As a thought leader and technology pioneer, KUKA also implements its own solution concepts in production at the Augsburg site. “KUKA SmartProduction Augsburg” is the name of the project in which production cells with robots, processes and a great many other assets are all interconnected.

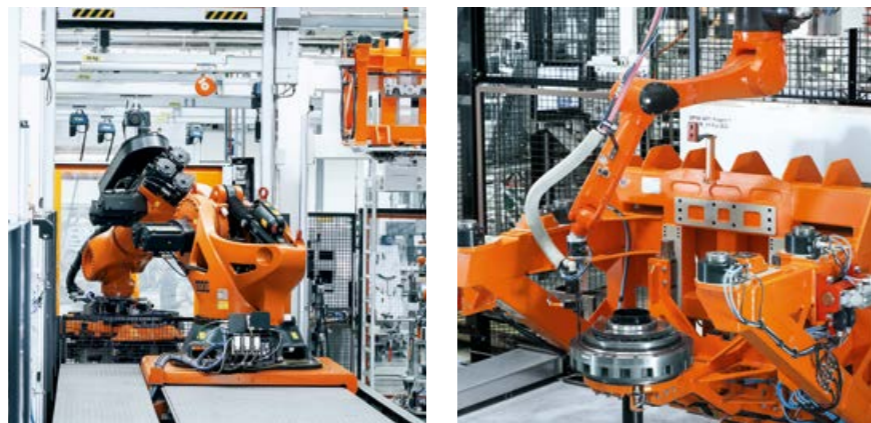
The experience with digitization in the company’s own manufacturing operations shows that the development potential and future prospects of this approach are enormous and a genuine benefit for the production workers.

The majority of robot types are built on a production line at KUKA’s Augsburg plant. For example in the cell for assembly of axis 1, where components for the first robot axis are joined fully automatically. The KUKA SmartProduction project kicked off with this assembly procedure as the preconditions for networking the production cell were ideal. All assets employed there are already “intelligent” or have a controller with an interface suitable for networking. Connecting all machines, also known as assets, to the cloud enables data to be collected and evaluated. The data and their analysis are visualized and presented to the user via a graphical user interface. These so-called asset views can be adapted as desired and also provided with alarm functions in the case of faults. Besides KUKA’s own products, such as the

KR AGILUS, KR titan or KMR iiwa, non-KUKA assets too, like the cell controller (PLC) or torque wrenches, are connected and visualized on the KUKA SmartProduction user interface.

This simultaneously demonstrated the performance of the KUKA middleware that is used, whose flexible and open architecture allows third-party assets to be connected without any problems. To provide a specific example, a dashboard with various performance indicators for the production managers was created via the cell controller (PLC). Integration of the wrenches also makes it possible for verification of all screw connections to be displayed on the KUKA SmartProduction interface. In the event of a defect, the point at which a problem occurred with one of the wrenches can thus be quickly identified.

—The success of the project opens up attractive perspectives for continued development. For this purpose, the responsible parties involved call on assistance from the company’s own Consulting group. In an intensive exchange with the production specialists, new potential applications are developed which are to be implemented in the near future.



Flexibility is the be-all and end-all in automobile production.

Starting a new era with detailed data analytics

Producers in the automotive industry are under pressure to minimize throughput times. This is why appropriate solutions are required: conveyor systems which allow for quicker processes in body-in-white production are thus attracting more and more attention from vehicle manufacturers.

KS PULSE (Propulsion Using Linear Synchronous Energy), the pallet-based transport system from KUKA, quickly and safely moves the various body components through the individual workstations of an automated assembly line – thus reducing non-productive times and downtimes.

It is no longer possible to imagine manufacturing shops without them: automated transport systems are today an integral part of production. Particularly for automotive manufacturers, moving large vehicle bodies from A to B is essential. This calls for handling systems which are robust and yet nevertheless fast and flexible. For this purpose, KUKA has developed a pallet-based transport system for automated assembly lines in body-in-white production: KS PULSE. The main element of the transport system is a carrier. Using various transport platforms, called skids, this carrier transports the individual body components through the assembly line. The carriers are moved through the process stations of the system by means of linear synchronous motors.

The system stands out for its low susceptibility to malfunctions because very few moving parts are used. The key advantages of KS PULSE are its high transport speed and flexibility: the skids are interchangeable in terms of cycle time, enabling multiple models to be produced on one line. Beyond this, additional components such as turntables or buffer stations can be integrated into the PULSE system, ensuring that the system can be adapted as required for individual production scenarios.

Carrier control (i.e. moving to the individual stations as well as collision protection) is carried out via software. No further sensors are required for precise positioning to ± 0.1 millimeters.

—KS PULSE is the optimal solution for high-volume production systems. KUKA's experts implement it in the context of complete solutions.

Robust and flexible: KS PULSE transports body components quickly and safely through the production stations.





HRC system for automated screw fastening

When robots help to build their colleagues.

Even the production of robots can be automated one step at a time. KUKA is demonstrating this at its own factory in Augsburg, where the company is using a versatile HRC system to automatically fasten two types of gear units for the KR QUANTEC robot.



The sensitive lightweight robot LBR iiwa is a pivotal element in a large variety of human-robot workstations at many companies. Either stationary or as a mobile assistant in the form of the KUKA flexFELLOW, it is ideally suited to playing an important role in the production process at the KUKA plant in Augsburg. Indeed, it is now successfully used in KUKA's robot manufacturing operations to support the human workforce with the production of its colleague, the KR QUANTEC.

For this purpose, KUKA developed a versatile HRC solution to make a non-ergonomic workplace more productive. The system, which is controlled using gestures, sensitively distinguishes between components and independently calibrates itself to determine its position at the workplace. The LBR iiwa then fastens 36 or 30 inserted screws on four housing variants with a torque of 104 Nm and documents the work steps through the wrench controller. The LBR iiwa pushes against the gear unit and is thus able to achieve the torque required for the screw fastening. At the same time, it can reach all screw positions without any restrictions.

„Certified by the employer's liability insurance association, the system thus helps to boost productivity using direct collaboration with its human colleagues. This is an important milestone on the way to intelligently networked automated robot production.“

The HRC-capable LBR iiwa works hand in hand with humans and, as a result, is revolutionizing industrial production and manufacturing.

90 tonnes positioned with millimeter precision

Robot platform assists in the A380 hangar.

Wingspan 80 meters, length 72 meters, deadweight 275 tonnes: according to any criteria in the aerospace industry, the Airbus A380 is a giant. Entirely new procedures had to be developed for its production in some instances, with great challenges for manufacturing technology. This is also evident at the Airbus site in Hamburg-Finkenwerder, where, among other things parts of fuselage of the A380 are built.

One of the difficult tasks to be mastered in Hamburg is also the transport of large parts along the production flow line. At 15 meters long and weighing 90 tonnes, these are among the largest individual components processed. This is then complicated by the fact that the space in the hangar is limited by the different work stations and the huge fuselage sections.

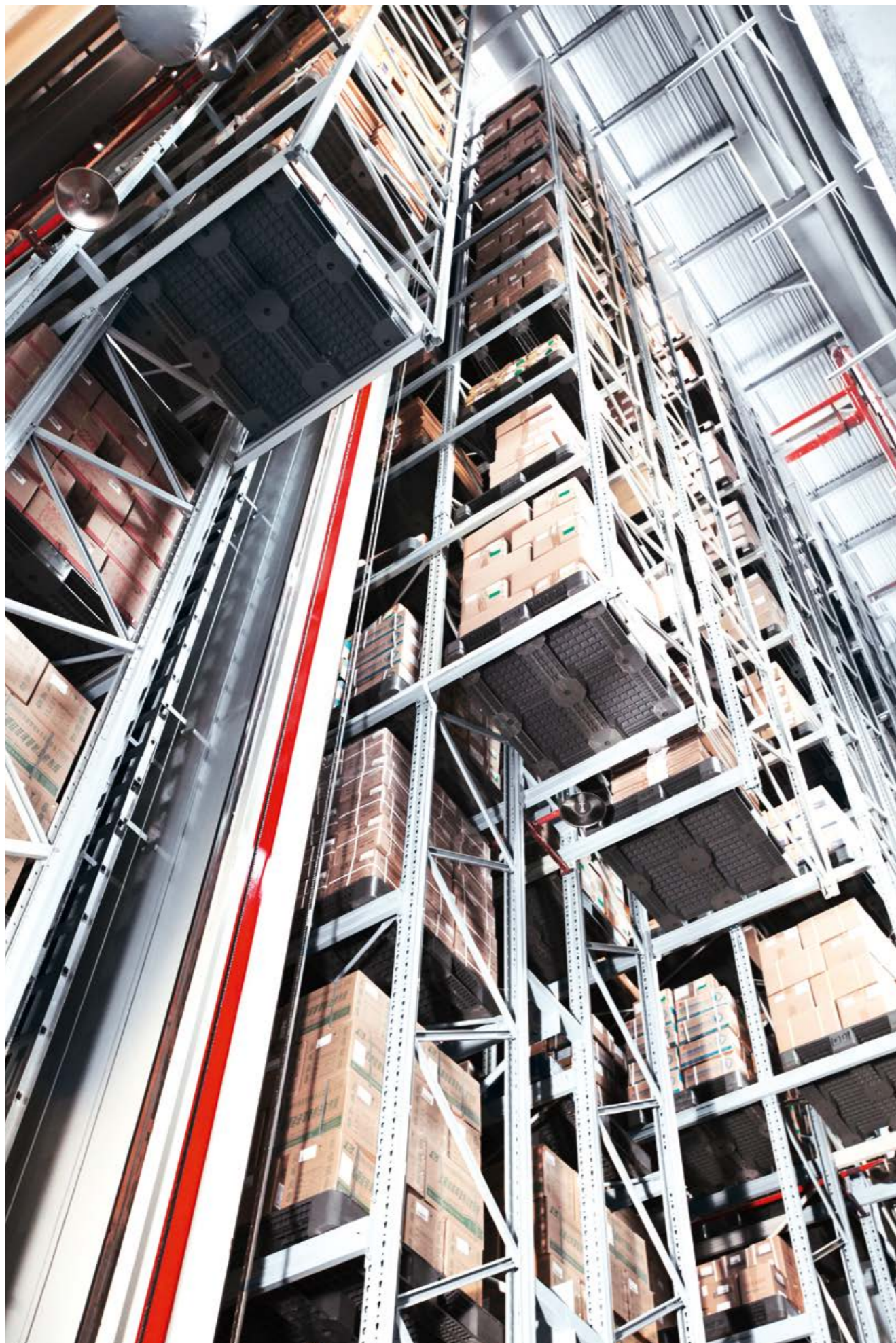
As a solution to meet this challenge, the Airbus engineers turned to cutting-edge technology from KUKA: two powerful mobile KMP omniMove heavy-duty transport vehicles are used to transport the parts. Their most important characteristic: they can turn from a standing start. This is made possible through the use of Mecanum wheels. They allow the vehicle to execute omnidirectional maneuvers, without requiring mechanical steering. The Mecanum wheels move in every direction and operate with the utmost precision even with a maximum payload of up to 90 tonnes. This wheel

design enables the KUKA omniMove to transport the gargantuan aircraft components with millimeter precision in confined spaces. Airbus uses two of these innovative vehicles at its plant in Hamburg-Finkenwerder. This makes it possible for the desired cycle time for the transportation of the fuselage sections to be maintained. As a result, Airbus employees profit from simple, easy-to-learn handling, flexibility and precision as well as the easy steerability of the KUKA omniMove. Another plus point: the transport platform operates tirelessly for 48 hours without the need to recharge the battery. After all, aircraft components do not wait.

—Precisely transporting heavy parts in confined space – this is the specialty of the KMP omniMove. Millimeter precision work facilitating aircraft production: flexible, economical and easy to use.



Where high-tech giants are being built, XXL parts have to be moved safely, quickly and with millimeter precision. At the Airbus plant in Hamburg-Finkenwerder, KUKA omniMove heavy-load mobile platforms take care of this tricky task masterfully and reliably.



Automated software upgrades Fountain of youth for warehouse management software

Digital solutions require continuous updating. Particularly in the era of Industrie 4.0 it is of great importance for the implemented solutions to be kept constantly up to date and not to cause performance bottlenecks due to inconsistencies or missing upgrades.

ForeverYoung is a service offered by Swisslog for automatically migrating the SynQ warehouse management solution to the current version. The great advantages of this service are proving effective in practical operation at Norwegian trading company Harlem Food.

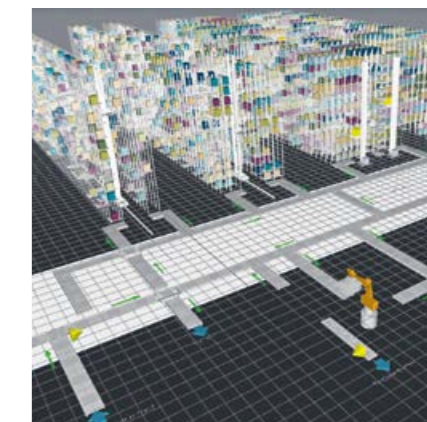
Alongside product quality, speed and flexibility are the most important demands to be met by food retailers. Modern trading companies can hardly satisfy these demands in the long term without sound digitization solutions. Major players in this sector therefore implement high-performance warehouse systems. The Scandinavian Harlem Group, for example, relies on the warehouse management and business intelligence platform SynQ from Swisslog, which makes warehouse management ready for Industrie 4.0.

The Harlem Group is a fully integrated trading company specialized in buying and selling consumer goods on an international scale. The company offers products and services for the retail market and food industry with a portfolio including commodities, consumer goods and private label products. It markets an assortment of over 800 products and makes annual trades of over 300,000 tonnes of commodities. As a user of SynQ software, the Harlem Group has the option to migrate the solution

to the most recent version every year so as to be able to use the latest features of the platform and also to support appropriately certified solutions from third-party vendors. As experience has shown that compatibility problems may repeatedly arise in the interaction between hardware, databases and operating systems on account of upgrades not being promptly implemented, the Harlem Group opted to make use of a Swisslog service that is becoming ever more important for Industrie 4.0 environments: the ForeverYoung migration service. This is an optional feature of Swisslog support and automates administration of the SynQ environment.

The ForeverYoung process begins by comparing the productive version of SynQ deployed by the Harlem Group with the youngest platform version available at the time. An upgrade version of the Harlem Group solution, adapted to any new features introduced in the meantime, is then automatically tested and validated before being migrated to the active work environment.

...This service reduces downtime and errors resulting from incomplete upgrades. As even minor updates are implemented promptly, the company also avoids more extensive upgrade procedures. ForeverYoung really keeps SynQ constantly up to date with the latest releases – a key element in a smart warehousing solution and the basis for further future Industrie 4.0 applications.



Automated fastening of pump wells

Measure. Fasten. Perfect fit.

As part of Industrie 4.0, monotonous and ergonomically straining manufacturing tasks are gradually replaced with automation solutions that enhance efficiency and productivity. This is demonstrated in the example of the changeover that took place at BSH GmbH for screwing pump wells into place on the dishwasher production line. An innovative solution is used with the KUKA flexFELLOW, equipped with the LBR iiwa.

In order to precisely fasten the pump wells, the operator is required to bend over into the dishwasher housing – an uncomfortable posture and a monotonous work step. This task perfectly lends itself to automation. Bosch Siemens Hausgeräte GmbH decided to take the leap and selected a mobile solution: the KUKA flexFELLOW, which is customized for the environment at the company's Dillingen plant.

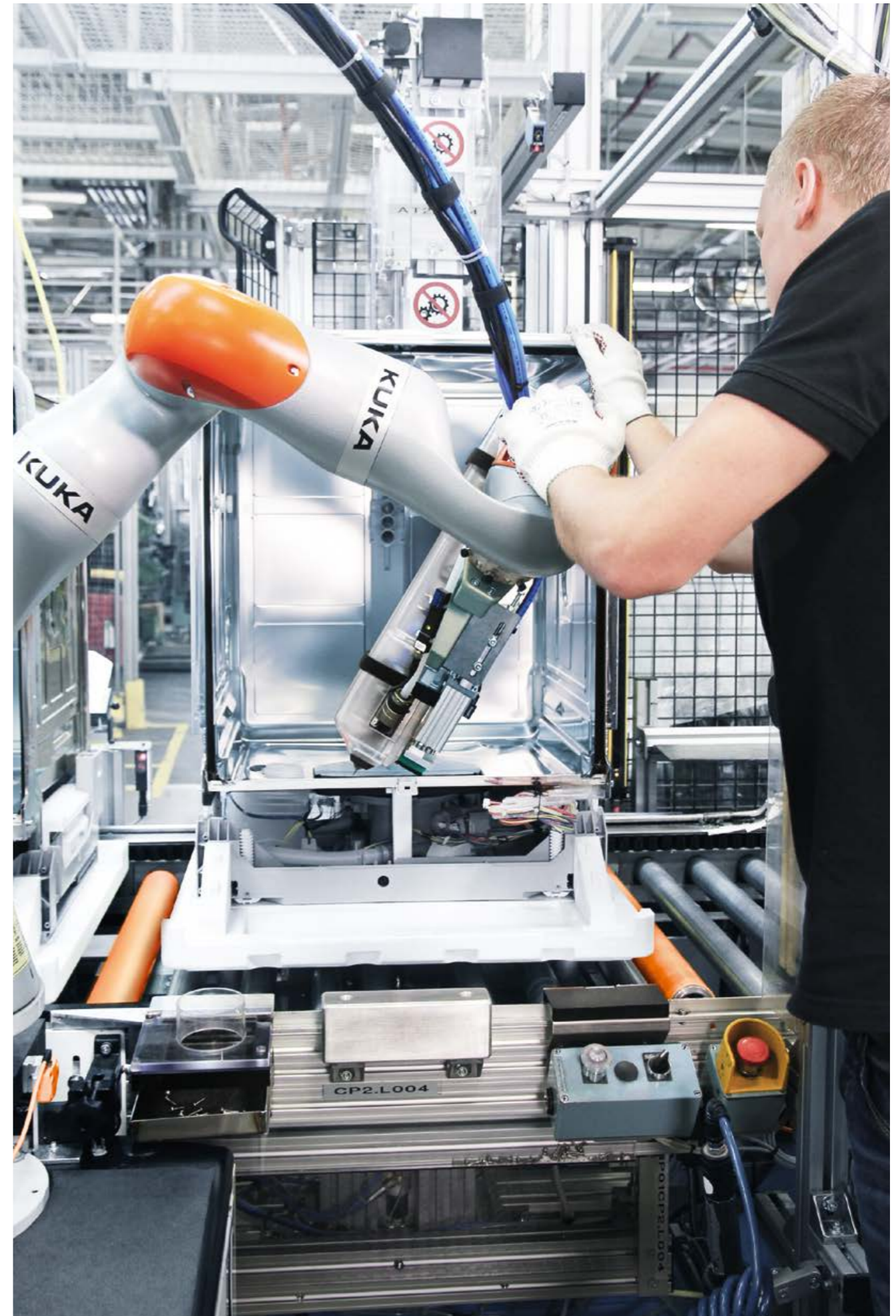
The robot was flexibly integrated into the production line, so that the existing manual workstation could be left unchanged. It is now independently fastening the pump wells – 16 screws

in four seconds, and doing so with the highest precision. The operator can walk right up to the robot during operation to observe and monitor the process. No safety fences are required.

The robot relieves the employees and increases productivity by adjusting itself: it calibrates independently within the workstation, uses search run mode to locate the screw positions, carries out fine adjustment of the part, and tightens the four screws. If the component concerned is not perfectly adjusted, the robot recalibrates the dishwasher housing. For this, it develops a search strategy for the screw positions and recalculates them. The mobile KUKA flexFELLOW platform enables this solution to be flexibly deployed at various locations.

...And, as is deemed appropriate for an intelligent Industrie 4.0 solution, the LBR iiwa contributes to collecting information: it documents its tasks and reports whether or not the screw fastening process was successful.

Thanks to its sensory capabilities, the LBR iiwa independently and reliably moves to the exact position of the workpiece to perform sensitive assembly tasks.



Automated dispensary for Chinese clinics

Robotics as a remedy for stressed pharmacists

Chinese hospitals are subject to constant intense activity when it comes to dispensing drugs. On average, this clinic processes 4,500 prescriptions daily, with peaks of 600 per hour. The automated drug dispensing system UniPick 2 swiftly transports the drugs from the storage racks to the transport basket after verification. Patients benefit from significantly shorter waiting times.



Tight spaces and little time – these are the conditions that pharmacists have to deal with in Chinese hospitals. In order to optimally exclude errors in administering medications, local pharmacies can now rely on an automated dispensing system from Swisslog.

This solution also offers hospital pharmacies an important edge in terms of productivity by increasing the process efficiency and quality.

Chinese hospitals and their pharmacies are under ongoing pressure; thousands of patients need to be treated and supplied with medication daily. The pharmacies are subject to constant intense activity, handling up to 600 prescriptions per hour. Medications are dispensed every second. Human error is unavoidable due to the highly stressful situation.

This has now fundamentally changed thanks to an intelligent hospital dispensary solution from Swisslog, developed specifically for the Chinese market. The combination of a special management app and the automated drug dispensing system UniPick 2 largely prevents errors. In addition, the manual process of drug and prescription management is digitized, increasing the hospitals' productivity.

UniPick2 consists of a conveyor which moves vertically up and down on the storage racks as well as a robotic loading module, the combination of which makes

it possible to fill the transport basket and distribute the drugs at the same time. On average, ten prescriptions per minute can be processed, which reduces the waiting time of customers. During dispensing, the system checks the storage in real time using a laser scanner to ensure that plenty of stock is available.

This automation technology is embedded in a software application, which automatically checks the prescription and thereby ensures that the right drug at the right dosage is removed from the respective cabinet every time. The prescription analysis, patient information, and drug handling process are paperless throughout. In addition, important performance indicators are measured and prepared in real time on a KPI dashboard. Information about prescription category, dispensing status, inventories etc. can be compiled in a graphical report and archived. This enables continuous digitized inventory management.

...As a result, the Swisslog solution provides an enormous increase in terms of speed, but above all it offers a drastic reduction of errors in drug dispensing and dosing.



KUKA ready2_use for 4.0 production

Digital support with a high IQ

The road to efficient manufacturing facilities in the Industrie 4.0 concept involves technologies with “built-in” process expertise. The solutions used must flexibly adjust to production processes while also being individually adaptable and versatile. This only works if they are designed from the outset for use in networked automated production facilities.

With ready2_use, KUKA has created a portfolio of flexible solutions which makes various automation technologies ready for Industrie 4.0. All packages are, for example, designed for integration into a cloud environment and can be integrated into any modern smart factory concept.

Every sector has very specific requirements for the automation of production. And even companies in the same market segment differ in their individual manufacturing processes – and therefore in the scope, degree and type of automation required. Solutions for networked automation must therefore be extremely adaptable and versatile. Against this background, the new ready2_use packages from KUKA are optimal solutions which are modularly scalable according to demand and can be adapted to the specific system.

Fastening M1 screws with consistent torque in a very short space of time and with the same quality and pose repeatability – a perfect field for a ready2_use application. The fast-moving electronics sector, with its extremely short product lifecycles, its rapid pace of innovation and its wide range of variants, is an

ideal field of application for tailor-made networked automation and application solutions. The space restrictions require utmost agility and accuracy to meet quality and throughput specifications.

As an Industrie 4.0 pioneer and world market leader in industrial robotics, KUKA provides the electronics industry with the perfect solution in the KR 3 AGILUS for meeting its challenging requirements. The KR 3 AGILUS is optimized for the production of the smallest components and products. Its reach of 540 mm is ideally tailored to the 60 cm x 60 cm surface of an average workplace in the electronics industry. Using a special screwdriver tool, it masters the attachment of micro screws in a wide range of positions with utmost precision. By doing so, it is the first six-axis robot for the fastening of type M0.8 to M2 screws on the global market.



A delicate touch is called for: with great sensitivity, the KR 3 AGILUS fastens micro screws even with a diameter of just 0.8 mm!



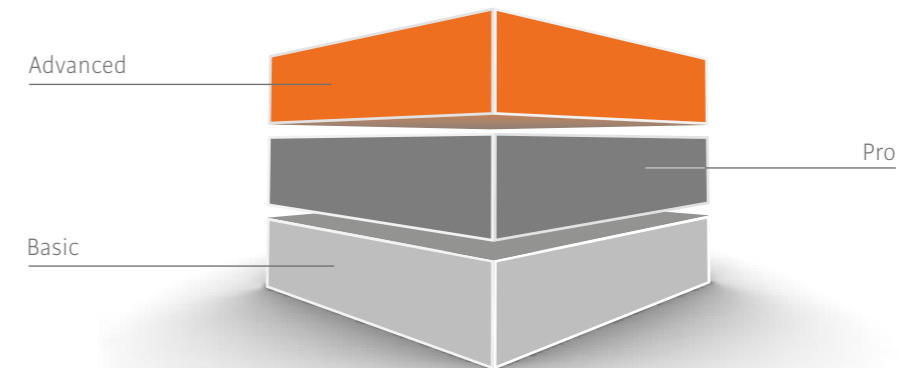
This solution of an intelligent screw-driver for fastening micro screws with previously unprecedented quality and precision is called “ready2_fasten_micro”. ready2_fasten_micro stands for a pre-configured complete solution which is easy to implement when using KUKA’s comprehensive process knowledge and can be quickly integrated into individual production units. In terms of flexibility, this concept is unbeatable. If the production specifications change, so too does the cell. The ready2_fasten_micro solution is simply reconfigured or combined with other units. The solution is cloud-capable and can be integrated into a smart factory via platforms such as KUKA Connect. Typical Industrie 4.0 functions such as process analysis and quality assurance are easy to implement with ready2_fasten_micro.

The substantial backlog of demand for automation in the electronics industry can be covered cost-effectively and sustainably using solutions like ready2_fasten_micro.

The smallest screws are positioned quickly and precisely by intelligent high-tech helpers – this is what smart manufacturing looks like in the electronics industry. ready2_fasten_micro from KUKA makes it easy to enter the world of automation.



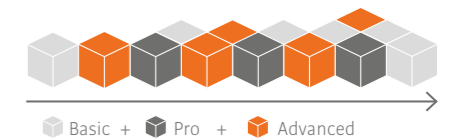
Powerful automation begins with “ready2_”.



ready2_use solutions support a more efficient, faster and more agile automation of industrial production. They facilitate the path to the smart factory through preconfigured and task-oriented solution packages that can be easily implemented.

We have the solution – the choice is yours.

Various ready2_use solution packages are available to meet individual requirements. The three levels Basic, Pro and Advanced create different possibilities of use. The different packages can be combined, resulting in a wide range of further solution options.



Practical, immediately available, ready2_use

Each ready2_use solution meets particular, industry-specific requirements. It seamlessly fits into the individual manufacturing environment and handles tasks where the automation of processes is effective and profitable.

Increase flexibility and productivity, gain time, cut costs

Processes automated with ready2_use improve the agility of manufacturing, optimize production performance, can be quickly integrated into the existing manufacturing environment and work cost-effectively in precisely the areas where they quickly pay for themselves.

ready2_use solutions:

ready2_grip
preconfigured gripper solution based on the KR AGILUS

ready2_spray
preconfigured automation solution for painting tasks

ready2_arc
preconfigured arc welding automation for the metal industry

ready2_spot
preconfigured spot welding automation solution

ready2_powerlink
solution for integrating KUKA robots in third-party controller systems

ready2_pilot
solution package for the easy control of a robot without a need for training

ready2_fasten_micro
complete automation solution for fastening of micro screws

Smartphone instead of clipboard

Mobile data management in the automotive industry

The manufacturing shops of the modern automotive industry are showpieces demonstrating automated production methods. Thanks to the full-scale introduction of industrial robots, the industry has been able to make a significant quantum leap in terms of efficiency and productivity.

With a mobile data management solution, KUKA helps to extend the potential efficiency gains through digitization to processes which currently still have to be largely performed with analog technology.

The processes that have often not yet been digitized even in the automotive industry include the management and monitoring of procedures in the construction or integration of manufacturing systems. As efficiency gains due to digitization translate into time and cost savings, KUKA offers a smart solution for mobile data management (MDM) in systems engineering. It makes all relevant data and documents for the construction or conversion of a system accessible on mobile devices such as tablet PCs or smartphones. As it is currently used on KUKA's own construction sites, the system architecture is centered on the cloud-based storage and management of data and documents. The advantages of this solution are obvious: mechanics, electricians or project managers can download all required information from the central database using any compatible mobile device, allowing them to work offline as well.

All incoming data such as information on the status of the construction measures or corrected and confirmed design plans are stored and managed in this database. By means of user profiles and defined responsibilities, the MDM system makes sure that all users can access precisely the information that is relevant for them. If a project team member scans a QR code affixed to a robot or another item of equipment, all data of importance for their field of activity at the system location are displayed on their mobile device. Additionally, a state-of-the-art OCR text recognition system enables them to retrieve information using the labels on existing system elements. In the automotive industry, the MDM system even provides yet another option for increasing process efficiency: as all relevant data are collected centrally, the time is saved that the personnel previously needed to search for the appropriate documents. Moreover,

central storage of the data makes for a substantial improvement in quality, currency and system safety. KUKA offers its customers the option of now also deploying this tried-and-tested system for documenting manufacturing systems and optimizing maintenance work. The focus here is primarily on speeding up the training of new personnel, reducing downtime through more effective problem localization and the additional option of building up a knowledge database. For this purpose, the MDM system can access real data from the system controller and display error messages directly on the mobile devices.

„With this mobile data management solution, KUKA has been able to put an end to the analog age at a central node of the value chain – a further, important step towards the Industrie 4.0 production environment.“





Human-robot collaboration in the manufacture of axle transmissions

The worker with seven axes

While not too long ago operators at the BMW Group plant in Dingolfing had to lift and fit differential cases for front-axle transmissions in the tightest of spaces, the early adaptation to Industrie 4.0 has now radically changed the workplace.

A specially designed human-robot collaboration (HRC) solution from KUKA Systems is now relieving the staff of all strenuous tasks while making the plant future-proof at the same time.

Lifting 5.5 kg differential cases that are difficult to grip, and fitting them with millimeter accuracy in the tightest of spaces – thankfully, this back-breaking task is now a thing of the past for the operators at the BMW plant in Dingolfing. Today, this immensely arduous work step is handled by an LBR iiwa lightweight robot with utmost precision and efficiency.

To maximize the LBR iiwa's efficiency, KUKA has developed a slim steel structure, which is mounted on the ceiling. From an overhead position (and thus saving space), the powerful yet sensitive machine goes to work. The entire control technology including the interfaces for the system controller has also been accommodated in the available space.

The robot fits seamlessly into the production environment. Not a single adjustment of the production line was necessary for installation. The biggest benefit of the new automation solution from KUKA is that the human colleagues of the LBR iiwa robot can safely move about in the production zone. For this purpose, the robot gripper is equipped with an HRC case, so that the operator is protected from injury at all times.

And this is what the collaboration between humans and robots looks like: the processed components are automatically transported to the system via a conveyor and are prepared by the operator. The operator places all of the small and lightweight parts, such as spacers and ball bearings, into the transmission case and the cover. The worker then activates the robot, which fits the heavy differential case in place. Next, the operator fastens the cover to the transmission. The procedure takes no more than 30 seconds.

„This highly effective KUKA solution is forward-looking Industrie 4.0 technology at its best – individually adapted to the conditions of a production line, intelligently networked with the control systems, space-saving, and designed for close collaboration with the machine operators. In short: the production of the future is already underway at the BMW Group plant in Dingolfing.“

Human operators and robots collaborate to install differential cases for front-axle transmissions.



An aerial photograph of New York City, featuring the Freedom Tower and other skyscrapers, with a digital network overlay of white lines and nodes across the sky. The sun is visible in the top left corner.

Industrie 4.0_Glossary

»Robotics, automation technology and digitization will shape the next half-century in the same way that the Internet, smart-phones and computers have shaped the past half-century. Our grandchildren will grow up as the first generation ‘R’ of ‘robotic natives’ – and we have to start taking responsibility for this today!«

Dominik Bösl
Vice President Consumer Driven Robotics
KUKA Aktiengesellschaft

Administration Shell

_All data in a single shell. The administration shell is the virtual image of a hardware or software component in a production process, containing all the specific production data. This data opens the way to entirely new possibilities and added value in networked production. One decisive benefit is that all information – from CAD data and maintenance information through to configuration details – is located in one place without media discontinuity. Data and functions are available on the component itself, in the company network and/or in the cloud. This collection of information results in an all-encompassing knowledge which, once stored, can be made available for any user and any application.

App

_Expertise from the cloud. Apps for industrial scenarios – programs for defined, specific applications – are the answer that experienced specialists with extensive process and industry know-how offer up for customers’ challenges. Intelligent mobile apps make modern companies Industrie 4.0-capable. KUKA offers apps for a wide range of challenges across the entire value chain – in manufacturing, for example, their functionalities encompass Maintenance Services through Asset Management to Demand Planning.

App Store

_New capabilities on demand. Already equipped for the future: for generations, KUKA robot controllers have featured a modular and scalable configuration on the basis of mainstream technologies. Among other things, KUKA has thus created the foundation for making smart tools available via app stores and marketplaces. Intelligent digital forms or complete applications, such as those familiar today from well-known app stores for smart-phones, tablets or computers, and which endow robots with new capabilities and functions on demand at the click of a mouse. For example, programs that only require entry of the desired parameters. With regard to Industrie 4.0, the immediate availability of new production capabilities will open up a whole new dimension of versatility for robots.

Artificial Intelligence

_Machines as intelligent partners. Artificial Intelligence (AI) is the step required for implementing the fourth stage of the robotic revolutions postulated by KUKA. It presupposes that machines, information systems and robots are capable of becoming still much more intelligent and responsive. In the fields of service robotics and home assisted living, these intelligent machines with their cognitive and sensitive capabilities will become increasingly important as helpers for humans. Today, these systems are still fully dependent on programming by humans. As the degree of autonomy of the systems increases, however, the issue of responsible management of artificial intelligence will become ever more pressing.

Batch Size 1

_Unique, one-off products for everyone. 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. This means high-quality, single-piece production at the price of current uniform, mass-produced goods. The networking of all systems involved in production, and their extreme flexibility, will make the fulfillment of individual customer requirements a matter of routine in the smart factory. While the desire for customized products is already a megatrend today, it will develop to become one of the decisive competitive factors in the near future. This trend not only offers new market opportunities for products, but also gives traditional industrial nations the option to return previously outsourced production capacity to locations in high-wage countries.

Big Data

_Data is the new oil. The term “Big Data” refers to quantities of data that are too large or too complex, that change too quickly or are too weakly structured for them to be evaluated with manual and conventional methods of data processing. In this context, experts talk about an inconceivably large data volume of currently more than eight zettabytes – with an increasing tendency. A substantial proportion of this already comes from the Internet of Things (IoT) and from the ever more numerous sensors in machines and vehicles. Data is increasingly being generated in real time. In connection with Industrie 4.0, however, it is the ability to evaluate and process this flood of data that is of paramount interest. That is how Big Data becomes Smart Data. The challenge is therefore not only for IT systems to be able to handle heterogeneous data correctly but also for them to analyze the data in order to create a reliable basis for business decisions – preferably in real time. Only in this way can processes be controlled intelligently and adapted to changing parameters. Taking the metaphor further, Big Data is thus the new oil of the 21st century.

Cloud Robotics

_Shared intelligence. Nowadays smartphones, tablets and computers utilize data and processing power from the cloud as a matter of course. In the context of Industrie 4.0, robots too will be able to access decentralized data in networks or in the cloud, thereby significantly boosting their performance and flexibility. The robot itself will only require a small chip to control functionality, motion and mobility. 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. In this way, specialists will become universalists that can be used for a wide range of different manufacturing processes. Cloud robotics enables the implementation of a broad spectrum of different industry-specific applications via “Robotics as a Service®”. Another effect of the cloud: robots learn from one another. If one robot encounters an obstacle, for example, it posts this information to the connected systems, which can use it to respond intelligently to the obstacle.

Collaborative Robots

_Hand in hand. Collaborative robots – sometimes also known as “cobots” for short – are robots that are capable of human-robot collaboration (HRC) and work hand in hand with their human colleagues. As collaborative robots operate without physical safeguards, they have to permanently calculate the risk of colliding with humans, constantly checking this via the robot controller. The strict safety requirements have been redefined in the revised EN ISO 10218 standard, parts 1 and 2, and in the ISO/TS 15066 specification initially drafted in 2010. Besides the robot itself, the standard also covers the adapted end-of-arm tooling with which the robot performs its tasks, and the objects moved with it. With the LBR iiwa, KUKA has made the world’s first series-produced, collaborative lightweight robot for industrial applications ready for the market, thereby proving that the visions of Industrie 4.0 can be turned into reality.

Committees

_Strong alliances with KUKA. As a leading supplier of intelligent automation solutions, KUKA is directly involved in Industrie 4.0 and sees itself as responsible for forming strong alliances with the goal of actively shaping the factory of the future together with other key players. That is why KUKA is a member of all major national and international advocacy groups and committees, such as the Industrie 4.0 Platform coordinated by the German Federal Ministry for Economic Affairs and Energy, the Industrial Internet Consortium IIC, the OPC Foundation, the german industry association VDMA and the associations BITKOM and VDE. As a trailblazer for Industrie 4.0, KUKA is a sought-after interlocutor for decision-makers in the worlds of politics, research, and business.

CPS (Cyber-Physical System)

_Physical world meets virtual world. A cyber-physical system (CPS) is a “thing” in the Internet of Things (IoT). It is a combination of mechanical and electronic software components that communicate via a data infrastructure such as the Internet, react flexibly to external influences and exchange data with information systems and other CPSs. In future manufacturing facilities, cyber-physical systems will communicate with intelligent, networked industrial production and logistics units – also known as cyber-physical production systems (CPPS). The CPSs exchange information, trigger actions in production and reciprocally control themselves autonomously. This enables industrial processes in manufacturing, engineering, use of materials, supply chain management and life cycle management to be fundamentally restructured and optimized.

Data Ownership

_Who owns the data? The data must belong to the originator. A principle that is regrettably contested in the cloud. The open exchange of data and information, however, is a vital ingredient of Industrie 4.0. Information that was generated in the company prior to storage in the cloud is generally subject to local copyright laws. But if the data is created in the cloud, things become somewhat more ambiguous. Cloud providers have a different approach to dealing with user data in terms of access rights and at times create confusion as to ownership. It is therefore important to ensure transparency in the use of cloud services and to select secure encryption for all data sent to the cloud. This gives users control over their data and thus some form of ownership, regardless of legal issues. Particularly with a view to the horizontal networking of various companies within a production process, the question of data sovereignty is of central importance. With cloud solutions meeting the highest data security standards, KUKA offers unique platforms on the basis of which customers can exchange their own data with others or enrich them with new intelligence and additional information.

Decentralized Intelligence

_Intelligence evolves in the swarm. Decentralized intelligence will play an important role in Industrie 4.0: all parties can communicate with one another – workpiece with machine, machine with machine or with higher-level processes. No central “brain” will control and monitor the things, but rather autonomous production units will carry out this function for both heterogeneous and homogeneous teams. Decentrality makes for greater flexibility and quicker decisions. Intelligence evolves in the swarm or through joint networking with the cloud.

Demographic Change

_Society is getting ever older. In principle, the term “demographic change” is a neutral reference to any alteration in the age structure of a society. At present, however, it is being widely used as a synonym for increasing overaging in the industrial nations. A trend that is diametrically opposed to the rapid growth of the global population. By the year 2020, more than half of the German population will already be over 50 years of age. An ever smaller number of people in employment will have to generate the entire productive output for the social systems. This challenge can only be met if the remaining workers become considerably more productive than all generations before them. At the same time, opportunities must be created for older, experienced employees to participate in the world of work for longer. In order to make new working environments both highly productive and ergonomically beneficial for the labor force, KUKA is developing central key technologies for Industrie 4.0: collaborative robots, mobile assistance systems, autonomously controlled vehicles and smart, digitized automation solutions that support humans in the work setting, easing the workload in a variety of ways.

Development Community

_Innovating together. Intelligent solutions benefit from the expertise of many creative professionals. KUKA offers interested developers access to a powerful platform that serves as a central point of contact for exchanging a vast variety of information. This community assists its members with expertise, support and resources. This platform for developers for developers, a “KDN – KUKA Developer Network” so to speak, facilitates the very exchange of information that makes the added value of team creativity fruitful. The bundled expertise further strengthens the potential of the KUKA ecosystem. As an example, the platform makes it easier for start-ups to generate business processes and develop new business models.

Digital Business Transformation

–**Creating the business of the future.** Digitization is upending a large number of existing business models. Networked automation, intelligent processes, shared expertise across companies and industries, and a holistic view of the value chain with involvement of the customer – these are the characteristics of digitized business models. They open up completely new business opportunities and options, and offer competitive advantages – and only they make it possible to fulfill customer requirements optimally. There is no economically successful future without the digitization of business models. With its own Consulting center of excellence, KUKA is assisting companies along the way to a digital future.

Digital Customer Journey

–**Journey through the digital business landscape.** In general terms, the “Customer Journey” represents the sequence of (digital) contacts that a customer may encounter when dealing with another company. Depending upon the issue, the first point of contact and subsequent contacts may vary. If a purchase is intended, for example, the customer’s journey may start off with the links in a search engine request or a rating portal, followed by a shop visit. The app store and support website are other possible starting points that are implemented in industry. For B2B processes, the initial contact may take place through the business cloud instead of a website, for instance by visiting a developer platform. KUKA serves its customers as a hub for organizing their digital journey.

Digital Shadow

–**Virtual image of real things.** The digital shadow is a digital image of a real object. This data contains both the current status and the desired status of the object, the possible ways and processes for achieving this desired status, and the history of what the object has already gone through. Only through the combination of a digital shadow and a physical object does a smart thing result. Every physical product can be manufactured more efficiently and with higher quality in the digitized production facility if a digital shadow has been created for it and it bears its own specific DNA.

Digital Value Chain

–**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. The potential of a digitized value chain lies primarily in the acceleration of the production and logistics processes, the reduction of effort for data acquisition and the optimization of data security and consistency. With integrated networking, the digital value chain is able to overcome current media discontinuity. One example from the field of procurement: where a steel-processing company previously had to activate a complicated process via different media for purchasing and replenishment, in the future purchasing will be automated on the basis of predefined parameters. Companies today are already making use of digital value 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. As the most flexible machine ever conceived by man, the robot plays a central role in the digital supply chain. In its function as the core component of intelligent automation solutions, it increases the entrepreneurial freedom of action, creates competitive advantages, speeds up production processes and assures quality in the long term. Integration into the KUKA Connect platform accelerates the conversion to a digitized value chain.

Digitization

–**Potential of the digital transformation.** Converting real products and analog sequences into digital data and processes is referred to as digitization. In Industrie 4.0, people, machines and industrial processes are networked on the basis of cyber-physical systems incorporating state-of-the-art information and communications technology. In this context, the intelligent exchange and interpretation of data determine the entire life cycle of a product: from the idea to development, manufacturing, use and maintenance through to recycling. Production and logistics processes will be globally networked beyond the factory gates in the future for the purpose of optimizing the flow of materials, detecting non-conforming parameters at an early stage and enabling a highly flexible reaction to changing customer requirements and market conditions.

Edge Cloud Gateway

–**The Cable Modem of the shop floor.** Much like a DSL Router connects peripherals to the Internet, an edge cloud gateway connects the various devices at the production level to a network or a cloud environment via EtherNet or wireless / mobile connection, so that data can be collected, exchanged and processed. Features such as secure communication and quality of service are implemented.

Flexibility

–**Flexibility in all dimensions.** Flexibility is the ability to react quickly to changing influences. In the smart factory, utmost flexibility results primarily from the combination of IT technologies, such as the Cloud and Big Data, with intelligent, generic production units incorporating robots and autonomously controlled mobile units. The factory of the future will not have any predefined routes or rigid processes. Mobile units will equip robots “on the fly” with other tools, enabling them quickly to carry out new tasks or process other workpieces. The smart factory is therefore able to manufacture different products or product versions without any significant retooling times. It thus completely redefines the concept of flexibility in production.

Framework

–**The programming kit.** Generally speaking, a framework is a defined structure for the programming of software or dynamic websites. So-called “pre-programs” allow developers to save time: frequently recurring program steps are already pre-programmed and can simply be called up when needed. Thus, it is no longer necessary to repeat certain functions and computer tasks. Frameworks provide valuable support particularly for quickly programming apps. In robotics, a framework provides software components for industrial use. This includes algorithms, libraries and methodological know-how. Standardized interfaces and appropriate middleware make it easy to replace hardware and software components. This simplifies and speeds up application development in automation.

Home Assisted Living

–**Living independently – even in later life.** Our society is becoming ever older: in 2035, one in every three Germans will be over 60 years of age. Everybody wants to stay autonomous and active for as long as possible when old, however. Home assisted living enables the elderly to continue an independent life within their own four walls. Besides service robots which take care of household activities, and smart home applications, services in the medical and nursing sectors will be a part of daily life in the future. With the aid of intelligent robots, rehabilitation treatment, for example, will be possible at home. Mobility assistants will help people to remain agile into old age, improving the quality of millions of lives.

Horizontal Integration

–**Dynamic company networks.** Exact coordination is not only indispensable for internal process optimization within a company, but also between all companies involved in the value chain. This horizontal integration – networking between different enterprises and their assets – is the starting point for the flexible design of their shared value creation processes. In the era of Industrie 4.0, companies will form dynamic networks in the future, linking order-specific and product-specific capacities in virtual production communities. Current data from the production-relevant processes will enable fast and precise reactions – for instance to planning changes or unexpected events occurring inside or outside an individual company. Production and logistics processes adapt to the real situation in real time, boosting the long-term flexibility and efficiency of the companies acting within an integrated concept. Process analyses to increase productivity involve many different components – and thus also their manufacturers. See also Manufacturing Ecosystem.

Individualized Production

–**Meeting every customer requirement.** Individualized, or customized, production refers to the concept of an intelligent, highly automated production system that allows high variance and dynamism in the product range with production costs at the level of mass production. The goal is to resolve the conflict between the customer’s desire for individualization and the process efficiency of production in an industrial setting. A batch size of 1 is the highest level of customized production. Besides proprietary solutions in the automotive sector, Industrie 4.0 with its universally networked production environments represents the world’s most advanced approach for implementing customized production.

Industrie 4.0

–**Production meets digitization.** Industrie 4.0, Smart Production or Internet of Things (IoT) – even if the names and terms used vary from one country to another, they all share the same goal. 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. KUKA is at the interface between these two worlds and is playing a decisive role in advancing this transformation as a thought leader and trailblazer for Industrie 4.0. It was back in the 1990s that KUKA as a first mover recognized the potential to be gained by combining the world of 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. In collaboration with experts from diverse sectors, KUKA is now already implementing highly flexible, digitized manufacturing processes that will open up new opportunities in a competitive environment and lastingly change the way we work and produce. KUKA supports companies with the digitization of production across industries – from small and medium-sized companies to large OEMs. This provides a platform for anyone who is ready to step into the world of Industrie 4.0.

Internet of Automation (IoA) / Internet of Robotics (IoR)

–**Basis for efficient production.** Both the Internet of Automation (IoA) and the Internet of Robotics (IoR) make use of defined open communications and data standards to network interoperable production processes even across company boundaries. In the IoR for example, KUKA robots, the KUKA App Store, middleware and monitoring tools are networked to form a highly efficient production environment in which analog and digital devices can easily communicate with one another. In the near future, it will be possible for all the cyber-physical elements involved in the automated manufacturing process to be networked in the IoA and to communicate with the IoR. Extensive standardization of protocols and technologies is required for this Internet-based infrastructure. See also Committees.

Internet of Things (IoT)

–**Everything communicates with everything else.** Like Industrie 4.0, the Internet of Things (IoT) presupposes a network of physical objects – devices, vehicles, buildings and other items – which are fitted with electronic components, software and sensors, all of them being linked interoperably via the Internet. Unlike Industrie 4.0, the IoT rather non-selectively refers to all things that could be connected to the cloud. The IoT thus also encompasses the private domain, including, for instance, the already well-known “smart home” applications. Strictly speaking, the smart factories of Industrie 4.0 along with all their production and logistics processes are a part of the IoT. Experts forecast that the IoT will comprise 50 billion objects by the year 2020.

Interoperability

–**Everything works together.** Interoperability (IOP) describes the ability of an object, device or machine to communicate with other things in the network. It must be able to do so regardless of whether the devices are from the same or different manufacturers. Interoperability is a fundamental precondition for creating a layer that enables cyber-physical systems to be interconnected such that interactions are possible without the participants knowing which technologies the implemented devices are based on. It is also the basis for the capability of the things in the network to communicate without any restrictions and to act intelligently as a swarm. See also Committees.

KMP omniMove

–**Strong on the move.** Wherever size, load-bearing capacity and precision are required, the KMP omniMove heavy-duty mobile platform is in its element. Individually or as part of a fleet, the KMP omniMove can effortlessly move beneath, and lift, workpieces weighing more than 90 tonnes and move in any desired direction with millimeter precision from a standing start, thanks to the multidirectional omniWheels. The KMP omniMove can move autonomously, under guidance along a programmed path or conventionally under manual control.

KMR iiwa

–**New horizons.** Shorter response times and greater flexibility going beyond full automation: these are the requirements of markets that are changing at an ever faster pace. The industrial manufacturing of the future will require modular, versatile and, above all, mobile production and manufacturing concepts. That is why the KMR iiwa unites the sensitive and compliant LBR iiwa lightweight robot with KUKA’s mobile platform technology to form a new, intelligent and fully mobile combination that can work in the vicinity of humans. Just like humans, the KUKA Mobile Robots (KMR) can also track moving workpieces, move around them freely and link solitary production islands to form new production units.

KMR QUANTEC

–**Large-dimension e-mobility.** Anyone thinking big and looking for flexible mobility will find the perfect powerful partner in the KMR QUANTEC. The combination of KUKA six-axis robots, mobile platforms, high-performance energy storage units and industrial-grade components creates a mobile solution for virtually any scenario. Despite its strength, the KMR QUANTEC is characterized by outstanding precision and maximum electromobility. Its small power plant supplies it with electricity for a full eight-hour shift. The position and number of robots installed are variable, as too are the size and payload capacity of the platform. Grippers, power-hungry tools and special equipment can also be transported on the KMR QUANTEC and continuously supplied with power.

KUKA flexFELLOW

–**Mobility on demand.** The KUKA flexFELLOW automation unit can be moved manually and allows ad hoc localized variation of the degree of automation in production. Without the need to alter the production layout, for example, the KUKA flexFELLOW is able to open the safety doors at machines, which it can then load and unload independently. It can also assist the operator in performing work steps in ergonomically unfavorable situations. In alternating operation, humans and robots can ideally complement one another. The combinability of manual and automatic tasks means that production can be optimally adapted to the specific requirements.

KUKA LBR iiwa

–**Robotic colleague.** KUKA is starting a new chapter in the history of industrial robotics with the lightweight robot LBR iiwa (intelligent industrial work assistant). As the first series-produced sensitive robot for human-robot collaboration (HRC), the LBR iiwa is tapping new applications that were previously closed to automation. Thanks to its sensory capabilities, it can intuitively learn new tasks on an ad hoc basis, simply through being guided by its human partner. The machine becomes a “robotic colleague”. It works hand in hand with the operator, thereby enabling him to work more efficiently, more ergonomically, more precisely and with greater concentration. As a robot that can genuinely be deployed universally, it is defining new standards on the road to the fourth industrial revolution.

Logistics

–**Now. Everything. Always.** Customized products and same-day delivery – customers have a growing expectation that everything will be available in all places, at all times. This ubiquity places the utmost demands on the logistics and process chains and is increasingly embracing the stationary retail sector and the structure of merchandise flows. The boundaries between individual delivery channels are successively vanishing and modern distribution centers are often being set up directly in metropolitan areas thanks to the reduced space requirements. Changes that can only be addressed through highly transparent, digitized networking of production and logistics. In this context, KUKA sees itself as a solution provider translating the individual requirements of the market participants into flexible, networked and software-supported logistics concepts.

M2M Communication Protocol

–**The universal communicator.** Machine-to-machine communication, or M2M, is the automatic exchange of information between machines. These may be vastly different end devices, from production machines through vending machines to vehicles or household appliances. A standardized set of rules is needed for M2M communication to work – in modern terms: a protocol. Such a standardized software interface enables universal communication. The most promising protocol at this time is the Open Platform Communications Unified Architecture (OPC UA).

Machine Learning

–**Knowledge through experience.** Intelligent machines garner their knowledge through experience. In the case of networked machines, it is irrelevant whether the experience is their own or originates from swarm intelligence. An artificial system always learns by comparing the desired objective and any anomalies that occur. It can recognize correlations, patterns and general rules, draw conclusions from them and modify its future behavior, this synthetic process being referred to as machine learning. Especially in unstructured environments and with highly flexible processes like Industrie 4.0, machine learning in a swarm or in the cloud is an effective method of adapting production processes intelligently and autonomously to the individual framework practically in real time.

Manufacturing as a Service (MaaS)/ Robotics as a Service (RaaS)®

–**Access rather than ownership.** Digitization has substantially changed the approach to physical possession. This is increasingly 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. As the name implies, manufacturing processes are provided as a service when offering “Manufacturing as a Service”: the machine does not change ownership, and only the service of the machine is paid for (for example in the form of a cost-per-uptime model). 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 a “pay-per-use” model, it will not be the physical object itself that is purchased in conjunction with “Robotics as a Service®”, but rather its performance, such as weld spots in vehicle body production, for instance. The smart factory of the future integrates these services seamlessly into its production processes and thus has the capability of reacting to varying capacity requirements and goods flows exceedingly flexibly and efficiently while conserving resources at the same time. Ultimately, these business models uproot traditional ideas of what a value chain may look like: the principle of shared production will become more important, allowing the end user to act as a co-producer. If desired, KUKA Consulting analyzes the business models of companies to determine whether they can be marketed profitably as a service (“Product as a Service”).

Manufacturing Ecosystem

–**Expertise is the raw material for creating value efficiently.** If the best available expertise can be focused upon every single process step and every single level of activity, all parties involved benefit: product designers, developers, manufacturers, logistics specialists and end customers. A complex network that optimally brings together all relevant expertise in terms of personnel, economy and technology is considered an ecosystem. This comprises hardware and software resources, process and project know-how, consulting expertise and complex networked architectures of production and information technology. What is important for such an interdisciplinary system is that the combined expertise is not just limited to a single company, but that the best possible personnel and the best available knowledge on the market is brought together under one project umbrella. As an experienced player across industries, products and processes at the interface of OT and IT, KUKA is in a unique position to “fuse in” the ideal experts and expertise for any given project. This yields an unbeatable team of resources provided by the customer, KUKA and external partners, with superior know-how and advanced technology from the shop floor to the business model level. Ecosystems add value beyond just optimizing the value creation processes: this bundled creativity allows for new products, solutions and business models to be developed jointly.

Megatrends

–What makes the world go round. Customization, digitization, responsible use of natural resources and demographic changes are the megatrends that will need to be mastered in the coming decades. With a forecast world population of eight billion by the year 2025 and ten billion by 2060, ever more customer requirements of increasing diversity will need to be satisfied. At the same time, demographic changes will be confronting industrialized and emerging countries with economic and social challenges over the long term. Humanity is thus facing a fundamental paradigm shift which will undoubtedly have far-reaching consequences for our worldwide economic systems. That is why Industrie 4.0 does not describe a purely technical innovation scenario but rather a way in which intelligent technology can help to overcome the global challenges of the 21st century. As a thought leader and trailblazer for Industrie 4.0, KUKA is working on production environments which increase economic efficiency while also using resources responsibly, which make high-quality goods more affordable and which are instrumental in sustainably improving human working conditions in factories.

Mobility

–Robots on the advance. The production of the future requires greater flexibility – for both faster manufacturing and customized products. One indispensable prerequisite for creating a higher degree of flexibility in industrial environments is greater mobility. This can be achieved by means of episodic, periodic or permanent mobility concepts that each bring about acceleration in industrial production in their own specific ways. For this reason, KUKA is paving the way for this key technology with platforms that can move intelligently and autonomously in order to transport things or machine workpieces. They can find their own way if necessary, aligning themselves with workpieces to within a millimeter or even moving the robot to them. They are also capable of responding autonomously and adaptively to changing conditions in complex logistics and production chains. Mobile automation solutions from KUKA show today what the future holds in store for highly flexible production in Industrie 4.0.

Monitoring & Stream Analytics/ Micro Services

–Data in real time. Monitoring and stream analytics compare and analyze data that is available to the smart factory from diverse sources – devices, sensors, infrastructure, etc. In real time they make comparisons with data records from the past, recognize anomalies and are able to categorize faults with the aid of machine learning. On this basis, intelligent systems initiate immediate countermeasures and generate forecasts and recommended actions for the future.

On Premises

–Software on board. On-premises solutions rely on the infrastructure of the company's in-house IT. The deployment model of such software can be designed as a service and thus take on the function of a "local cloud".

People First

–Production and products for people. In the factory of the future, the focus of thought and action will shift to the human worker with his changed requirements, desires and capabilities. Networked and flexible production technologies combine the cost advantages of mass production with the customization potential of craft manufacturing. This means that the customers' desire for high-quality individualized products does not lead to higher prices, as is currently the case. But humans are at the center of the future world of goods not only in their role as customers. Intelligent robots that collaborate with humans, and mobile assistance systems will improve the world of work in many different ways. They handle heavy loads, carry out activities that are not ergonomic or are simply too dangerous for people and perform tasks which require levels of precision and speed of which humans are not capable or which are cognitively stressful.

Predictive Maintenance

–Eliminating static maintenance intervals. Dependable production planning and maximum machine availability through the avoidance of unscheduled downtime are the practical advantages of what is internationally known as predictive maintenance. On the basis of real-time data, all relevant parameters of the machines involved in the manufacturing process are acquired and evaluated for anomalies by means of stream analytics. In a subsequent machine learning process, specific fault patterns and the causes of a problem are detected in good time. This results in fewer rejects and maximum availability over the entire life cycle of the production line. The requirements on machine operating times vary depending on the specific branch of industry and its product cycles. While this could be up to 30 years in the aerospace sector, it is a matter of just a few months in the case of fast-moving goods, such as smartphones. With the aim of enabling an accurate assessment of the future performance of the machine or one of its components, intelligent predictive maintenance systems interconnect the largest possible amount of data from decentralized sources for the purpose of analysis.

Preventive Maintenance

–Efficiently controlling necessary downtime. Preventive maintenance is usually carried out on the basis of fixed contracts, which provide for an inspection of critical elements of the production systems at regular intervals or at fixed times. This may include analyses and cleaning the machines, for example. One of the advantages offered is the easy-to-plan and predictable maintenance times, which serve to prevent unforeseen downtime and ultimately save costs.

Reshoring

–Available is the new cheap. 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. This necessitates new manufacturing and marketing methods and structures that will only become possible as a result of networked production in smart factories. Short distances will be an important factor in achieving fast availability. Due to the high degree of automation, production steps that are currently outsourced to low-wage countries can be repatriated to high-wage countries in a process known as "reshoring". Irrespective of wage structures, intelligent automation allows cost-efficient and high-quality production in the vicinity of the consumers.

Resource Efficiency

–Sustainable production. The ability of humanity to handle the future will be determined by a responsible and sustainable approach to natural resources. In a just world, it may be assumed that ever more people will want to be supplied with ever better products. 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 chain and recycling them to a great extent for the sake of the planet.

Robofactoring

–Craftsmanship meets robotics. Unlike a conventional factory, with its high degree of uniform mass production, craft manufacturing combines the virtues of skilled craftsmanship with a low level of mechanization. Craft-manufactured products convince with high-quality and a distinctly unique character. Robofactoring unites the advantages of craft manufacturing with the low price of a mass product, making individual and high-quality products affordable for large parts of the global population.

Robotic Governance

–Creating a responsible future world for generation "R". Robotic governance is a concept which, among other things, considers the ethical/moral, socio-cultural, socio-political and socio-economic effects of robotics on society and provides a framework for solving problems resulting from these changes. The governance principles include accountability, responsibility, transparency of structures and fairness. In this way, robotic governance helps to create a sustainable and responsible future world for the upcoming generation "R".

Robotic Natives

–Robots as natural companions. Future generations, "robotic natives", will see robots as the state of the art, as a lifestyle, or quite simply as normal. Just as commonplace as smartphones and the Internet, for example, are for the digital natives of today. They will have overcome the old human versus machine antagonism. The robot-oriented generation will shape a society that not only works differently, but also thinks differently. 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. While nowadays robots are primarily known as work assistants in industrial processes, in the future they will be found in all areas of our daily lives as driverless cars, robo-furniture, carebots and a wide range of home and personal assistants. By 2050, a robot in every household will be part of everyday life.

Security

–No success without security. The issue of safety and security is one of the most multi-faceted business aspects of modern companies. In the separate worlds of production (OT) and information (IT), a basic distinction is made between safety and security: in OT contexts, the term "safety" is used to refer to the safeguarding of people and machinery as well as the availability and reliability of production equipment. In the IT environment, the term "security" primarily relates to data security, integrity and confidentiality. OT and IT are merged in the networked world of Industrie 4.0, which brings the issue of safety and security to a new level of complexity. The use of cloud models and the networking of entire companies and organizations exacerbates the security aspects (see also Data Ownership). KUKA Consulting offers well-founded advice on all safety and security questions and can draw on a broad network of expertise, including strategic alliances with international experts.

Service Robotics

_Robots enter daily life. Even today, useful robotic assistants are making everyday life easier. Small, specialized service robots, for example, have long since established themselves in our private sphere. They are deployed as assistants in the home – vacuuming, mowing the lawn or cleaning windows. As yet, their capabilities are mostly limited to a single task. However, they do demonstrate one thing: collaboration between humans and robots works in everyday life. Thanks to the progressive development of service robotics, robots will shape daily life in the future in various ways. Whether it be as a nursing robot in clinical settings, as helpers for the elderly at home or as assistants in many other areas which today sound futuristic. For the robotic natives of tomorrow, service robots will be as self-evident as smartphones are for people of the present.

Smart Data

_Intelligent data exchange. If Big Data is the oil of the future, then Smart Data is the fuel that drives the production of the future. Currently, data is just data. To turn it into information, it must be interpreted. This is the step from perception (recognizing) to cognition (understanding). Books, for example, are at first merely collections of letters. They only become knowledge when they are processed and interpreted in the brain. KUKA is developing smart data technologies for the digital domains in the age of Industrie 4.0. In the context of intelligent automation, the central focus is on the topics of data communication, process modeling, machine learning, autonomous self-configuration and process optimization.

Smart Factory

_Intelligent and self-organizing. The intelligent factory of the future is a production facility in which manufacturing systems, robots, logistics systems, products and their components are largely able to organize themselves autonomously. The smart factory is undergoing a paradigm shift towards an entirely new production logic: smart products, components, tools and machines are unambiguously identifiable, can be localized at all times and are aware of their history, their current status and multiple ways to the desired goal. With the smart factory's high degree of flexibility, customization with a batch size of 1 will become reality in the context of industrial mass production. To achieve this, the production systems must, on the one hand, be networked vertically, for example with business processes within factories and companies. On the other hand, they must also be linked horizontally across company boundaries – from the purchase order through to outbound logistics – to create distributed value creation networks that can be controlled in real time.

Smart Platforms

_Intelligent and flexible. New, intelligent platforms will be created for the implementation of Industrie 4.0. They will support collaborative industrial processes and use their services and applications to network people, things and systems. The result will ensure greater flexibility and a continuous flow of information: smart platforms will document the entire business process, work safely and reliably at all levels, and support mobile end devices and collaborative production, service, analysis and forecast processes along the entire digital supply chain. For the smart factory, KUKA already has modular software architectures in its portfolio, based on mainstream technologies and prepared for the entire evolutionary process of Industrie 4.0. The Java platform of KUKA Sunrise makes it ideally suited to future app-based programs. Such a platform sets the stage for cross-industry digitization and thus increased value creation. This forms the foundation for the smart factory of the future.

Social Machines

_Interconnected. Intelligent. Flexible. Machines in production which are intelligently interconnected, communicate with one another and can instantaneously react to deviations and changes in an independent and situation-based manner are called social machines. They are part of the Industrie 4.0 vision. The underlying idea is that machines are able to share their knowledge like in social networks – information about themselves as well as experiences and “lessons learned” from their processes. At the same time, social machines coordinate the information received and learn from the network too. Similarly to Facebook users, they independently obtain information from the Internet and connected social machine networks. Through swarm experience, they are aware of the best parameters for machining a particular material, for example, and they exchange them with “befriended” machines.

Standardization

_General requirements for reliable interaction. In the course of any technical evolution, different solutions, formats and approaches usually compete with one another – developed and propagated by various fractions, committees or companies. Only standardization, with its exact and binding definition of framework parameters and the possible interfaces, makes it possible to create appropriate expansions, counterparts and communication bridges to a new technology. Of particular importance in this context with regard to the implementation of Industrie 4.0 are the new definitions of safety in the area of human-machine collaboration and the standardization of interoperability in the area of data exchange. KUKA is striving for OPC UA to be established as one of the future standards. This protocol not only transports machine data, parameters, process values and measured data, but can also, in combination with other standards, define them semantically in a way that is machine-readable.

Standards

_The basis of all constructive cooperation. Standards are the elementary basis for breaking down barriers in the globalized world of Industrie 4.0. As a world leader in automation, KUKA sees itself as responsible for playing a key role in shaping the areas of standards and standardization. To this end, KUKA is driving forward the harmonization of communications, data exchange and safety, for example, in the field of direct human-machine collaboration. In this way, it is creating new standards to ensure interoperability in the smart factory of tomorrow. As one of the key players in the paradigm shift from the third industrial revolution to the fourth, KUKA is thus laying the foundation for successful cooperation between all those involved.

Time to Market

_Meeting customer requirements more quickly. The time to market (TTM) denotes the length of time from development of a product to its availability on the market. In the factory of the future, this time, which is often decisive for the sales success of a product, will be significantly shortened. Positive effect: changing requirements and trends in increasingly volatile markets can be met with corresponding products much more quickly than previously.

Traceability

_Keeping track. Traceability here refers to the ability to fully trace all raw materials, producers, upstream suppliers, individual parts or assemblies as well as the complete product and its consumers in the digital value chain. It is possible at all times to determine when, where and by whom the goods were produced, processed, stored, transported, used or disposed of. Irrespective of whether an individual part or a finished product is concerned, a distinction is made between two directions of traceability: from the manufacturer to the consumer and from the consumer to the manufacturer.

Value Data

_From worthless data to valuable information. Individual data is like isolated objects in a void. They only make sense in context, and meaningful data can yield information that increases in value through being made exploitable for various purposes. Without being assigned, processed, compared, etc., data about the actual states of different parameters of a machine are nothing but loosely connected numbers. Intelligent evaluation of these data can provide valuable assets, for example by using forecasts that minimize or prevent maintenance and downtime.

Vendor Cloud

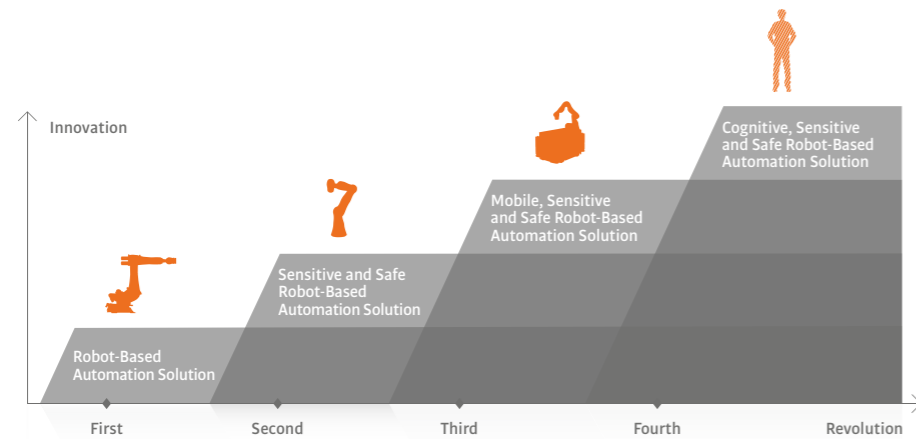
_Cloud with limited access. Large manufacturers with extensive supply networks avoid amalgamating different production data in the cloud, as they are concerned that this could reveal information about the production processes. But since the various suppliers and partners need important information from the production process, the manufacturers implement their own production cloud on the Internet or on their premises. In this vendor cloud, the production company can give suppliers access to exactly the data and information that are relevant to them, while all the rest remains hidden. KUKA can develop, implement and operate such cloud solutions for OEMs. KUKA is the ideal partner for operating vendor clouds thanks to its many years of experience with similar projects (including infrastructure work and coordination with suppliers and customers).

Vertical Integration

_Internal networking optimizes the production landscape. Networking the various assets within a company into an efficient production unit is one of the prerequisites for creating a smart factory. The different manufacturing stages with their respective specific assets can thus be merged into an integrated production process, for example. The networking of individual levels and assets via a cloud enables company-wide horizontal integration of the value chain as described in the Industrie 4.0 concept. For example, it allows integration into the KUKA ecosystem with all the resulting benefits (see Manufacturing Ecosystem).

Four Robotic Revolutions

–The disruptive force of robotics. Robotics will change the world. In the next 50 years, it will have a disruptive influence similar to the one exerted by the Internet and information technology over the past five decades. The societal change that will accompany this is reflected in the “four revolutions in automation technology” postulated by KUKA. Alongside industrial robotics, which will continue to grow strongly with new, networked manufacturing processes, the area of service robotics – and ultimately robots – will become more established in private settings. In addition to ever faster response and development times for new robot generations, this step will also require a radically new approach.



Yesterday – The 1st robotic revolution

–Robot-Based Automation Solution. The age of robotics began in the 1960s and 1970s. Industrial robots brought greater efficiency and productivity to simple manual tasks such as lifting, spot welding and packaging. They began their triumphant advance in the automotive industry, spreading successively to other sectors. In this manufacturing environment, the robot operated in a fixed location within safety enclosures or zones to which humans had no access. Its tasks were clearly defined: relieving humans of monotonous work and assembling cars or other goods in large volumes as quickly and as precisely as possible.

Today – The 2nd robotic revolution

–Sensitive and Safe Robot-Based Automation Solution. What was science fiction just a few years ago is now a reality: robots and humans work hand in hand. Collaborative robots like the LBR iiwa developed by KUKA enable an entirely new relationship between humans and robots: direct and safe collaboration – without any safety enclosure. Where there is no fence restricting freedom, the way is open for new, highly efficient and far more flexible applications. The robot is now a machine that can be touched and with which interaction is possible. It will shape daily life in various ways in the future. Whether it be as a work assistant in industry, a service robot in the public sphere, a nursing robot in clinical settings, a helper in the home or in many other areas which today still sound futuristic.

On the starting grid – The 3rd robotic revolution

–Mobile, Sensitive and Safe Robot-Based Automation Solution. As autonomous mobile units, collaborative robots are able not only to react intelligently to their surroundings, but also to change their place of use. The ability to interact with people, machines or workpieces in varying locations gives mobile robots virtually boundless application potential. Mobile robots can already perform logistics tasks independently, collaborate directly with humans or quickly take on new tasks at different workstations. Essentially, there are as many potential applications as there are ideas for such applications.

In the future – The 4th robotic revolution

–Cognitive, sensitive and safe robot-based automation solution. If the robots of the future are characterized by artificial intelligence, they will reflect on and cognitively understand what they do. They will increase the productivity of humans to a much greater extent than today, while the interactions between humans and robots will become ever simpler. They will have the ability to interpret human language and gestures (smartphone voice recognition systems are already a first step in this direction). On this level, robots will finally become active companions for humans. The “thinking” maid, Rosie, from the science fiction cartoon “The Jetsons” or Lieutenant Commander Data from “Star Trek” will indeed remain fiction for a long time, but in terms of their capabilities robots will come ever closer to these imagined characters.

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