

# futur

VISION | INNOVATION | REALIZATION

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## Resilience for All!

The keys to success for holistic production systems are intelligent information management and flexibility.

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**RESILIENT  
PRODUCTION**

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**»The best way to predict  
the future  
is to invent it.«**



## Production Technology Center (PTZ) Berlin

**PROFILE** The Production Technology Center (PTZ) Berlin houses two research institutes: the Institute for Machine Tools and Factory Management IWF of the TU Berlin and the Fraunhofer Institute for Production Systems and Design Technology IPK. As production-related research and development partners with a distinctive IT competence, both institutes are in international demand. Their close cooperation in the PTZ puts them in the unique position of being able to completely cover the scientific innovation chain from fundamental research to application-oriented expertise and readiness for use.

We provide comprehensive support to companies along the entire process of value creation: Together with industrial customers and public-sector clients, we develop system solutions, individual technologies and services for the process chain of manufacturing companies – from product development, planning and control of machines and systems, including technologies for parts manufacturing, to comprehensive automation and management of factory operations. We also transfer production engineering solutions to areas of application outside industry, such as traffic and safety.



### DEAR READERS,

for almost one year now, we have been living with the novel coronavirus SARS-CoV-2, and a lot has changed during this time. From our interactions with the people around us and our behavior as consumers of goods and culture, from the way we work and produce to economic processes on national levels and global supply and value chains – all societal areas are affected in one form or another. With impressive speed and reliability, the German government has opened up a protective umbrella under which freelancers and artists can apply for funding and special loans. Beyond this, there are ways to proactively leave the role of the »affected« behind to become a »creator« or a »decision-maker«. We will show you how to achieve this certain autonomy by means of various success stories and solutions in this issue of FUTUR on the topic »Resilient Production«.

A key player in this context – how else could it be – is the German Mittelstand. In our feature article you will learn how medium-sized companies have fared in recent months and how they can position themselves flexibly and robustly for the future. The right corporate management is essential to be prepared for times of crisis or even emerge from them stronger than before. The corporate situation picture provides our clients with a tool for developing new routines for uncertain times. Also in this issue: How can robotics and artificial intelligence offer support when companies are not able to fall back on their full workforce, due to security precautions and sickness related absences.

There is no need to reinvent the wheel. Managers and engineers can rely on other experts' testimonials in order to use their own resources wisely. For this issue, we interviewed several thought leaders who report from their own experience of how they are steering their companies safely through the current crisis. For Prof. Dr. Helmut Schramm, head of the BMW Group's Berlin plant, his team is the most important success factor. Our alumnus Dr. Mark Krieg reports as Bosch-Rexroth's Vice President Development Industrial Hydraulics on the changes necessary for operational success. Lastly, I had an insightful talk about the importance of innovations to maintain a resilient production with Roland Bent, CTO of Phoenix Contact, a German company on the verge of entering the Clarivate »Top 100 Global Innovators«.

On that note, I would like to wish you good health and a positive outlook.

Yours sincerely,

**Eckart Uhlmann**

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# 50%

of companies stated in June 2020 »that they will not survive for more than six months if the restrictions due to the corona pandemic are maintained for a longer period of time.«

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Find out **what technology** we are looking at here.

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## JUST DO IT!

How far along is your company when it comes to digitalization? We help you find out in just 15 minutes. As part of a study on digital transformation, we invite you to take part in a free self-evaluation. This will give you a clear picture of where you stand in terms of digitalization – a solid starting point for putting existing business practices and strategies as well as your own processes, structures, and products to the test.

↳ Find out more on

[s.fhg.de/digital-transformation-assessment](https://s.fhg.de/digital-transformation-assessment)



## THE THING



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**Open source devices** can efficiently alleviate bottlenecks in the provision of medical equipment because they can be manufactured, maintained, and modified directly on site. This even applies to urgently needed ventilators due to COVID-19. The OPEN.Effect project investigates how the open source community can contribute to the provision of such devices while complying with the necessary medical regulations and ensuring safe manufacturing.

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## WELL SAID

**»An energy or mobility transition will not succeed without digitalization. During the corona crisis, we are currently learning how digitalization can also help make our companies and our value chains more resilient. Starting with working from home and extending to the possibility of bringing production back to high-wage countries by means of intelligent automation, thereby relativizing the fragility of global value chains.«**

© Phoenix Contact



Roland Bent, CTO of Phoenix Contact, on the question of where he sees the greatest potential for digitalization solutions.

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# Flexibly Robust, Robustly Flexible

Entrepreneurial resilience means combining existing resources with technological innovations using intelligent and agile methods.

For manufacturing companies, remaining viable in the future means reacting with agility to changing market requirements, efficiently addressing new products and manufacturing concepts, and sustainably expanding both technological and human resources. With its large percentage of medium-sized companies and its high vertical range of manufacture, the German industrial landscape is virtually predestined to ensure resilient value creation.

chains. The most promising approaches for manufacturing companies are more individualized manufacturing, the development of new business models and digital services, and more robust supply chains with a higher emphasis on local and regional suppliers.

A second representative survey based on the KfW SME Panel from early June 2020 confirms and supplements these findings. Around 2.3 million or 60 percent of all small and medium-sized enterprises expect to feel the effects of the crisis for a long time to come. Manufacturing enterprises are particularly impacted. They see their business situation as being »significantly worse than SMEs in all other sectors of the economy.« But this survey also brings a ray of hope as the respondents are not only focusing on cost reduction, short-time work, or layoffs but also on innovation: 43 percent of all companies have optimized products, processes, or business models or are planning appropriate measures despite the negative economic impact of the pandemic. In comparison, only 19 percent of SMEs established product or process innovations between 2016 and 2018.

In summary, SMEs in Germany are aware that they can best anticipate disruptive changes via resilient value creation and digitally integrated production. But how can they put this into practice?

## NEW TECHNOLOGIES FOR AGILITY ...

New ways of creating value for the manufacturing industry lie in digitally integrated and tool-free production processes using additive manufacturing. For example, digital assessment of raw parts can be used to automatically extrapolate suitable finishing steps for additive manufacturing processes, allowing for the efficient, component-specific repair of turbine blades. Process

How to utilize this unique potential to survive turbulent times is a question not just medium-sized companies are concerned with. Scientific research is also developing targeted strategies for the production processes of the future. Which of the insights we have gained as production technology experts can we pass on to the industry?

## QUO VADIS, MITTELSTAND?

The McKinsey study »How the German Mittelstand is mastering the COVID-19 crisis«, published in May 2020, paints a picture of a confident and resilient Mittelstand in the face of the current disruptions. 77 percent of respondents were optimistic about the future, and 79 percent said they were acting counter-cyclically. However, only 17 percent of the SMEs surveyed have actually taken measures that go beyond operational crisis management. Based on the results, the study suggests a catalog of measures to help German SMEs develop resilience against future crises. The key components: high levels of adaptability and flexibility.

Specifically, McKinsey recommends reassessing the competitive situation, entering into new relationships with customers, actively enforcing counter-cyclical behavior, and re-evaluating procurement and supply

»The best way to predict the future is to invent it.«

Alan Kay

**Image:**  
Additive processes such as Direct Metal Laser-Sintering (DMLS), as shown here, open up new ways of value creation for medium-sized companies in the manufacturing industry.  
© Protolabs



knowledge based on machine learning for the finishing of additively manufactured components can quickly be transferred to new product classes and manufacturing technologies. This eliminates the need for costly and open-ended parameter studies with limited transferability.

## ... ESTABLISHED TECHNOLOGIES FOR STABILITY

The best basis for increased flexibility is a broad technological wealth of experience. Therefore, the importance of established manufacturing technologies for resilient value creation should not be underestimated. The advantage of these process technologies based on expert knowledge is that they can be transferred to new manufacturing tasks without having to perform complex parameter studies. Unfortunately, technological potential often remains unutilized because the day-to-day business of industrial manufacturing does not focus on process analysis and process optimization. Reacting to sudden changes is then only possible by expending a great deal of time and money. Even companies in highly demanding technological fields can sustainably augment their resilience by consistently implementing the concepts and technologies of digitally integrated production. With approaches such as consolidating expert knowledge in digital process twins and implementing self-compensating

closed-loop processes, an adaptable production environment can be created even in a technological field such as ultra-precision machining for the production of smallest batch series.

These examples demonstrate that change is possible without German SMEs having to shift their core competencies. Resilient value creation requires that decisions for or against a manufacturing process no longer be based on subjective expert knowledge. This renders rigid manufacturing processes obsolete. Instead, in order to cater to changing requirements and workloads, fact-based domain knowledge and flexible manufacturing options are required. ♦

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# The Most Important Factor Is Our Team

Interview with Prof. Dr. Helmut Schramm,  
Director BMW Group Plant Berlin



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**| futur |** Professor Schramm, BMW sold over 50 percent more motorcycles in Germany in July than in the same month last year, and worldwide even more than ever before. And it did so even though you only resumed production at the Berlin plant at the beginning of May after a six-week stop due to the corona pandemic. How did you manage the rapid ramp-up?

**/ Schramm /** We succeeded primarily thanks to the people we have on board. We have an extremely motivated, highly competent, and powerful team, of which I am really proud. Within a very short time, this team restructured all production areas

in the facility so that we can work safely despite COVID-19. Not only have we staggered shifts or timed conveyor belts differently, but we have also built hundreds of acrylic glass partitions and 3D printed door handles – all using our very own technologies. Then there are the pragmatic and professional recommendations and directives in our BMW corona manual. As a result, we were able to restart directly in two-shift operations after almost six weeks of shut-down and are now in the fortunate position of producing at full capacity.

**| futur |** Which elements in your value chain do you currently experience as being

critical and how do you approach potential problems?

**/ Schramm /** With complex products such as our motorcycles, there is naturally a lot of value creation on the supplier side. We have 900 active suppliers worldwide, including in India, China, Mexico, and Spain, all of whom are more or less severely affected by the corona crisis. In this respect, our production system must work as a whole. And at the moment, I openly admit that this is a major challenge because the conditions in the individual countries are so different. And yet we launched our latest and most important ramp-up this year, the R18, right on time for the SOP,

which stands for start of production – despite corona, despite the fact that we had no predecessor vehicle, and despite the high complexity of the vehicle. Thanks to our robust technologies – whether it was engine construction, paint shops, frame construction, or bodywork – it worked perfectly, although it also took a lot of work and energy.

**| futur |** Resilience is considered an indicator of whether and how companies or organizations master difficult situations technologically, socially, and economically. What makes BMW resilient?

**/ Schramm /** The greatest asset of our facility is our employees. Here, we rely on close communication channels, as well as on trust, openness, responsibility, and mutual appreciation. In this way, we motivate our team to react quickly and prudently in the event of such disasters, yet still find creative solutions. The second is our business model in collaboration with our suppliers.

Although the pandemic is not over, there are already signs of a slight stabilization in our supply chain, but we are far from out of the woods. That's why we are strengthening our resources in the individual regions in Asia, America, and Europe so that we can immediately intervene locally, if necessary. At the Berlin plant, we have already enhanced our processes and technologies accordingly in recent years to ensure that they are stable and not prone to disruption. We are also well prepared in terms of flexibility and vertical integration. We have working time models that allow us to operate in different shifts seven days a week, 24 hours a day. This gives us a high degree of flexibility, which, incidentally, we have also agreed on with the employee representatives. In addition, there is our technical flexibility: Together with our suppliers, we can react easily to fluctuations in demand without having to create major redundancies. Together, all these aspects increase the resilience of BMW.

**| futur |** Let's talk about digitalization: At the Berlin motorcycle plant, you are already making intensive use of Industry 4.0 technologies. Where do you see potential for the future?

**/ Schramm /** Data analytics holds potential of which we are perhaps not yet fully aware. I am certain that one first has to achieve a certain degree of professionalization in this field in order to actually exploit it. It is true that we are already using many standard Industry 4.0 technologies – ranging from the virtual commissioning of systems to autonomously driving robots and predictive maintenance. We also use AI models and train our employees with 3D glasses. With data analytics, however, I believe we could do much more. And we can, also in cooperation with Fraunhofer, take established 4.0 technologies a significant step further. I am thinking of our human-machine-robot collaboration in assembly or of surface design in fine printing. These are technologies we

## PROF. DR.-ING. HELMUT-JOSEPH SCHRAMM

has been in charge of BMW Motorrad's global production and the BMW motorcycle plant in Berlin-Spandau since 2017. He has a doctorate in industrial engineering and began his professional career as an assistant to the general management of a medium-sized logistics company in Berlin. He then held various specialist and management positions at Daimler AG before joining the BMW Group in 2003. Here, he held several positions in production, quality management, logistics, strategy, and factory structure planning in Munich, Dingolfing, and Leipzig. Since 2004, he has been an honorary professor in logistics and production management at the Technical University of Applied Sciences Wildau.



© BMW Group

»We launched our latest and most important ramp-up this year, the R18 right on time for the SOP – despite corona, despite the fact that we had no predecessor vehicle, and despite the high complexity of the vehicle.«

Prof. Dr. Helmut Schramm

are developing here in Berlin, which we will make ready for series production and which we will subsequently introduce to our Group's passenger car segment.

**| futur |** BMW has been building motorcycles in Berlin-Spandau – the only location in Germany – since 1969. What role does the Berlin plant play in BMW's international production network?

**/ Schramm /** In the BMW Motorrad production network, BMW in Spandau is what we call the flagship unit, i.e., the leading plant, and certainly the largest. Another plant in Brazil and one in Thailand

also belong to our organization. Both are smaller but highly flexible, very innovative, and produce a wide range of motorcycles. We also have two production partners in India and China, each of which produces starter models. We manage these plants and partners from Spandau as a production network and also control the overall distribution of all vehicles. Then there is our role in the BMW Group. As a production site, we are a link between all plants in the BMW Group's production network. For example, as already mentioned, we take on technology and research projects from which the entire Group benefits.

And we provide resources for the network. This also includes the fact that at BMW, we operate a joint human resources development program, which gives us access to a phenomenal level of expertise. That is also one of our competitive advantages.

**| futur |** What do you expect from Berlin as a business location for the future?

**/ Schramm /** We are very happy and proud to have been here in Berlin for over 50 years now. We feel that we are very appreciated as a partner in Berlin. I say this with all due respect because something like this has to be earned and the city is

demanding. But the city also offers a great deal and provides numerous opportunities. Take the university and research landscape, which is second to none. I think Berlin also has what I call a »logistical« attractiveness. And we work very constructively with Spandau's local political representatives and Berlin's state political representatives. I appreciate that very much and I would like to take this opportunity to thank them. But what is most important here are the people, the style, the geniality, the honesty, the down-to-earth mentality, and the expertise of the people in Berlin and Brandenburg. After

all, many of them work for us, and BMW Motorrad would not be the same without them. That's why I am very pleased that we are bringing the legendary BMW Motorrad Days from Bavaria to Berlin and Brandenburg next year, as another commitment on our part to the region. ♦

# How to Handle Staff Shortages

Short-term absences of employees in key positions pose a threat to complex production processes. Intelligent decision support systems can prevent disruptions.



**Images:**  
 1 Detection for multiple components  
 2 Part recognition via mobile device  
 3 AI assistance for incoming goods

×

For a long time, the question of how to optimize personnel deployment in production using intelligent decision support systems was mostly a niche topic in research. In the past, it was mainly the lack of skilled workers and accelerated exchange of know-how that drove developments in this area, but with the COVID-19 pandemic, this question has taken on a new urgency. Company hygiene concepts, a rising number of cases of illness among staff, and quarantine regulations require new solutions as quickly as possible.

## EXPERT KNOWLEDGE ON DEMAND

Current developments in the field of artificial intelligence are offering increasingly better methods to predict and evaluate processes or situations on the basis of data. When used as a decision support system, AI simplifies complex processes in the background and presents them to the user in a process-oriented way. Employees thus only receive relevant information and can record and evaluate processes faster and more reliably. In other words: AI methods can digitalize expert knowledge and make it accessible. If the machine learning processes required to improve the AI run parallel to the application, the AI can use the new data to understand the process better and better. This enables it to flexibly adapt the process to a changing production environment and to different users. These data-driven systems are able to react to the environment and are therefore more dynamic and powerful than conventional systems with fixed program sequences.

## INCOMING INSPECTIONS AS A CHALLENGE

Such decision support systems can assist companies with processes in a wide variety of areas and thus also ensure

the quality of the results of the process. Within the value chain of operative production, they can commence right at the beginning of the goods receipt processes. If the personnel specifically trained for incoming goods are not available, this has far-reaching consequences for subsequent processes, such as processing or assembly. The high levels of qualification and experience staff need to fulfill when working with incoming goods make it almost impossible to deploy staff from other departments or areas at short notice. However, a closer look at the incoming process shows how a decision support system can increase flexibility, reducing the consequences of a lack of personnel in such cases.

In essence, an incoming goods receipt contains at least one check to determine whether the item that has been delivered corresponds to what was ordered. In the case of wholesalers for B or C components or an assembly service provider, the number of items delivered daily can quickly become extremely large. The inspection process is often carried out manually by trained employees. Not only do many components have to be visually distinguished – a damage inspection may also be part of the job. Even despite high levels of expertise, components can often not be identified directly, resulting in time-consuming manual catalog or database searches. If one or perhaps several of the trained incoming inspection experts cannot be present due to unforeseeable circumstances, this may even result in the complete breakdown of downstream production. A similar difficulty is encountered when sudden production peaks occur. Manufacturing companies are often unable to meet the increased personnel requirements for incoming goods simply by restructur-

ing or hiring new staff due to the extensive training required.

Intelligent decision support systems can help to simplify the inspection process, thus minimizing the training period. In the case of incoming inspections, image-processing recognition offers a promising approach. The user scans the component to be inspected employing a camera system. The captured images are processed using AI methods and the result is presented in the form of a suggestion list, for instance. The suggestion list contains probable matches for the components being searched for, from which the user can then make a selection. The right object only has to be determined from a small number of possibilities. The sorting provides an additional indicator, but the final decision is still being made by a human being, allowing for corrections at any given time. The detailed documentation of the processes in the decision support system also makes it easier to understand them. While employees in a classic goods receipt process require a high level of technical and methodical qualifications, the decision support system takes over the role of a second expert supervisor according to the two-man rule. It immensely reduces the requirements for methodical expertise thanks to its easy handling. Training a new employee is now limited to comparing a component to the proposed items and interacting with the decision support system. If desired, there is also the option of integrating escalation management into the decision support system.

## ARTIFICIAL INTELLIGENCE AS A DECISION-MAKING AID

Current artificial intelligence technologies and methods

can thus ensure that processes remain executable under difficult conditions. The decision support system takes over the information processing in a partially automated fashion and delivers only prepared, relevant results to users. In this way, decision-making is simplified and greatly shortened. The effort required to train new personnel is reduced. Decisions are logged by the interactions with the system and are therefore reproducible. An interdisciplinary team at Fraunhofer IPK is dedicated not only to improving AI-based methods but also to the meaningful combination of different types of data for decision-making with a focus on their respective use. In the future, it will be possible to use delivery and customer data in addition to image data for incoming goods. The researchers are also investigating the combination of process and image data in quality control. Their goal is to develop an application-specific system that incorporates a holistic analysis of the existing data. ♦

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00: Reducer 6X4



01: Relief valve X5



02: Coil spring N065



## The Fine Line between Savings and Damage

During milling, the tool substrate, the coating, and the geometry of the cutting edge are decisive for high machining quality with low cutting forces. Tool wear leads to unstable processes that cause defects in the component or even lift the component out of its clamping and do damage to the machine. Nonetheless, at this point in time indexable inserts are only being inspected and replaced in an analog fashion, resulting in unnecessary waste. Hence, Fraunhofer IPK is developing PoWer, a digital, automated inspection and replacement system for indexable inserts, which not only evaluates the condition of the tools but also carries out the replacement.

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### 01

**Tool(s) with indexable inserts:** To date, machine operators visually evaluate the condition of the cutting edges. As a result, the inserts are often discarded too early, as machine damage can be more expensive than the premature replacement of cutting edges, which collectively could still operate for thousands of hours at the end of a working day.

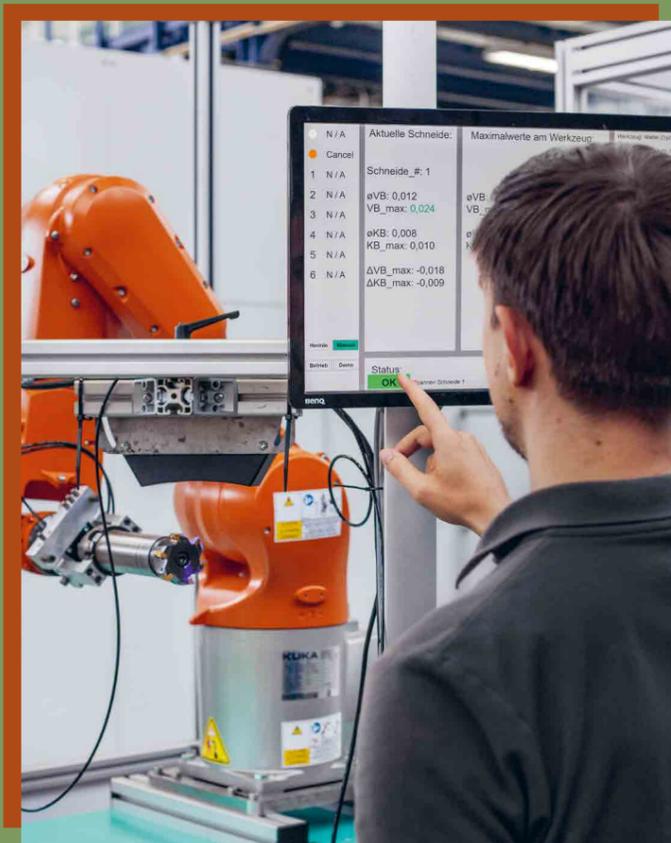
### 02

**Machine add-on:** The PoWer system can be directly coupled with a machine tool. Alternatively, it can be used as a decentralized system for several machines. Tools to be inspected are identified via RFID. The current insert type and the positions of the individual inserts are also queried.



### 03

**Automated inspection:** A robot guides the tool to a scanning station, where each cutting edge is recorded as a 3D point cloud and a black-and-white image. The sensor is capable of scanning cutting edges with a spatial accuracy of 6 µm. In addition to wear and tear, other signs that indicate spontaneous failure are also identified.



## 04

### Keeping an eye on wear:

The collected wear data provides information on more than the condition of the cutting edge. It also enables process optimization. Whether it is faster machining with the same amount of wear or particularly low-wear processes, PoWer makes it possible to set the most economical machining parameters.

## 05

**Intervention required:** For carbide tools, the flank wear should not exceed 0.2 mm. But whether a scratch measures 0.1 mm or 0.2 mm is not discernible to the naked eye. If PoWer detects that the wear limit has been exceeded, the system automatically takes the necessary measures. At a screwdriver station with a bit changer, the affected insert is first loosened.



## 06

### Automatic correction:

A magnetic device removes the insert from the tool to rotate or replace it. Automating the process saves the machine operator working time that can instead be used to prepare the process for the next part or to monitor the machine. This reduces non-productive time.

## 07

**Rotation principle:** It is not always necessary to completely replace an insert when one side is worn out. As an initial step, the system rotates the insert to an unused position on the turning station or reverses it completely.



## 08

**New insert required:** Only when an insert has reached its end of life does the tool receive a completely new one via a replaceable insert magazine. The PoWer system makes it possible to save tool cutting edges from the trash bin while simultaneously preventing cutting edge failure. For many companies, these advantages pay off after just a few months.



## Resilience for All!

**Holistic production systems are an excellent basis for making companies crisis-proof. The keys to success are intelligent information management and flexibility.**

Corona versus the German economy: The outcome of this match is yet to be decided. What is certain is that the pandemic has hit the economy hard. According to surveys conducted by the online portal Statista in June 2020, around 77 percent of domestic companies expected a decline in sales in 2020. More than 50 percent of the companies stated »that they will not survive for more than six months if the restrictions due to the corona pandemic are maintained for a longer period of time.« The challenges are manifold. They range from disrupted and unreliable supply chains and distribution channels to the customer to loss of the entire business base, such as in the event sector.

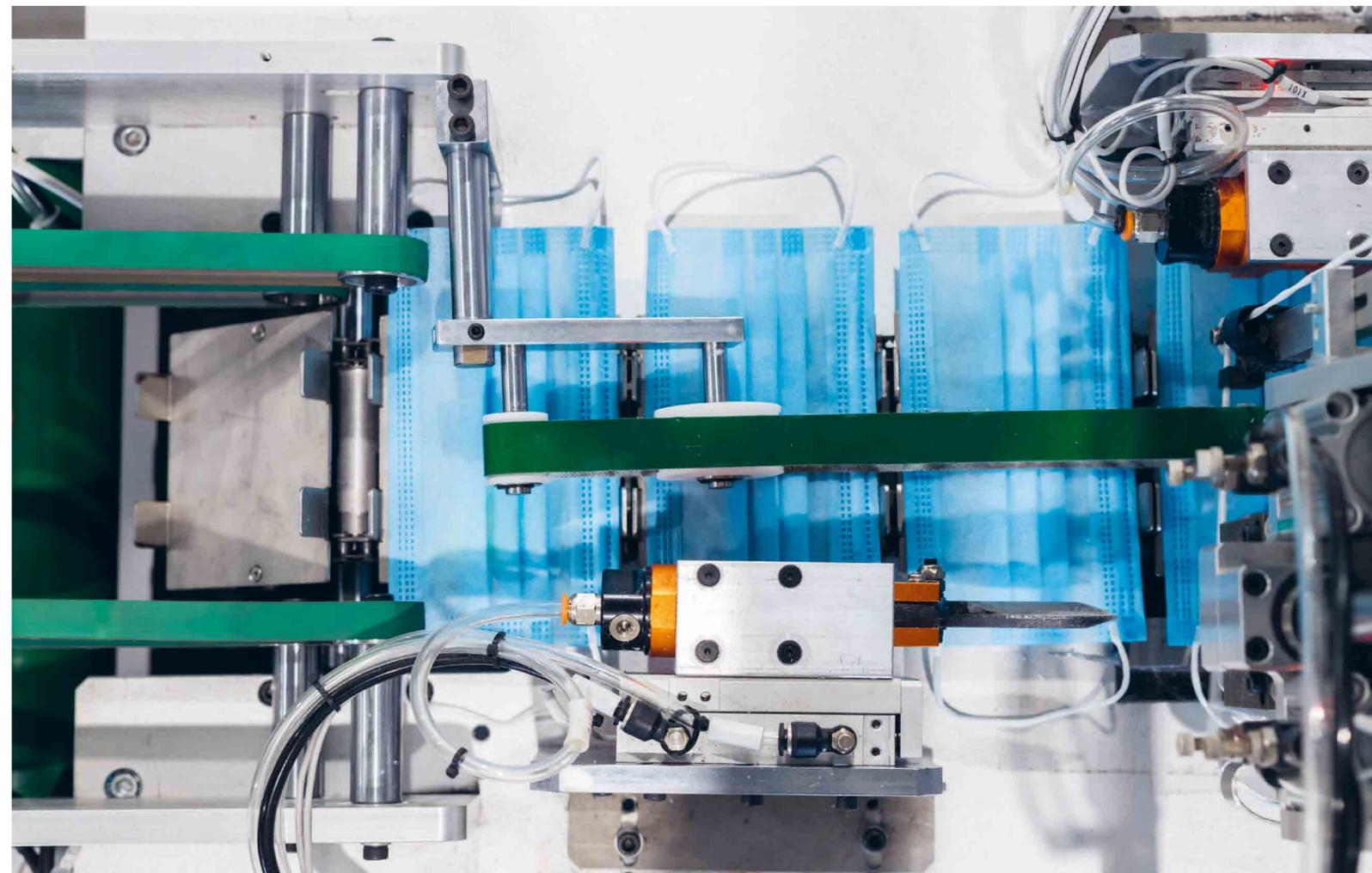
But other stories have also been written during this pandemic. For example, a medium-sized plant manufacturer from the German state of Thuringia managed to add a system for producing medical protective masks to its portfolio within six weeks in spring 2020. Until then, the company had focused on areas that were hit particularly hard by the crisis. The new system was able to partially compensate for revenue losses in this area and significantly reduce the number of short-time work hours.

Six weeks from the drawing board to the first delivery: Looking at such results, one realizes that the recipe for success, in addition to excellent management, is often that an holistic production system (HPS) is consistently and proactively implemented with regard to resilience – even if the companies concerned are not always aware that they are applying resilience principles. But what does it actually mean to trim an HPS for resilience?

An HPS strives to organize all company divisions close to or directly involved in production according to the same principles and to control their processes with the

same methods and systems. By »resilience« we mean the ability to not only survive crises and setbacks – regardless of whether they are caused by internal or external disruptive factors – as an individual or as a group, but also to emerge from them stronger and capable of action. Unlike traditional risk management, which focuses on identifying and dealing with specific risks within a company's processes, resilience management takes a more holistic approach.

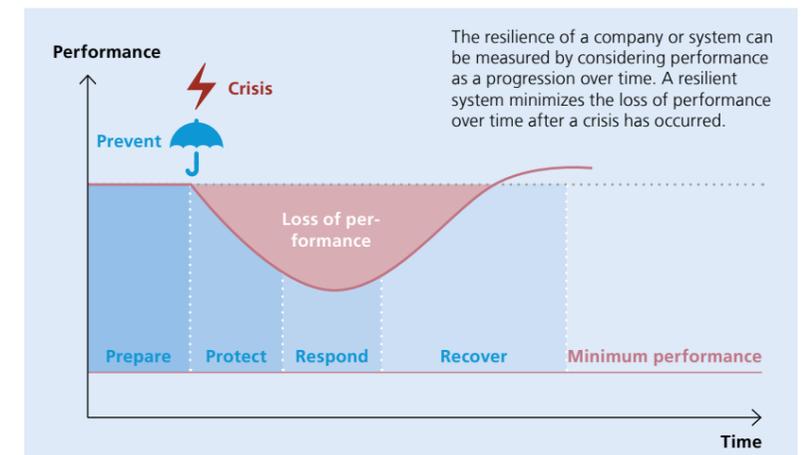
Instead of simply asking which factors could have a negative impact on the company's own economic performance, it sheds light on which measures can be used to maintain or improve performance before, during, and after the crisis. Crisis management is divided into five phases, as depicted in the diagram on the right, for which various instruments, responsibilities, and approaches are defined.



### DIFFERENT PATHS, SAME GOAL

But how do you integrate resilience into an HPS? There are various approaches to do so. Firstly, you could try to build an entirely new management system, applying a concept based on resilience phases. However, experience with introducing lean management over the past thirty years or so shows that the introduction process is complex and lengthy and that no rapid successes can be expected.

In addition, this procedure would not be beneficial, as evidenced by companies that already have an HPS organized according to lean principles. They could attempt to include the resilience phases as additional aspects in the goals and design principles of the production system. However, this increases the complexity of the overall system, making the entire HPS more cumbersome.



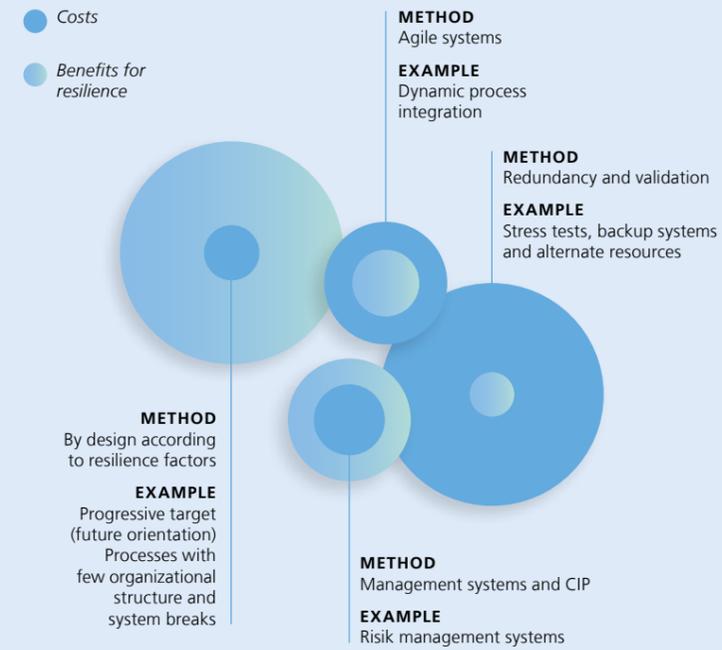
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An example: HPS can certainly define how to deal with external disruptions. However, the types of disruptions that are defined are usually relatively simple breaks in the supply chain or events that could lead to dissatisfied customers. Larger disruptions, such as the failure of the entire supply network due to border closures or the termination of a customer relationship due to unexpected customer insolvency, are not covered by an HPS. This is a good thing because developing procedures for averting all conceivable disruptions and integrating them into an HPS would result in immense effort and the entire system being considerably sluggish.

### PREPARING RESILIENT PROCESSES

Rather, the solution should be to include resilience in the application of an HPS. Or even better, to set up the entire company from the outset in such a way that all processes promote resilience. Additionally, the processes should be set up with few organizational and system breaks. Also, when implementing the processes in times of crisis, an increased degree of flexibility should be permitted. In this regard, companies can learn from the principles of the safety and protection sectors. In those sectors, procedures are applied that, regardless of the specific cause of the situation, include the same mechanisms for preparing, avoiding, and preventing negative influences. For example, the structural and procedural organization of a police or fire department crisis response center is always self-similar, regardless of whether the cause is a natural disaster or a pandemic. In a corporate context, this

**Image:**  
A resilient company from Thuringia was able to launch a system for producing medical masks in record time.  
© Barcelona Dreams / Adobe Stock



»Instead of simply asking which factors could have a negative impact on the company's own economic performance, resilience management sheds light on which measures can be used to maintain or improve performance before, during, and after the crisis.«

Prof. Dr. Thomas Knothe

1

means that even during normal operation, resilience principles must be applied in a forward-looking, standardized manner. Training for handling exceptional situations must be provided and provisions made to establish a crisis management team. Handling critical situations can be rehearsed regularly, such as in simulations, similar to the way fire alarms are handled in schools. When roles and responsibilities have been internalized, flexible measures can be taken to deal with the incident in the event of a crisis, regardless of the cause. For this purpose, an assessment of the external environment in conjunction with internal processes and capabilities must first be made possible. Situational awareness concepts are helpful for this, as they ensure well-founded decision-making and the optimization of processes already during normal operation. Provided the application of such concepts has been rehearsed regularly under normal circumstances, situational awareness achieves its full impact in an exceptional situation, thereby also enabling companies to successfully cope with unforeseen events, also called »black swan events.«

Another useful extension of an HPS is inverse risk analysis. Instead of simply considering from the perspective of a possible event how dangers over which we have no influence can be averted – such as a natural disaster – the perspective is inverted: Strategies are developed for achieving a desired state of performance in

**Diagrams:**  
1 Comparison of costs and benefits of different resilience principles  
2 Extension of the IPK reference model for holistic production systems

the event of a failure of resources, processes, or even business relationships. Such considerations lead to resilience through flexibility. For example, production facilities and processes can be designed so a company's vertical range of manufacture can pivot within a defined time window if the supply chain breaks down.

»MacGyverism,« also known as »bricolage,« takes it one step further. In this case, employees are trained not to wait for all the resources necessary to fulfill their tasks to be available. Instead, they learn to find solutions in an exceptional situation with currently available resources. However, this principle should be applied with caution so that optimized process flows are not jeopardized during normal operation.

**NETWORKING FOR SUCCESS**

Finally, institutional networking can significantly increase the resilience of companies. Observations have shown that companies that were able to fall back on many different partners during the current pandemic – whether for sharing experience or in technology and supply relationships – were able to overcome the challenges much better than others. One of the recipes for success of the Thuringian equipment manufacturer mentioned above, for example, is that its network also included partners who had no connection to its core business. Only in the pandemic situation did their value for maintaining the company's operations become

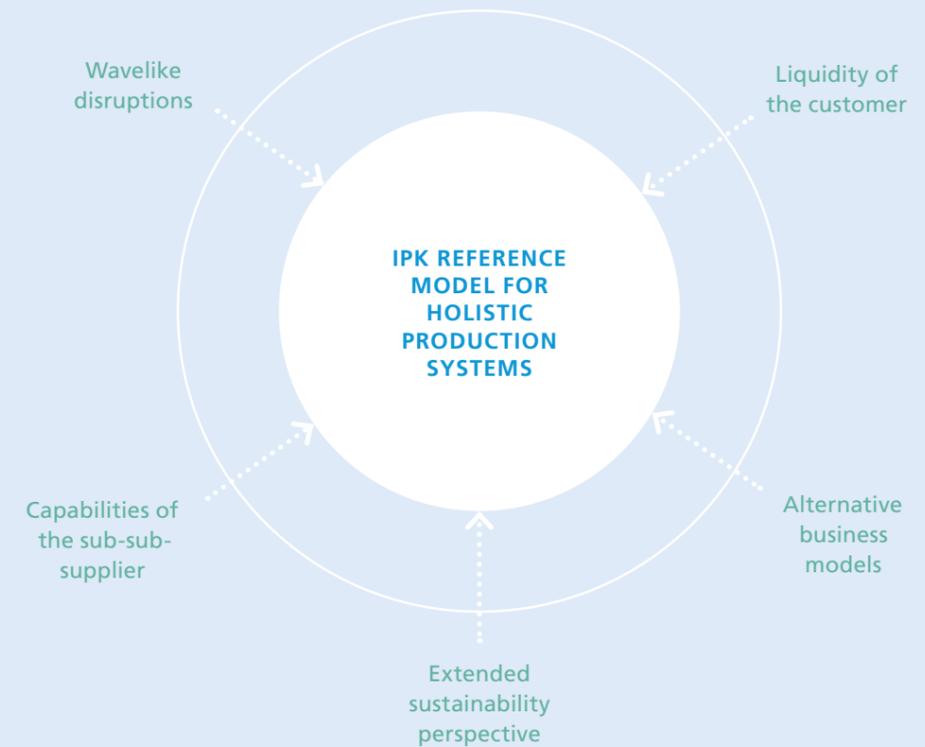
2

apparent. Networking also makes it possible to dispense with far-reaching structural and operational expenses, such as those associated with creating redundancy and additional intensive precautionary measures to avert crises.

The diagram on the left shows how different approaches to resilience differ in terms of cost and benefit. Further examples of solutions for increasing resilience for manufacturing companies can be found on the right. In order to anchor the strategies mentioned for increasing resilience in companies, especially in the production sector, Fraunhofer IPK extends the reference model for holistic production systems with important aspects of resilience. Essential characteristics include the integration of liquidity as well as the dynamic configuration of the production system according to the phases of an event. This aims at making it possible to, for instance, shift value chain segments around according to the abilities of partners ad hoc and securely in such a way that end-to-end processes are not interrupted. ♦

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**SOLUTIONS FOR INCREASING RESILIENCE IN COMPANIES**

**Constant ramp-up and temporary series production:** Scalable pilot production across the entire process using different degrees of automation

**Liquidity orientation:** Design interfaces and systems in such a way that defined costs only arise when a new variant is introduced (e.g., in respond and recover)

**Efficient monitoring of changing environment and black swan effects:** Adaptive interactive situational awareness, AI-based pattern recognition of process anomalies

**Development of event-independent crisis organization:** Adaptive virtual response center based on principles from the security sector but under the consideration of liquidity aspects

**Dynamic and secure shifting around of value chain segments:** Maturity-based cross-organizational technology chain generation (incl. distribution and integration) and assurance (certification)

**Organization-wide integration of business model, product, production, and distribution development in regulated markets:** Networking of different models with the help of adaptors and synchronization systems such as the High Level Architecture (HLA), virtually assisted training of partners



# Routine for the Crisis

Sudden failures of suppliers and customers, short-term changes in regulations – SME are currently facing enormous challenges. Situational awareness concepts developed by emergency services offer orientation.

March 2020: From one day to the next, everything has changed. Suddenly strict minimum distances between people apply, not only on the streets, but also in workshops, offices, and stores. A large proportion of retail and service businesses have to close, hygiene regulations for handicraft and manufacturing enterprises are radically rewritten within a very short time. Then national borders close, air traffic virtually comes to a standstill, international freight routes, conveyor belts of a global economic system, are held up. And as if all this were not enough, all recommendations, conditions and regulations change almost weekly.

The unprecedented exceptional situation into which the coronavirus SARS-CoV-2 has plunged the world at the beginning of the year has put even the most productive, best organized and profitable companies in trouble – at breathtaking speed. Often it was the question »What are we allowed to do now, and how?« that caused the business processes to lurch. Legal uncertainties met with disrupted supply chains, which made the just-in-sequence production applied by many businesses partially impossible.

In order to remain »master of the situation« under such exceptional circumstances, companies need structured

**Image:**  
New concepts are needed in order to keep production running in spite of the pandemic.  
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littlewolf1989

In addition to crisis management concepts that can be planned and prepared, it is needs-based procurement and evaluation of relevant information that are core elements in coping with exceptional situations critical to the company.

and systematic strategies. In addition to crisis management concepts that can be planned and prepared, it is needs-based procurement and evaluation of relevant information that are core elements in coping with exceptional situations critical to the company. Because even the best preparation cannot foresee every possible critical situation. These can only be mastered by quickly understanding which factors have an impact on the company situation and how.

## FROM DAILY BUSINESS TO CRISIS MODE AT THE TOUCH OF A BUTTON

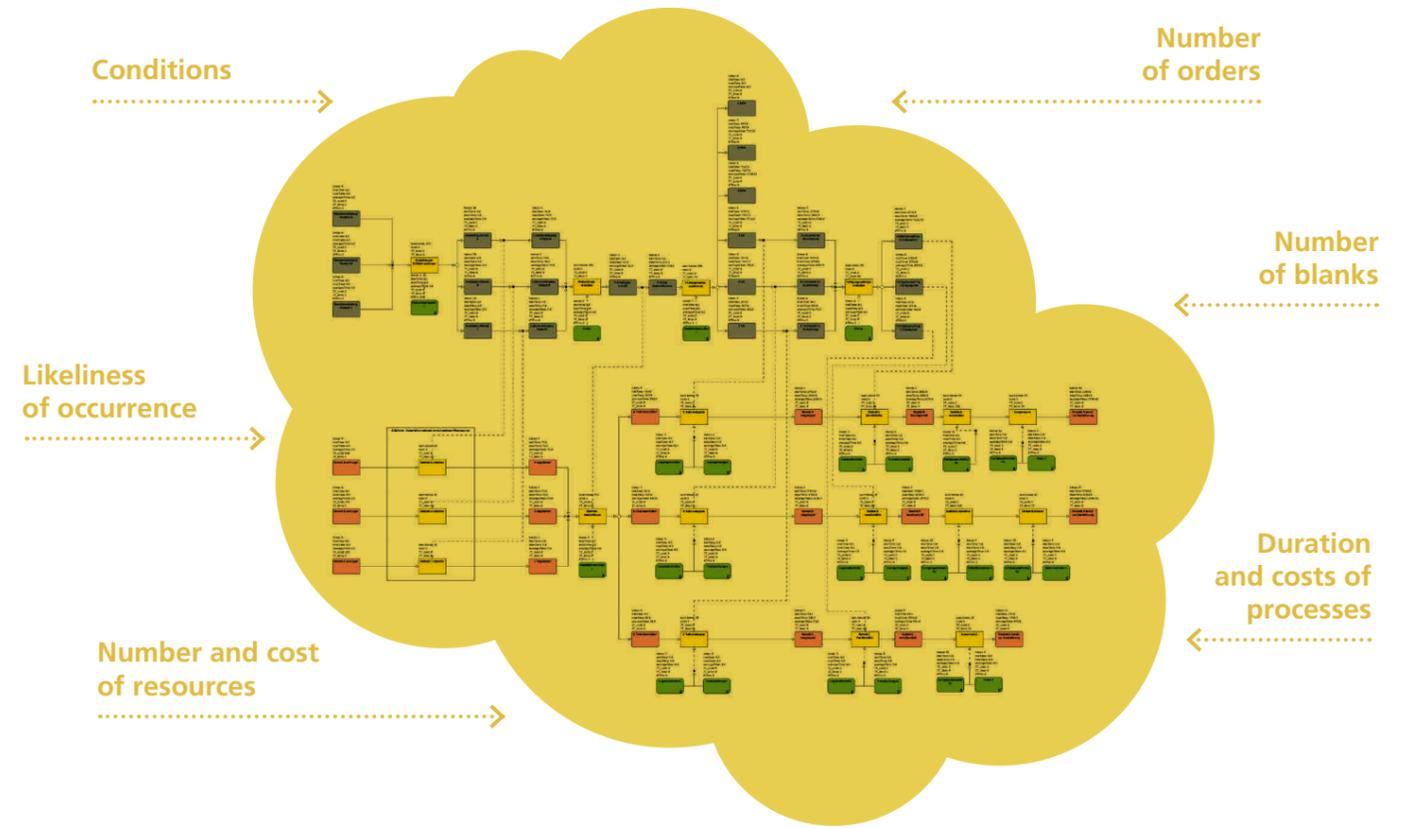
If you look at organizations that have to deal with exceptional situations on an almost daily basis – such as disaster control and security forces – it quickly becomes clear that companies can learn a lot from them. This is especially true when it comes to accessing and handling information. Such organizations have established methods for collecting all necessary information in the shortest possible time and interlinking it appropriately. They work with situational awareness concepts that bundle geo-referenced near-real-time data and information from various authorities, platforms, sensors and other sources and make them available to the respective crisis response team for decision support.

But how would such situational awareness concepts have to be adapted for the corporate context and how can the rapid creation of situation reports for companies be supported? First of all, it is every company's interest to survive a crisis with minimal losses and to maintain its capability to do business during the course of the crisis. In turn, the capability to do business results from the feasibility of the company's processes. In the event of a disruptive incident, it must therefore quickly become

**Image:**  
The situational awareness cockpit helps to develop action alternatives in a quick and targeted manner.



With the help of the model-based approach, internal and external information can be quickly networked in a company-specific manner and iteratively refined and expanded as the crisis progresses.



clear which business processes are subject to critical influences and how they are related to the delivery structure. Only then is the company able to set up and evaluate alternatives in order to derive targeted measures and monitor their implementation and effectiveness.

**SITUATION AWARENESS INDICATES THE DIRECTION**

Fraunhofer IPK’s interactive situational awareness cockpit makes such correlations visible. An important basis of the system is the process management suite, also developed at the institute. This is an established toolset for recording, modeling and clearly displaying business processes.

In the situational awareness cockpit, the process management suite is used to first create a model of the corporate structure. This model is linked to the operational systems available in the company, so that the required data can be combined on a case-by-case basis.

The model should be composed as holistic as possible – in addition to critical internal process structures, it must also consider customers, suppliers, resources and products. This creates comprehensive transparency as to which of the company’s capabilities and processes are influenced by which external developments. The affected processes are then continuously monitored with regard to their status.

To protect processes in the further development of the crisis, it is essential to create transparency by means of »what-if« combinations and to assess the possible effects of alternative scenarios. Here, the interactive situational awareness cockpit offers model-based simulation tools that show the consequences of certain decisions or developments for business capability, such as liquidity. To mitigate these consequences, the critical process structure has to be subjected to measures whose implementation and effectiveness must also be continuously monitored.

**Diagram:**  
If a company’s processes are depicted in the model, the situational awareness picture reveals which factors influence the process landscape.

With the help of the model-based approach, internal and external information can be quickly networked in a company-specific manner and iteratively refined and expanded as the crisis progresses. This makes it possible to establish a transparent control instrument for supporting the work of the crisis response team within a few days. It consistently links short-term goals, critical processes and resources, and possible developments with the management of measures and compiles them online for all members to access. And the system can do even more: It can act as a process assistant in the integrated management system of a company to temporarily adjust process definitions. This also supports the daily work of all employees. The system takes particular account of the process changes caused by the crisis and the required documents and responsibilities, even at short notice.

**SURVIVAL THANKS TO CONSTANT ABILITY TO ACT**  
Fraunhofer IPK’s situational awareness cockpit provides

an information technology center of company management in case of a crisis. Critical situations are quickly recognized and their effects analyzed. Even during first-time setup, the situational awareness cockpit can be made ready for action within three days in such a way that initial orientation and ability to act are ensured. Thus, the fragile balance between effort and benefit is maintained in exceptional circumstances – even in companies that have not worked with process support systems before. ♦

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# Optimistically toward the Future with Modular and Digital Solutions

A guest article by Dr. Mark Krieg,  
Bosch Rexroth AG

»There is reason to hope that we have passed the low point in terms of orders, even if we will still see negative rates compared with the previous year for some time to come,« said VDMA Chief Economist Dr. Ralph Wiechers at the beginning of September when speaking about incoming orders in the German mechanical and equipment engineering industry. Current figures at Bosch Rexroth Industrial Hydraulics do not yet corroborate this statement, but they certainly give cause for optimism for a supplier to the mechanical and plant engineering industry.



## Local for Local

This includes not only the localization of our production and supplier networks but also the development of products tailored to local market requirements.



## Modular Systems

Developing products in modular systems in order to be able to react quickly to the individual and ever more rapidly changing needs of customers without increasing complexity in production and purchasing.



## Digitalization

Creating digital added value for our customers along the product lifecycle and optimizing our own production with the help of reasonable data management.

The corona crisis has led to a sharp drop in sales and incoming orders at Bosch Rexroth. It has also shown, however, that mobile working arrangements function better than expected and that flexible working hours and short-time work hours are well suited to weathering such hopefully temporary and unexpected crises. We will continue to have to adapt to challenges such as global competitive and cost pressure, trade barriers, or technological change, not only in the automotive industry – and we will have to do so in the long term. To have a strategy for this based on the principle of hope would be negligent. In the development of Bosch Rexroth Industrial Hydraulics, we are therefore pursuing three focal points.

Productivity increases are possible at various stages of the product lifecycle, starting with machine design and construction. At Bosch Rexroth, we already support our customers in the selection and configuration of our hydraulic systems.

We are currently working on seamlessly integrating both static and dynamic models of our products and systems into common software tools and engineering suites. It is a great advantage if the designer has direct access to hydraulic components in their familiar engineering suite and can easily integrate them into their circuit diagram, fluid diagram, mechanical design, or even 1D dynamic models for pre-simulation. Depending on the level of detail, such digital twins of both components and systems enable various forms of added value along the lifecycle, for example the virtual commissioning of machines. Because once the product has been configured and commissioned in the virtual space, nothing stands in the way of »plug and produce« in reality. Along with product commissioning, the transition from the OEM, i.e. the machine and equipment manufacturer to the machine operator, the end customer takes place.

The customer's ultimate focus is on the efficient use of a machine in production.

We can also offer added value for this. For example, digital on-board electronics with access via standardized communication interfaces such as IO-Link, various industrial Ethernet fieldbuses, Bluetooth, and in future also via OPC UA make it possible to react better to disturbances. In the event of material or mold changes, such as in plastic injection molding, control parameters can be adapted during operation, or new parameters defined and tested with the aid of a digital twin can be transferred to the machine. Non-productive times are thus reduced. Digital condition monitoring and predictive maintenance also offer added value for the end customer by creating the prerequisites for avoiding unplanned downtimes. If a spare part is required, it can be preconfigured and procured in good time. ♦



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## Dr.-Ing. Mark Krieg

As Vice President Development at Bosch Rexroth AG, Dr. Mark Krieg has been responsible for the development of the Industrial Hydraulics business unit since 2018 and is a member of the business unit's Executive Board. Prior to this, he held various positions at the motion and control technology manufacturer Parker Hannifin. As an alumnus, he still maintains close contact with Fraunhofer IPK, where Krieg received his doctorate in production technology in 2008 and was most recently deputy head of the Production Systems business unit. »Here in the Industrie 4.0 Transfer Center, approaches very similar to ours are being pursued to create digital added value along the product lifecycle,« he says, convinced that: »Despite all the cost pressure, research and development remain indispensable if companies want to meet both short-term and long-term challenges.«

# Is Open Source the Solution?

In the COVID-19 pandemic, life-saving ventilators are in short supply. Could open development processes make them freely available?

At the beginning of the COVID-19 pandemic, it became clear that there was a global shortage of life-saving ventilators – even in Germany. Established manufacturers were not the only ones to react to the increased demand. Other companies, research institutions, and private individuals also began developing and producing improvised devices. Thus, an active movement has emerged that wants to find an answer to supply shortages with the help of open source hardware. In the OPEN.Effect project, experts from Fraunhofer IPK have been evaluating the performance and effectiveness of the open source community for the development and production of ventilators since May 2020.

## OPEN SOURCE HARDWARE IN MEDICAL ENGINEERING

Open development processes make it possible to reduce development time and expenditure by reusing designs and distributing development. This helps prevent shortages during and after production, even during an exceptional situation such as the COVID-19 pandemic. For example, between April and May 2020, volunteers from the NGO Open Source Medical Supplies (OSMS) produced and distributed around seven million items in over 50

countries – including masks, protective clothing, and medical devices. Thanks to the collaborative nature of open source projects, unlike proprietary solutions, the results can be widely used and applied. The jointly collected data is disclosed and serves as a basis for research institutions and companies to further develop the project results. In doing so, the scientists of the OPEN.Effect project demonstrate ways to quickly tap into the potential of the open source community to develop and produce ventilators.

## COMMON QUALITY STANDARDS

A sound understanding of the strengths and challenges of open source hardware projects facilitates the development of sustainable solutions and shared best practices. To this end, Fraunhofer IPK collects project data together with the established open source community Public Invention. Public Invention has already evaluated open source solutions for ventila-

tors as part of its Ventilator Verification Project. The project, published as a spreadsheet, evaluates 137 ventilator designs according to selected criteria such as manufacturability, functionality, reliability, user-friendliness, and regulatory approval. The list of criteria was expanded in close collaboration between Public Invention and Fraunhofer IPK to evaluate the performance of open source solutions. The project is currently in an interview phase to document the community's practical experiences and insights and make them available for further research projects. The results can be found on the Fraunhofer IPK website as an open access report.

»It is already becoming clear that open source hardware can effectively complement proprietary technology developments, especially in order to jointly overcome global crises,« says Sonika Gogineni, project coordinator at Fraunhofer IPK. »The huge advantage is that urgently needed products

can be manufactured, maintained, and modified directly where they are being used.« Nevertheless, open source producers are faced with a variety of challenges, such as the establishment of supply chains, decentralized certification, and the integration of feedback loops for all participants. In light of this, OPEN.Effect evaluates if the ventilators developed and produced comply with all necessary medical regulations and can be manufactured safely. ♦

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»It is already becoming clear that open source hardware can effectively complement proprietary technology developments, especially in order to jointly overcome global crises.«

Sonika Gogineni

**More information:**  
[www.ipk.fraunhofer.de/open-effect-en](http://www.ipk.fraunhofer.de/open-effect-en)



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# Innovation Breeds Opportunity

Experience from past economic slumps shows that companies that remain innovative even in times of crisis are significantly more resilient than others. Roland Bent, CTO of Phoenix Contact, and Eckart Uhlmann, Director of Fraunhofer IPK, discuss in the context of the current pandemic how companies can not only master difficult phases, but also grow from them.

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**Roland Bent** has been working for Phoenix Contact in Blomberg since 1984. As CTO and member of the Executive Board he is responsible for marketing and product development as well as innovation and technology management.



**Eckart Uhlmann** is director of Fraunhofer IPK und a university professor for machine tools and manufacturing technology at IWF of the Technische Universität Berlin.

**DERWENT TOP 100 GLOBAL INNOVATORS™ 2020**

This ranking is compiled annually by Clarivate Analytics to identify companies and research institutions at the top of the innovation ecosystem. The patented ideas of more than 14,000 companies are assessed in terms of their investment level, impact, and quality. Phoenix Contact is the only German company currently listed among the aspirants to the Top 100. In 2014, Fraunhofer was the only European research institution to make the leap into the Top 100 and has since been able to maintain its position there.

**PHOENIX CONTACT**

is the only German company currently among the aspirants for the »Top Global 100 Innovators«. The family-owned company is a global market leader for components, systems and solutions in the fields of electrical engineering, electronics and automation, with headquarters in Blomberg, Westphalia. Company founder Hugo Knümann developed the first modular terminal block in 1928 together with Rheinisch-Westfälische Elektrizitätswerke and applied for a patent for it.

**2,860**  
Property rights

**17,600**  
Staff worldwide

**2.48 bn**  
Euro turnover

**18**  
Companies in Germany

**55**  
Sales companies and ...

**11**  
production sites worldwide

**FRAUNHOFER**

has been among the »Top Global 100 Innovators« for seven consecutive years. As the world's leading organization for application-oriented research, the Fraunhofer-Gesellschaft concentrates on key technologies relevant to the future and on the exploitation of the results in business and industry.

**7,050**  
Patents

**28,000**  
Staff worldwide

**2.8 bn**  
Euro research volume

**74**  
Institutes in Germany

**20**  
Sites worldwide

| futur | **Mr. Bent, according to Clarivate, Phoenix Contact is the only German company to be one of 24 »innovators to watch« worldwide for the »Top 100 Global Innovators« ranking. What is the secret of your success?**

/ BENT / I believe it is our will to always make things a little bit better. We are determined to be at the top of our game, technologically speaking. This idea is in Phoenix Contact's DNA and is exemplified by the owner's family and passed on to our employees as a defining corporate philosophy. What's more, we have an exceptionally broad product portfolio for a company of our size. We cover the entire range of industrial automation and connection technology with a high degree of vertical integration and with the ambition of mastering the technologies we need to do so ourselves. This ranges from a surge protection plug, a basic technical connection element, to cybersecurity, software, and cloud connectivity. We not only want to follow trends, we want to set them. And we want to be on the podium when market shares are distributed.

| futur | **Mr. Uhlmann, how has Fraunhofer managed to hold its own in the rankings for seven years in a row?**

/ UHLMANN / We were born into this, so to speak. Fraunhofer was founded in 1949 to help the economy get back on its feet after World War II. It aimed to do so with application-oriented research and development and strove to transform new ideas and technologies into products that could assert themselves on the market. This commitment to innovation is what drives us even today. Therefore, exploiting solutions that we develop from prototypes into mature applications plays a central role in our innovation process. That is why Fraunhofer is one of the most active patent applicants worldwide.

| futur | **What general conditions are necessary for a successful innovation strategy?**

/ BENT / First of all, it must mesh with the corporate strategy. That sounds trivial, but is not always the case. And, above all, you need an innovation culture. We need employees who feel like entrepreneurs and take responsibility for the company's success. We need to be willing to take risks: Mistakes are part of any success. Market proximity: A developer who never sees the application of their products will not realize their full potential. Trust: If someone constantly fears for their job, they will not be creative. And transparency: To really talk to one another instead of talking about each other. If you take this to heart, you will generate enthusiasm among your employees – for your company and for its innovations.

/ UHLMANN / For us at IPK, there is an additional factor: We require a broad spectrum of fundamental knowledge as the basis for our application-oriented research. That is why our innovation strategy is called alliance. We work very closely with our partner institute at TU Berlin and the Bundesanstalt für Materialforschung und -prüfung (BAM) and transform the results of their basic research projects into application-ready solutions. And we do this starting from a batch size of 1: We do not sell millions of units of a particular clamp. Rather, we sell a single technology just once. Therefore, we have a wide variety of expertise and methods as well as a high level of interdisciplinarity, so we can not only offer individual components but complete systems.

| futur | **A McKinsey survey among medium-sized companies published in May revealed that the more companies invest in digitalization, the better they expect their own sales prognosis to be. In which area do you**

**currently see the greatest potential or need for digitalization solutions?**

/ BENT / In addition to value creation processes, it is primarily the administrative processes. We have more or less well integrated ERP systems in almost all companies today, but otherwise a low level of automation in administration. The same applies to product development as well as marketing and sales departments. At the moment, we are also very much driven by major social problems. Take the UN Sustainable Development Goals, for example. An energy or mobility transition will not succeed without digitalization. During the corona crisis, we are currently learning how digitalization can also help make our companies and our value chains more resilient. Starting with working from home and extending to the possibility of bringing production back to high-wage countries by means of intelligent automation, thereby relativizing the fragility of global value chains.

/ UHLMANN / Above all, I think we need digitally integrated value creation networks. This is where we can gain momentum, also in the integration of SMEs as system suppliers. The concept of crowd production has potential for the digital networking of individual specialized companies, which then act as one face to the customer. Digitalization can also provide even more support with developing new business models – away from selling a product to selling an availability, a benefit. I also see great potential in transitioning from digitally networked forms of production to sustainable, fully integrated production system environments. This is a huge challenge that can only be met with modular digitalization.

| futur | **Current economic figures indicate that the industries particularly hard hit by the current crisis are those whose international supply chains**



»Fully integrated production system environments can only be realized with modular digitalization.«

Prof. Dr. h. c. Dr.-Ing. Eckart Uhlmann

**have collapsed due to the pandemic. In your opinion, what impact will this have on the future organization of production? Will entire value chains move closer to the sales markets?**

**/ BENT /** I believe so, yes. Such effects will occur as a result of people learning from the crisis. This is not an argument against globalization but a meaningful reaction to what we are currently experiencing. We ourselves are pursuing a local-for-local concept. That means we are consolidating the value chains at the sites where we produce. This does not always work, nor does it always make sense, but if it does, it leads to much more robust systems. In this case, digitalization gives us new opportunities to increase the efficiency of our production sites and value chains so that greater local autonomy can also be implemented economically.

**/ UHLMANN /** Local networks are also being strongly promoted in our region. After all, it is no longer just a question of

quality, time, and costs when it comes to evaluating supply chains, but a matter of dynamics and flexibility in cooperation. Nevertheless, international networks will continue to exist. This is precisely why the aspect of production resilience is as topical as it is. How can we react quickly to unexpected changes in order to keep our production systems stable? We need solutions for this. That is why Fraunhofer has established its own resilience research. Adaptability and speed of change, robustness, reliability, and predictability are the aspects we are investigating here.

**| futur | How important is it to be internationally positioned, not only in production but also in research and development?**

**/ BENT /** It is extremely important, even for small and medium-sized companies like we were when we set up the first local innovation teams in the USA and China. Today, teams of more than 100 development experts are active at each location.

Being on site is simply part of a globalization strategy. We have an extremely high level of convergence of technology and knowledge, and yet the demands on technology vary from region to region on the world market. The reasons may be economic in nature or due to different norms and standards, but they are, above all, related to cultural aspects. Recognizing a customer's needs and understanding the relevance of their problem does not work over a distance of 10,000 kilometers. Nor does it work with a German understanding of engineering when it comes to issues in India, China, or the USA. That's why we are internationally involved, not only in production, but also in research.

**/ UHLMANN /** The German economy is very export-oriented and as an R&D service provider, we must also be where our customers are. There are clear prerequisites for our international commitment: Scientific value creation for our institute on the one hand and positive effects for both Germany and the respective partner

country on the other. In São José dos Campos, for example, we work together with one of Brazil's top engineering universities as well as German and Brazilian companies from various sectors and support SENAI, the Brazilian National Service for Industrial Training, with the strategic planning and nationwide implementation of research institutes.

**| futur | What advice do you have for other companies like yourself, but also for small and medium-sized enterprises with whom you work, as well as for start-ups, to help them stay ahead of the international competition in the future?**

**/ BENT /** Think visionary. Think about future possibilities and consider what is necessary to achieve these goals. That will enable you to overcome even apparent limitations. Let me give you an example: Today, we are one of the leading suppliers of charging connector systems for electric mobility. Ten years ago, e-mobility was al-

most exclusively a topic for geeks. At the time, we decided to back this horse because we had certain assumptions and technological insights, but also because we thought we could do it. Today, this is a very successful business unit for us, with more than 300 employees and sales in the upper seven figures. It could certainly have been a huge flop. But if you are not prepared to take such risks, you will not be able to go beyond the normal incremental development of a company. I believe that right now is the time to have the courage to push companies to take the next big leap.

**/ UHLMANN /** We need to rethink our business models. Medium-sized companies in particular will not survive, if they continue to sell individual components in as large quantities as possible. In many cases, we are already experiencing today that it is no longer a product that is sold, but a function. Companies must open up and develop a capacity for cooperation in order to develop systems solutions togeth-

er with others. My recommendation for SMEs as well as for start-ups: Join strategic alliances in order to stay competitive in the long term. ♦

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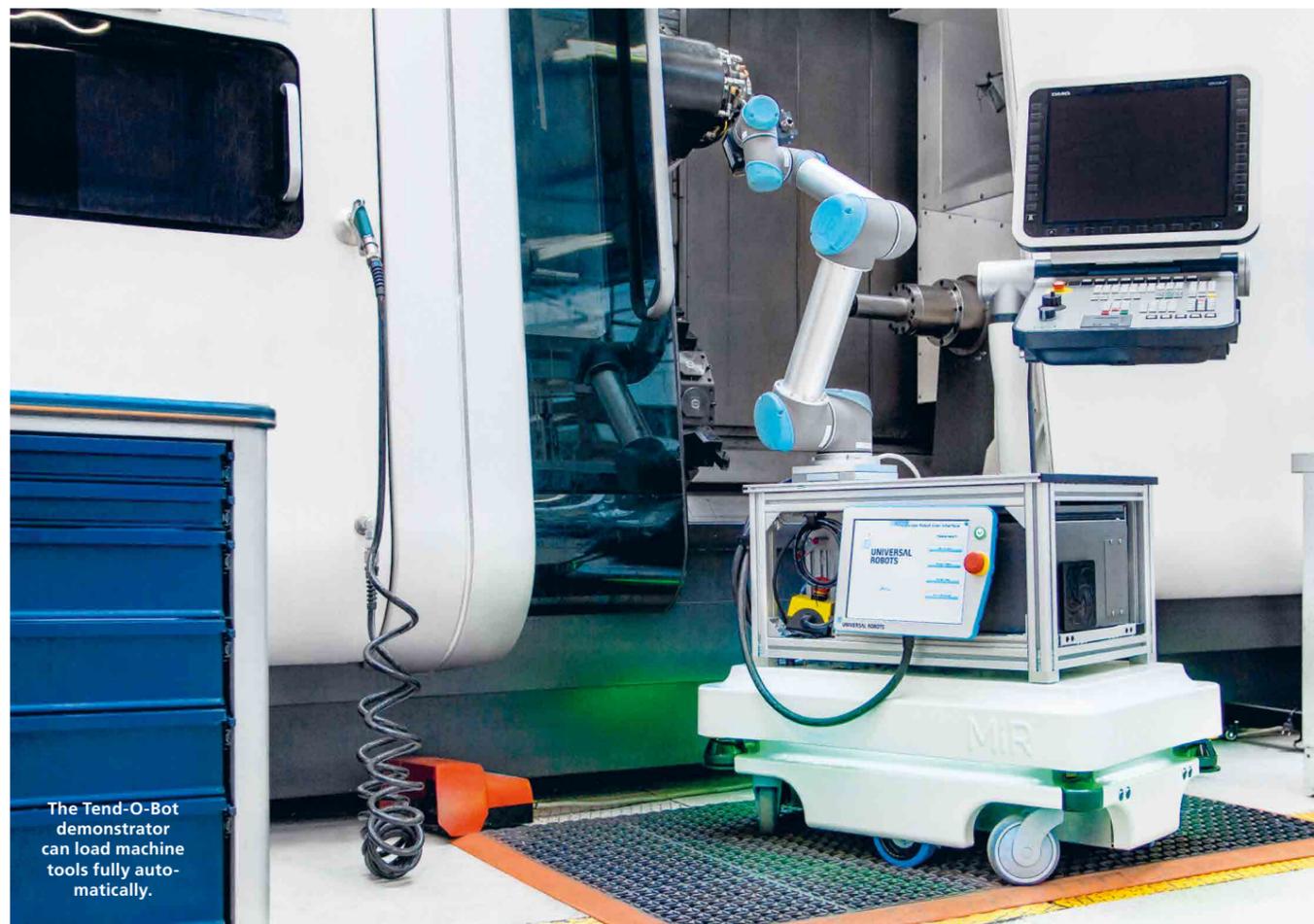


»If you are not prepared to take risks, you will not be able to go beyond the normal incremental development of a company. Right now is the time to have the courage to push companies to take the next big leap.«

Roland Bent,  
Chief Technology Officer, Phoenix Contact

# Intelligent Machine Tending

Production plants will be linked ever more flexibly in the future. Tend-O-Bot researches the use of mobile robots and intelligent software for autonomous machine tending.



The Tend-O-Bot demonstrator can load machine tools fully automatically.

Imagine the factory of the near future. You are certainly seeing complex, digitally networked machines and systems. The automation degree is presumably quite high and the workers are probably assigned monitoring tasks rather than having to perform physically demanding work. Perhaps the machine tools are also automatically approached and loaded by transport vehicles?

Most of these ideas are already a reality in some places. Only the latter idea, the automatic mobile loading of machine tools, has proved difficult in practice so far. In fact, the loading and unloading of machine tools and machining centers tie up the human resources capacities of many manufacturing companies, which would be better allocated in other activities. The first

few systems for automated machine tending available on the market need to be set up manually, which is very time-consuming. They usually perform rigid, pre-programmed motion sequences that are played back step by step. The process of approaching the machines is usually quite slow and the tending processes are not initiated until the transport system arrives at the machine.

This step-by-step approach requires a lot of time, during which the machines and systems are not able to work. This results in idle time, thereby reducing production efficiency. Furthermore, the transport routes set up in this way are inflexible, making it difficult to process customer-specific orders.

To provide the systems with additional freedom of movement, a research team at Fraunhofer IPK is investigating new approaches for combining Automated Guided Vehicles (AGV) and industrial robots. As part of the project Tend-O-Bot, different machine tools are to be loaded with a wide array of workpieces by a mobile robot system. The system's setup process, which has so far been carried out manually, is to be largely automated.

## FASTER AND MORE PRECISE

The AGV is equipped with a robotic arm and provides added value with its transport services. This includes a cloud-based path planning component as well as camera technology and interchangeable grippers. This system allows for machine tending with different workpieces without the need to manually program the robot for each individual job. Even when the workpiece is unfamiliar, the robot can place it correctly using its smart equipment.

While being transported, the workpieces can be measured by the cameras and the path planning for the target machine can be prepared. The trajectory planning depends on the actual positioning of the AGV in front of the machine, as well as on the specific internal space and the fixtures inside the machine. A combination of 2D and 3D camera technology is used to locate the AGV relative to the machine and measure the machine's interior.

In order to keep the capacity requirements of the on-board computing unit low, the calculation of the robot movements is outsourced. It takes place on powerful computing units such as edge clouds. Due to the centralized structure of the robot controller, several units can be operated simultaneously and the path planning and fleet management for the AGVs can also be outsourced. The trajectory planning for the robot arm can allow different accuracy tolerances between different events. This allows the robot to reorient itself while the AGV is still moving. As the robot approaches the target point, accuracy requirements increase. The tolerances are reduced and the positioning of the robot is refined.

This adaptive action during driving replaces the existing step-by-step sequence »programming – driving to destination – execut-

ing the defined path«. In addition, AGV can also be used to analyze the workpiece on board using the built-in camera technology, e.g. for quality control.

## A DEMONSTRATOR FOR THE SHOP FLOOR

As part of the Tend-O-Bot project, a functional demonstrator will be developed, which showcases the novel flexible chain-linking of different manufacturing units. Different requirements of selected pilot customers shall be taken into account in the design of the demonstrator. Currently, the phase of identifying customer requirements is in progress. ♦

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## WE WANT YOUR OPINION!

What requirements do you have in your company for a mobile robot in terms of machine tending? Learn more about the Tend-O-Bot project and answer our short survey to become part of our pilot project!

→ [www.ipk.fraunhofer.de/tend-o-bot-en](http://www.ipk.fraunhofer.de/tend-o-bot-en)



## Energy Efficiency for a Head Start

**Energy efficiency in production is crucial for the ecological footprint of products. Considering it during product development will give you a head start.**

Modern energy management is a Herculean task for manufacturing companies. Rising prices for energy on the global market, increasing scarcity of resources and the introduction of a carbon tax are all factors that raise the importance of energy-efficient production whilst also rendering it more complex. Consumers explicitly want energy-saving products and thus help them to create a stable, attractive sales market. It is high time now for companies under competitive pressure to think about designing both their production stages and their products to meet the criteria of energy efficiency in a timely and holistic manner. What role does product development play in all this? And what new solutions could be integrated in the production processes?

### IN THE BEGINNING WAS PRODUCT DEVELOPMENT

Decisions that a product developer or designer makes before the first prototype, have a direct impact on the carbon footprint of a product. Researchers at Fraunhofer IPK are exploring how sustainability in products can be improved across the whole product lifecycle. Designing a product for maximum sustainability is not just a matter of ensuring that the product itself saves power or fuel when in operation – because the energy used in its manufacturing must also be kept as low as possible. According to the Federal Environment Agency, industry is the second largest consumer of energy in Germany, after transport and before private households. As the German electricity mix still consists of just under two thirds of conventional energy sources (i.e. fossil fuels plus a dwindling part of nuclear power), this means a large amount of greenhouse gas emissions. In comparison to 1990, energy use by German industry has declined, and over

the past few years has plateaued on a stable level. In the mobility sector, energy-saving measures have been established in industrial practice, making both cars and their production increasingly energy-efficient. For instance, in the period 1995 to 2017, the fuel consumption of the average car has been reduced by 1.4 liters per 100 kilometers. On the other hand, economic growth and increasing consumerism are offsetting factors that impede energy consumption from falling further.

A team from Fraunhofer IPK is now exploring how the basis for an energy-efficient production can be set in the early product development stage. The research team is working on a company-specific model for the qualitative assessment of decision-making in product creation and process planning and its impact on energy consumption in production. The project goes by the name DEEP (Qualitative Design Dependencies Model for Energy-Efficient Decisions in Product Creation).

The goal of DEEP is to give the relevant decision-makers transparency about how much energy is used at which points in a plant's production system from the early stages of product design. To show how the developed model runs with real energy data, a representative product or system with a wide solution space in terms of product design and production process decisions has to be identified. This gives the research team an adequate basis to identify potential for optimizing energy consumption.

For companies to implement this model and use it as basis for feedback-to-design, the methodological groundwork for the concept of decision-making support has to be laid. This happens in three stages:

#### STEP 1: MODELING OF DECISION-MAKING PATHS

In the first step, the relevant decisions in product development and process planning are identified and modeled in a tool developed by Fraunhofer IPK scientists. For this purpose, the decisions are linked to the activities that are taken in the decision-making process. The result is a model with all relevant decisions, their solution space and the concretely chosen solution result. In addition, information flows within the company are also represented, i.e. the data and models that are created from the initial idea to the start of production. The methodical approach behind the tool is based on the theory of the holistic development environment (EOS). Accordingly, IT systems and responsible roles are also modeled as part of these decision paths.



1

#### Images:

1

Production of a camshaft tube

2

The Fraunhofer IPK team together with Carsten Klemm, Mercedes-Benz AG (left) in the production of the camshaft tube at the Berlin Plant  
© Mercedes-Benz Berlin Plant



2



# Are You Ready?

Companies agree that digital twins are the future. But what about the present?

With the Digital Twin Readiness Assessment, we have developed an innovative approach for the structured determination and evaluation of companies' maturity on their path toward implementing digital twins. This helps companies to find out, where they stand while at the same time supporting the development, introduction, and operation of digital twins. In a cooperative study by Fraunhofer IPK and msg, the maturity model has been applied to 26 companies in the manufacturing industry in the DACH region (Germany, Austria, and Switzerland). We were able to gain exciting insights into the challenges digital twins present to companies, their advantages and their impact on business models and necessary skills from the job market in the near future. This spread is a preview of the study, provided by some of its respondents, editors, and authors.

↳ The full study in German as well as an English-language summary can be downloaded for free at [www.ipk.fraunhofer.de/readiness](http://www.ipk.fraunhofer.de/readiness)



**Matthias Schultalbers**  
CHIEF DIGITAL OFFICER, IAV

»Thanks to the digital twin, we can offer our customers better quality assurance through greater testing depth. At the same time, the digital simulation saves resources and increases the development speed, thus enabling us to bring customer projects to series production more rapidly.«



**Markus Samarajiwa**  
LEAD BUSINESS CONSULTANT, MSG

»Companies must open up their data silos in order to be competitive and future-ready with their digital twins.«



**Prof. Dr.-Ing. Rainer Stark**  
HEAD OF THE VIRTUAL PRODUCT CREATION DIVISION AT FRAUNHOFER IPK

»It is only through cross-company collaboration and networking of the digital twins that the full potential of the approach will unfold.«



**Heiko Witte**  
BUSINESS DEVELOPMENT MANAGER DIGITAL, ROLLS-ROYCE DEUTSCHLAND

»Cross-functional skills are required for digital twins. In addition to the necessary digital expertise in data innovation and cybersecurity, skills of ›digital natives‹ from the specialist departments will be just as crucial as agile management, agile process methods, and the corresponding process specialists.«



**Theresa Riedelsheimer**  
DEPUTY HEAD OF THE INFORMATION AND PROCESS CONTROL DEPARTMENT AT FRAUNHOFER IPK

»The fact that many companies want to use digital twins to optimize sustainability – often to increase energy efficiency – is of particular interest to our research. We will also continue to focus on the topics of intelligence and interconnection of digital twins in our future research activities.«



**Andrea Denger**  
PROGRAM MANAGER INFORMATION MANAGEMENT AT AVL LIST GMBH

»For AVL, the digital twin not only offers added value in terms of the virtual representation of all relevant properties of smart IoT objects along the product lifecycle, but above all in its use as a fundamental basis for new digital offerings.«

»To make a business model fit for digital twins, companies must conceive of offerings consisting of hardware, software and customer service holistically and find suitable billing options. A data connection must be established and the distribution of the products must be adequately designed.«

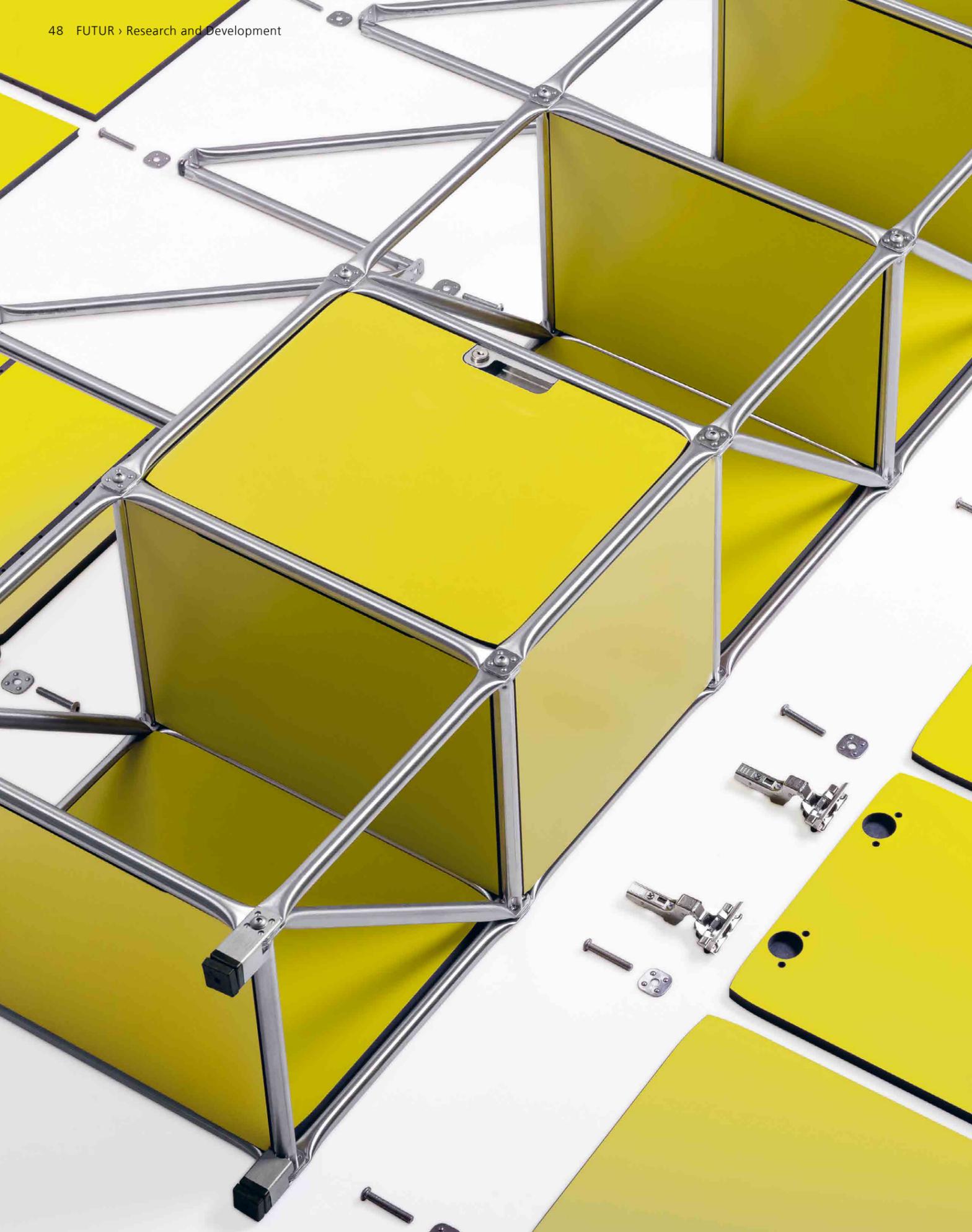


**Dr. Michael Hoffmeister**  
DIGITAL BUSINESS – EXECUTIVE EXPERT, FESTO

**Thomas Seeger**  
PLM PROFESSIONAL / CAX SYSTEM MANAGER INFORMATION TECHNOLOGY, AUTO-KABEL MANAGEMENT

»The biggest challenge in developing digital twins is to overcome interface problems. Digital twins require sensors, connectivity, and defined data structures.«





## Toward a Circular Economy in the Furniture Industry

New Work is revolutionizing the demands on the workplace: The environment must adapt to the people. The furniture industry and designers have reacted accordingly and offer flexible working environments.

In the future, furniture will no longer merely be functional items but increasingly assume design functions. Teamwork with open, communication-promoting structures as well as oases that promote concentration demand novel spatial concepts. The flexibility and agility required for this pose new challenges for the furniture industry. While conventional office furnishings were designed for long-term use within a company, more solutions must now be found for variable and resource-efficient furnishing concepts.

#### WHAT TO DO WITH DISCARDED FURNITURE?

Industries such as the mobility sector show how it is done: The introduction of innovative sharing and leasing concepts is leading consumers to rethink the ownership of material goods and enabling providers to better adapt to new customer needs. The furniture sector is also gearing itself to the established ideas of related markets. For example, IKEA aims to become a circular and climate-friendly company by 2030 by helping customers to reuse materials and components as often as possible. Digitalization also supports product placement through platforms such as Opendesk, an online marketplace that connects customers with independent local furniture makers and designers.

#### PLATFORM ECONOMY MEETS MATERIALS-CYCLE MANAGEMENT

A resource-saving solution is required for furniture from all companies and organizations that is no longer needed after the first cycle of use. Can models of reuse through rental, leasing, or subscription also be transposed to other furniture manufacturers? How can furniture be recycled as efficiently as possible? In the project PERMA (platform for efficient resource utilization in the furniture industry), a network of various stakeholders from scientific and commercial fields researches solutions to these challenges. The potential lies in connecting the platform economy and materials-cycle management: Establishing a strongly circular ecosystem forms the basis for developing new platform-oriented

### Can models of reuse through rental, leasing, or subscription also be transposed to other furniture manufacturers?

**Image:**  
Locally produced high-quality system furniture can be easily disassembled into its component parts.  
© System 180 GmbH

business models in the furniture industry. This results in new types of product lifecycles and cross-manufacturer compatibility guidelines. As a result, companies will be able to equip their offices in line with the requirements of modern workflows as well as ensure sustainable and flexible reuse and further use of products in a manner that preserves value.

#### ONE PLATFORM THAT DOES IT ALL

PERMA wants to create a framework that brings together manufacturers and users while promoting the exchange of know-how on topics related to maintenance, reuse, refurbishment, and recycling to extend the life of furniture and its components. The platform is aimed at business customers from private and public sectors with the motivation of spreading investments across the entire product lifecycle and achieving extensive functional flexibility. In this respect, rental or subscription models are the means of choice. Review systems are meant to provide a guide for customers while at the same time encouraging manufacturers to design furniture that is suitable for reuse. PERMA plans to offer comparison and review options, an online marketplace and agency services, making a significant contribution to increasing resource efficiency. ♦

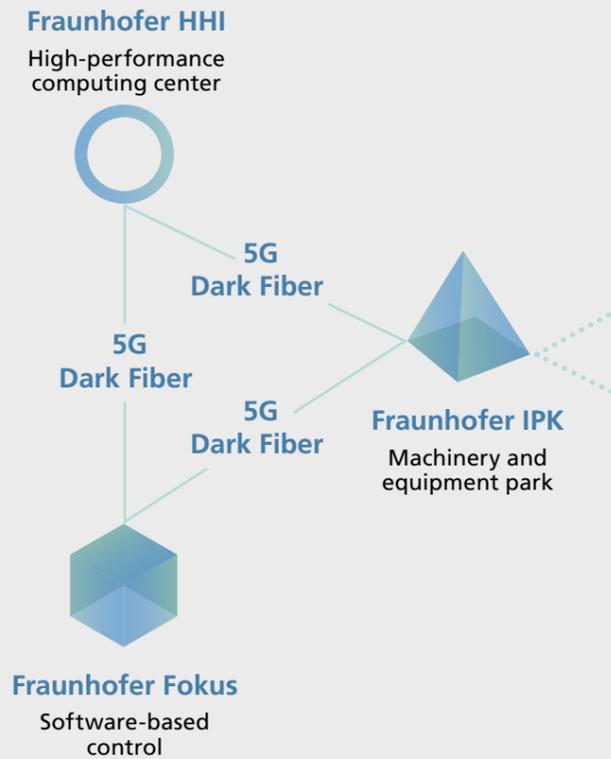
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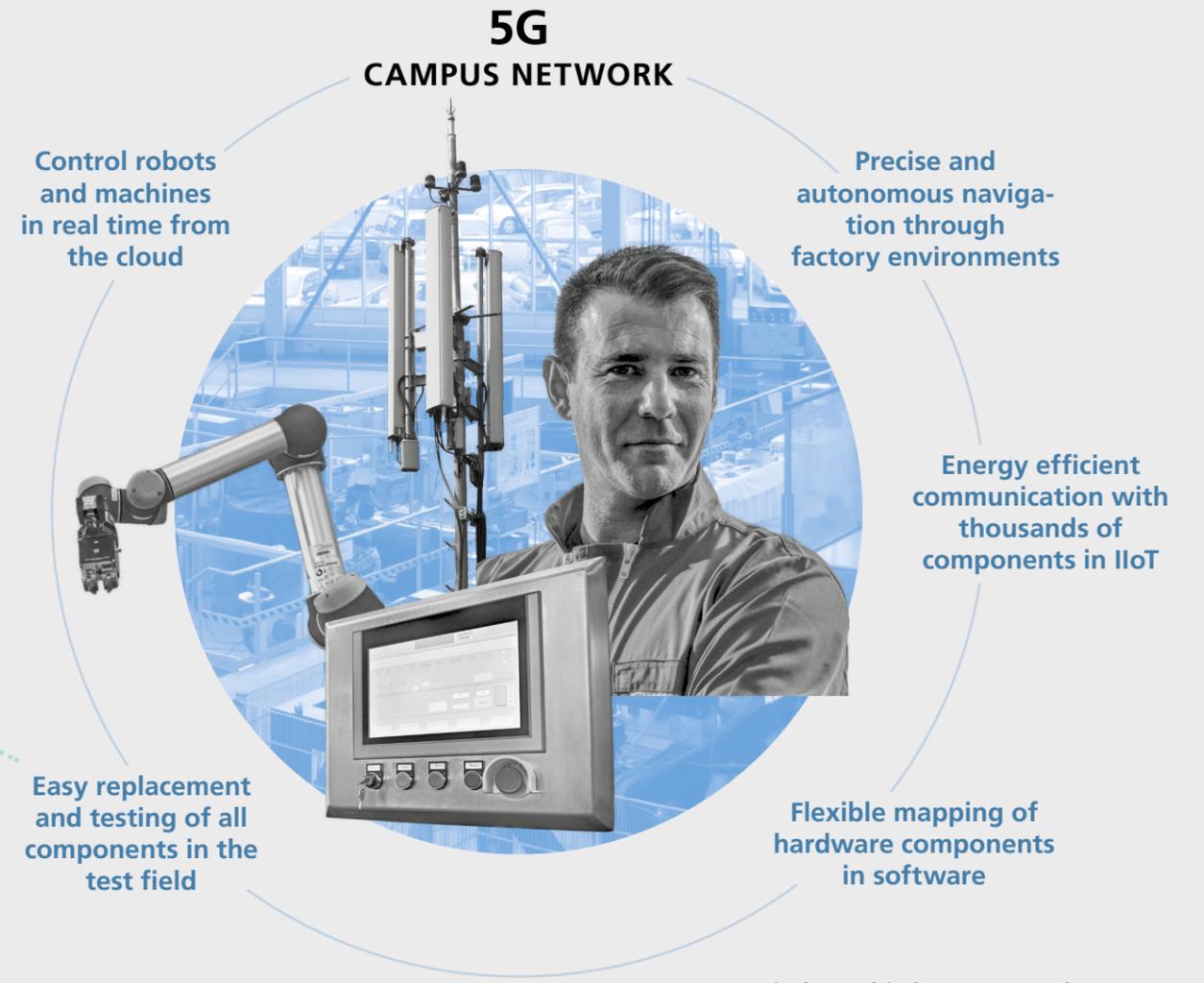


# Software-defined 5G Factory

Starting at the end of 2020, companies will be able to test factory processes in a 5G infrastructure in the PTZ test field – thanks to the Berlin Center for Digital Transformation.



**Combined know-how**  
For the 5G networked future, Berlin's Fraunhofer Institutes are cooperating in the research areas IoT, Cyber-physical Systems, Industry 4.0 and 5G technologies in the Berlin Center for Digital Transformation.



**Lived research in the campus network**  
Industrial application scenarios are implemented in the 5G infrastructure of the Production Technology Center's machine park, connecting people, machines and processes in real time.  
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The 5G mobile communications standard promises to meet high expectations in terms of the comprehensive networking of people, objects, and processes in industrial production. A higher bandwidth means faster transmission speeds that can transfer large data packets in real time. 5G enables robust, fail-safe communications for networking intelligent machines and devices in the Internet of Things (IoT) and the implementation of distributed production. This will allow industrial production and service processes to be carried out more effectively and efficiently.

**TESTING FUTURE TECHNOLOGIES LIVE**  
At the Berlin Center for Digital Transformation, the four Berlin-based Fraunhofer Institutes are jointly researching the development of future communication technologies in various fields of application. For this purpose, Fraunhofer FOKUS, HHI, and IPK are networked via a dark fiber optical network and a 5G radio link. Using this communications infrastructure with real-time capabilities, the software-defined 5G factory, in which all aspects of factory operations will be implemented, will be configured by the end of 2020.

**PERFECTLY NETWORKED AND OPTIMIZED IN REAL TIME**  
Fraunhofer IPK will directly be providing this infrastructure with the latest machines and robots from its experimental field, while older machine tools will be integrated subsequently via sensors and communications modules. This retrofitting is being developed by Fraunhofer IZM. The systems' software can be controlled both locally at Fraunhofer IPK and remotely from Fraunhofer FOKUS. A high-performance computing unit (HPC) at Fraunhofer HHI will perform computationally profound tasks and

provide analysis results to the control software in real time. Coupled with process management systems, this creates a real-time cockpit that controls production processes variably and according to specific situations. The software-defined 5G factory of the Berlin Center for Digital Transformation has been designed as a test field for industry. Every component of the 5G infrastructure is interchangeable and can be replaced with custom-developed components such as antennas, software modules, or sensors. Using predefined factory processes, companies can test the functionality

of their components in a real environment and verify their impact on the 5G infrastructure. ♦

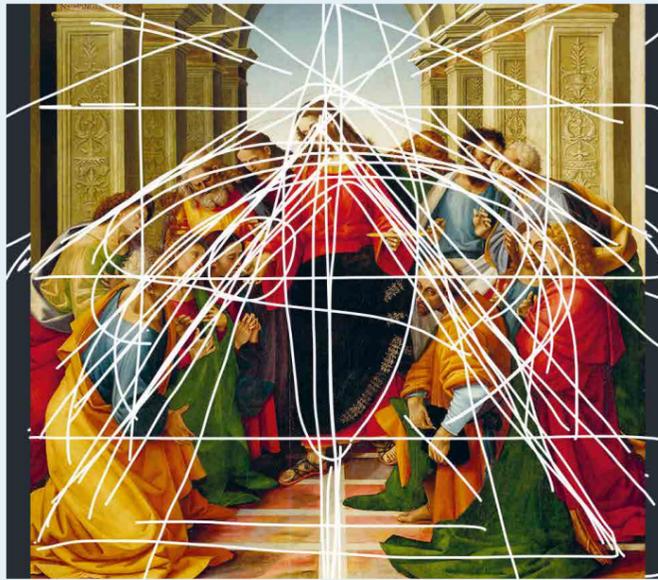
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Watch the entire virtual discussion on [www.ipk.fraunhofer.de/the-eye-of-the-beholder](http://www.ipk.fraunhofer.de/the-eye-of-the-beholder)



## The Eye of the Beholder: How Humans and Machines See Art

The question of which opportunities arise from the conflicting priorities of digitalization, culture and society is the focus of the new series »Science and Culture in Conversation« organized by the Austrian Cultural Forum Berlin and Fraunhofer IPK. The series was kicked off on November 13 with the virtual session »The Eye of the Beholder: How Humans and Machines See Art«.

The fascination with viewing works of art has occupied mankind for centuries. Now new technologies like machine vision offer completely new possibilities. How this different view can be compared to human perception is the question discussed by Prof. Dr. Raphael Rosenberg, Professor of Medieval and Modern Art History at the University of Vienna, and Dr. Bertram Nickolay, Head of the Department of Machine Vision at Fraunhofer IPK. ♦

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## Research and Manufacturing in Times of Corona

The COVID-19 pandemic is confronting manufacturing companies with far-reaching changes. There are numerous reasons why companies are unable to offer their usual product portfolio or can only do so to a limited extent. At the same time, there is an increasing demand for products that a company may not have manufactured previously – which could be an interesting addition to the company's product range if manufacturing processes are adapted slightly. We would like to support you in adapting quickly and efficiently to these conditions. Our extensive experience in production technology and process organi-

zation helps you to adapt manufacturing processes with minimal friction and to implement new processing options. This will enable you to stay in business even in exceptional situations. Get in touch with us and we will find the right solution for your company. ♦

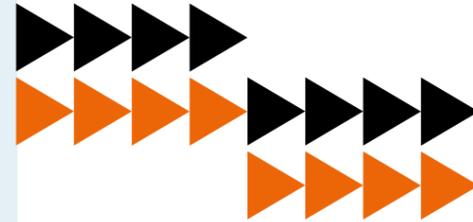


Examples of successful projects from our »Manufacturing in Times of Corona« campaign can be found on our website: [www.ipk.fraunhofer.de/manufacturing-in-times-of-corona](http://www.ipk.fraunhofer.de/manufacturing-in-times-of-corona)



The »B-A-D Seal for Industrial Safety Standard COVID-19« confirms that Fraunhofer IPK fulfills the Industrial Safety Standard COVID-19, which has been valid nationwide since April 16, 2020, and complies with it in an exemplary manner to protect its employees, customers and the institute's operations.

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In our professional education program we transfer technology-based know-how directly into business practice. By participating in our advanced training formats, you invest in your professional development and at the same time promote the economic success of your company. Take advantage of the opportunity to receive further training in a scientifically sound and implementation-oriented manner. Establish networks with experts from other companies, even beyond your own industry boundaries.

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You can find **current information** about our program on our website [www.ipk.fraunhofer.de/en/events](http://www.ipk.fraunhofer.de/en/events)

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