THE MAGAZINE OF THE **PRODUCTION TECHNOLOGY CENTER BERLIN**

futur

VISION | INNOVATION | REALIZATION

All Hands on Deck

Today, those who develop complex products do so using data and collaborative methods. Gaia-X aims to provide the framework for this.

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Spotlight on Data Selection

Data from manufacturing processes is used to evaluate process quality. Often, only a fraction of the available data points is sufficient, but they must be the right ones.

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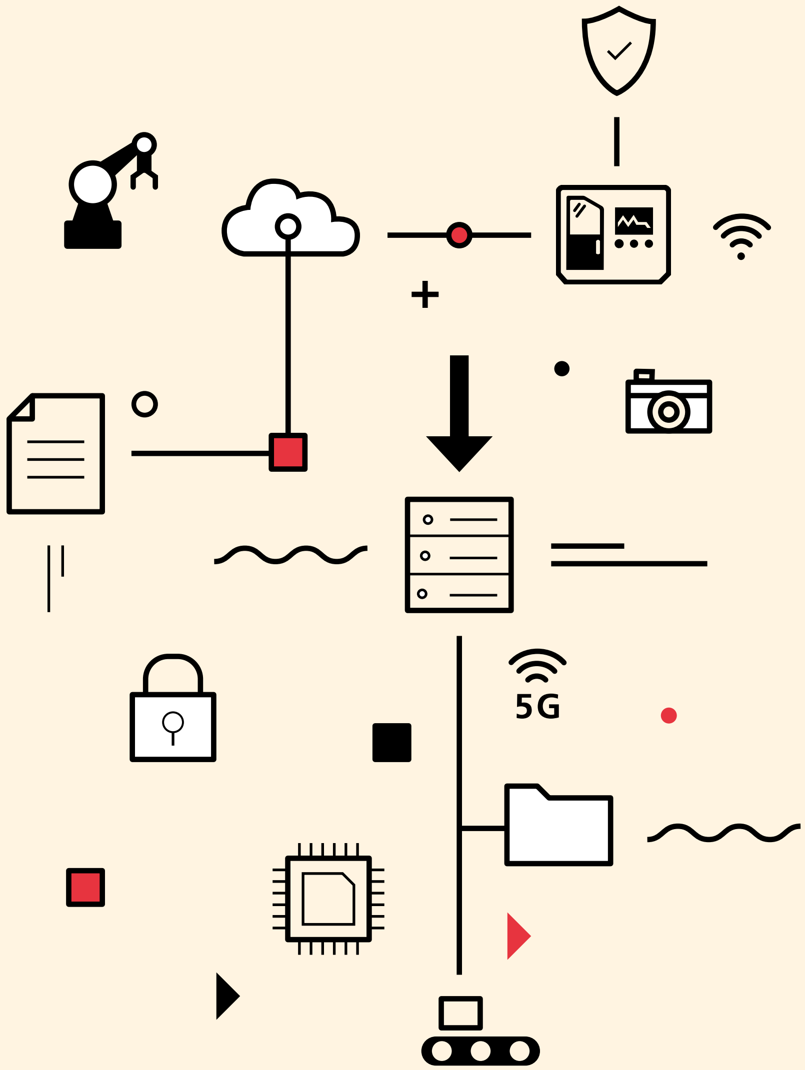

No Waste Today

Effective take-back management and recycling enable companies to not only save material costs but also reduce their ecological footprint.

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AI-tailored Wish Fulfillment

The first draft rarely is the final one in product development. With the help of artificial intelligence, this labor-intensive but essential stage can be accelerated.

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DATA

INSTITUTE
PRODUCTION SYSTEMS AND
DESIGN TECHNOLOGY

INSTITUTE MACHINE TOOLS
AND FACTORY MANAGEMENT
TECHNISCHE UNIVERSITÄT BERLIN

We are bringing the virutal world onto the physical shop floor.

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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,

the German government's Digital Summit took place in Jena at the end of November 2023. The topic: »Digital transformation at the turn of an era. Sustainable. Resilient. Future-oriented.« The priorities that politicians are addressing here have been part of our agenda at PTZ Berlin for some time.

In close cooperation with industry, our scientists are getting the digital transformation of production off the ground. To this end, they are also investigating the smallest building blocks of this transformation: data, and how it can be collected, analyzed and processed in a beneficial, secure and high-quality manner. In short, they never lose sight of what this data is actually used for: to create specific solutions for the challenges industry and society are facing.

This is why our researchers are actively involved in the Gaia-X initiative, which aims to facilitate the collection and exchange of data along the value chain at European level. In this issue of FUTUR, you can read about how this enables the use of collaborative digital twins. With their help, cross-company and cross-organizational product development teams can, for example, more easily design and manufacture innovative, efficient and holistically thought-out products. In the Gaia-X sub-project Catena-X, researchers at Fraunhofer IPK are also developing assistance software to help companies in the automotive industry design suitable recycling strategies. In doing so, they are making a decisive contribution to the circular economy.

Due to a lack of transparent data and benchmarks, it is often difficult for companies to determine how they are positioned in terms of their greenhouse gas emissions compared to others. A benchmarking procedure developed at Fraunhofer IPK provides clarity and transparency, especially for small and medium-sized companies.

In the future, a novel software will also help product development to move quickly from idea to prototype. It transfers designs 1:1 into virtual environments, facilitating joint processing and helping to identify weak points earlier. In the spirit of »extended reality«, the virtual world is having an impact on the physical world. We are also presenting two very different use cases that have one thing in common: the clever handling of data when training artificial intelligence. And we present approaches developed at Fraunhofer IPK for data economy in industrial image processing and in the quality control of additive manufacturing processes.

Wishing you a data-rich, informative read.

Yours sincerely

Eckart Uhlmann

Index

Data needs space, sovereignty and continuity. How do we make sure we can provide all that?

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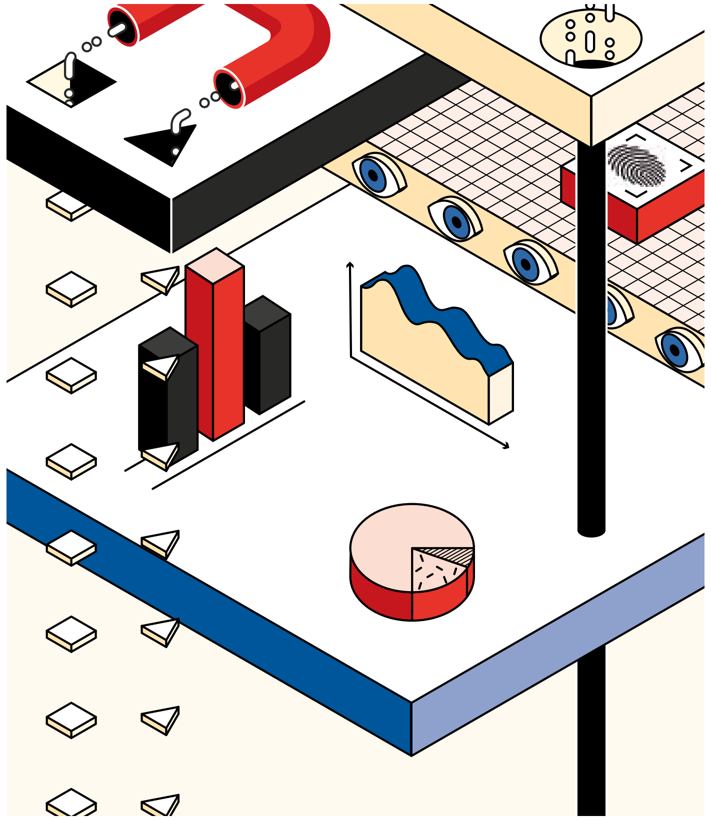

So far, components are usually tested after, not during production
↳ More on page 24

Similar to the sports world, where individual performance is compared with the best, companies want to compare their emission data with market leaders or at least similar companies.

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Machines can now identify used parts and surgical instruments
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Recycling is becoming increasingly important in the automotive sector
↳ More on page 42

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SHORT CUTS

NUMBER OF THE ISSUE

98 %

of all used parts were correctly identified by an AI-supported assistance system developed at Fraunhofer IPK and could be sent for remanufacturing.

↳ Learn **how researchers can simplify the training of AI** on page 48.

WELL SAID

© UVB

»For manufacturers, suppliers, and infrastructure operators to communicate across borders, they require not only uniform data standards and legal certainty but also high-performance digital infrastructure and robust IT security architecture. These tasks must be at the top of the agenda for Berlin-Brandenburg's digital policy.«

Sven Weickert, Managing Director of the Business Associations Berlin-Brandenburg (UVB)

↳ Learn more on page 20.

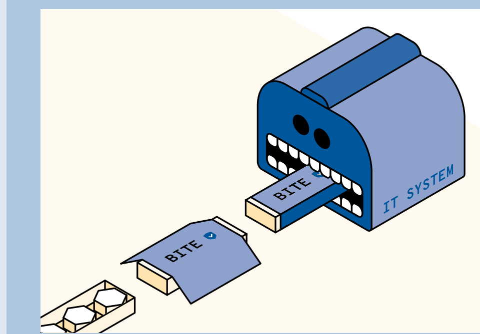
ZERO WASTE THANKS TO AI

© BSR Berliner Stadtreinigung

»To give away, slightly used« – with the Kiez-Locker, such items can already be distributed practically and safely in the neighborhood in two Berlin districts. And all without give-away boxes on sidewalks or house calls from strangers. Researchers from Fraunhofer IPK supported the Berlin city cleaning service (BSR) with their expertise during the development.

↳ **More information (in German):**
www.bsr-kiezlocker.de

IN DETAIL



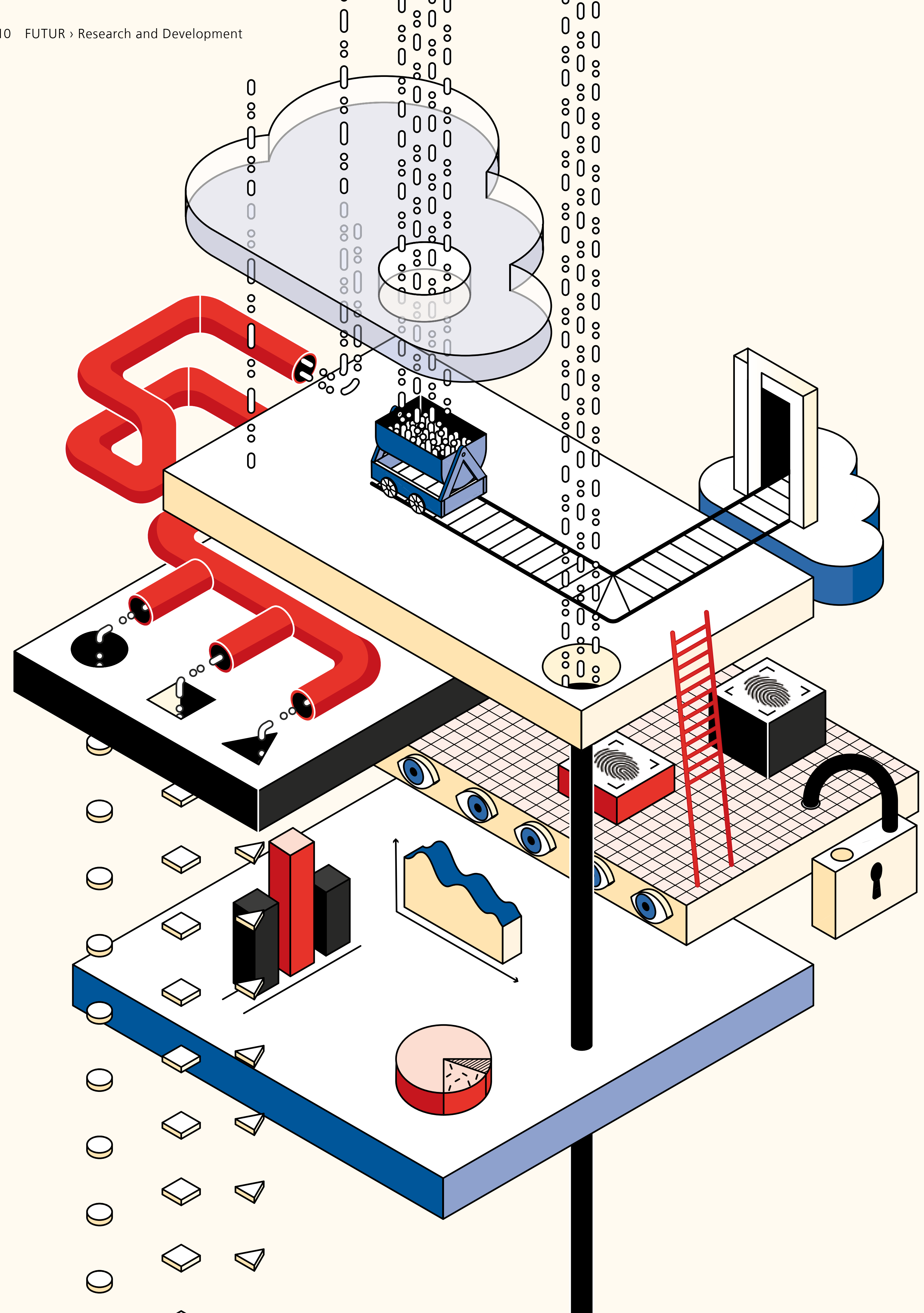
Find out **what this data-hungry colleague is all about** in our lead article

↳ on page 10.

FRAUNHOFER IPK DISTINGUISHED FOR FAMILY FRIENDLINESS

The Fraunhofer IPK was awarded the »Fraunhofer FamilienLogo« for the first time, in acknowledgement by the Fraunhofer-Gesellschaft for outstanding framework conditions for balancing work and private life. We are one of the 20 institutes that received the award out of 44 submissions and scored at least 80 out of a possible 100 points.

The Fraunhofer FamilienLogo is based on comparable external certifications, such as the »Work and Family« audit. It covers six subject areas, ranging from flexible working options, childcare facilities and support during parental leave to the use of Fraunhofer support services, which are of central importance for achieving a good work-life balance.



From Raw Data to Refined Resource

A few years ago, The Economist boldly declared, »The world's most valuable resource is no longer oil but data«. While previous industrial revolutions were defined by the dominance of fossil fuels, the age of Industry 4.0 revolves around data.

Much like coal-fired steam engines powered the first factories and connected cities and entire nations through railways in the 19th century, data now fuels the Internet of Things (IoT) and data highways within and between enterprises. Just as the developments of the 19th century ushered in substantial infrastructure improvements and social and political reforms, the rapid pace of technological advancement of the 21st century demands that companies and policymakers adapt with new investments and regulations.

In manufacturing companies, the digitalization of processes has led to an increased reliance on cross-enterprise data management throughout the entire product life cycle. Rising regulatory demands, such as supply chain laws and transparency requirements for environmental standards compliance, continue to propel data exchange. To harness vast volumes of data from various sources efficiently and effectively, businesses and other societal stakeholders require appropriate technologies and strategies. In this article, we delve into the key concepts and developments essential for digital value creation.

DATA SPACES: ENABLING EFFICIENT DATA MANAGEMENT

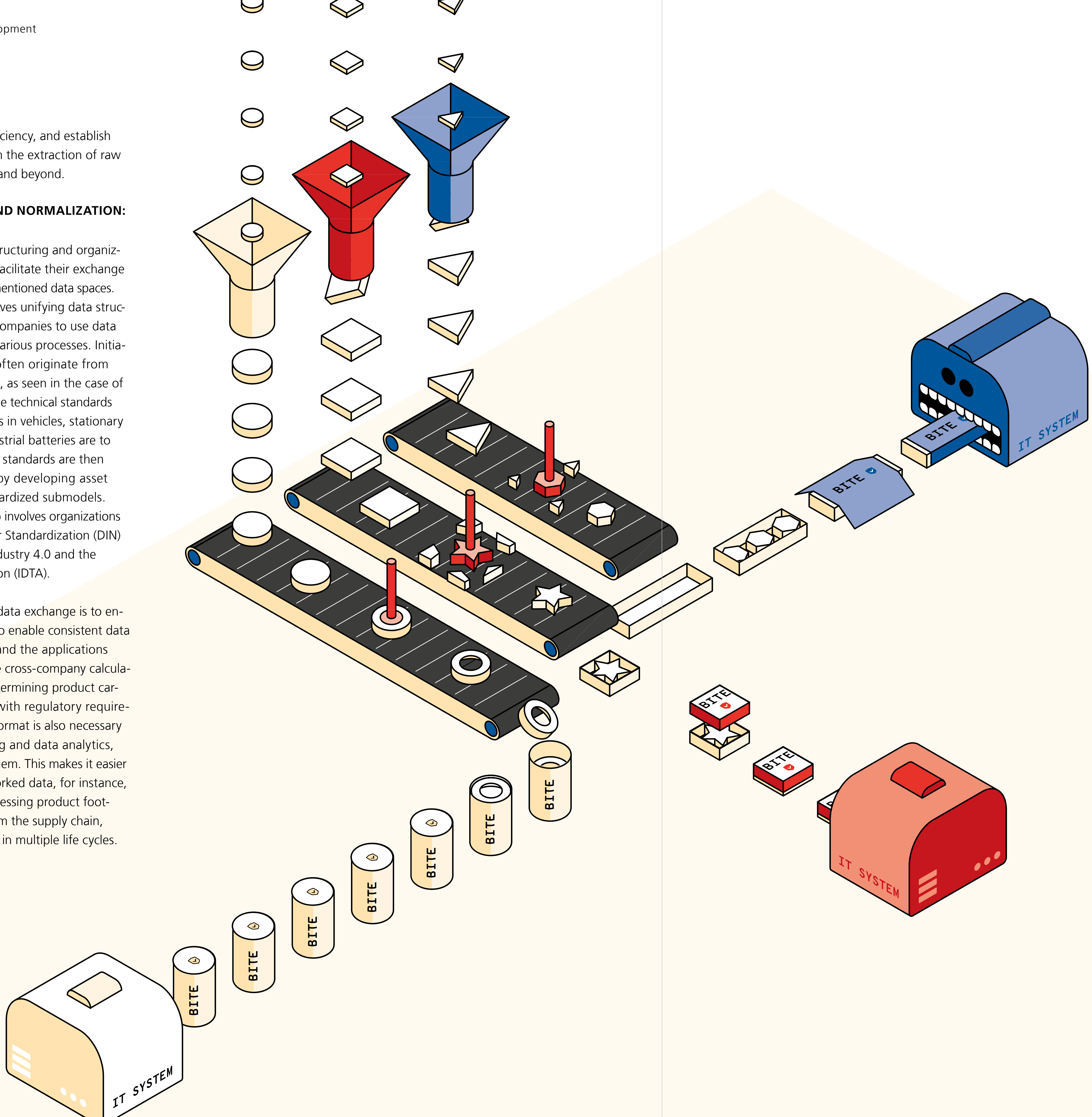
Data spaces represent virtual environments or platforms for storing, managing, and exchanging data. They serve as secure and increasingly decentralized repositories for various types of data related to products, processes, and companies. This includes, for example, material data for products, quality data from manufacturing processes, and financial data verifying a company's operational capability.

Data spaces adhere to the principle of sovereignty, ensuring that companies retain control over their data and can determine who can access it, when, for what purpose, and under what conditions. Within shared or interconnected data spaces, companies can securely share and manage data. For example, they can engage in research and development activities across locations with internal teams, share data along the development or supply chain with external partners, or provide product, machinery, and equipment usage data to customers. This enables manufacturing companies to save time, enhance collaboration efficiency, and establish comprehensive data chains from the extraction of raw materials to product utilization and beyond.

DATA STANDARDIZATION AND NORMALIZATION: ENSURING DATA QUALITY

Data standardization involves structuring and organizing data in uniform formats to facilitate their exchange and processing within the aforementioned data spaces. Standardizing data models involves unifying data structures, allowing manufacturing companies to use data across different data spaces in various processes. Initiatives for data standardization often originate from entities like the European Union, as seen in the case of the Battery Passport, in which the technical standards for all newly purchased batteries in vehicles, stationary storage systems and larger industrial batteries are to be set out from 2026 on. These standards are then specified at the national level by developing asset administration shells and standardized submodels.
In the case of Germany, this step involves organizations such as the German Institute for Standardization (DIN) and entities like the Platform Industry 4.0 and the Industrial Digital Twin Association (IDTA).

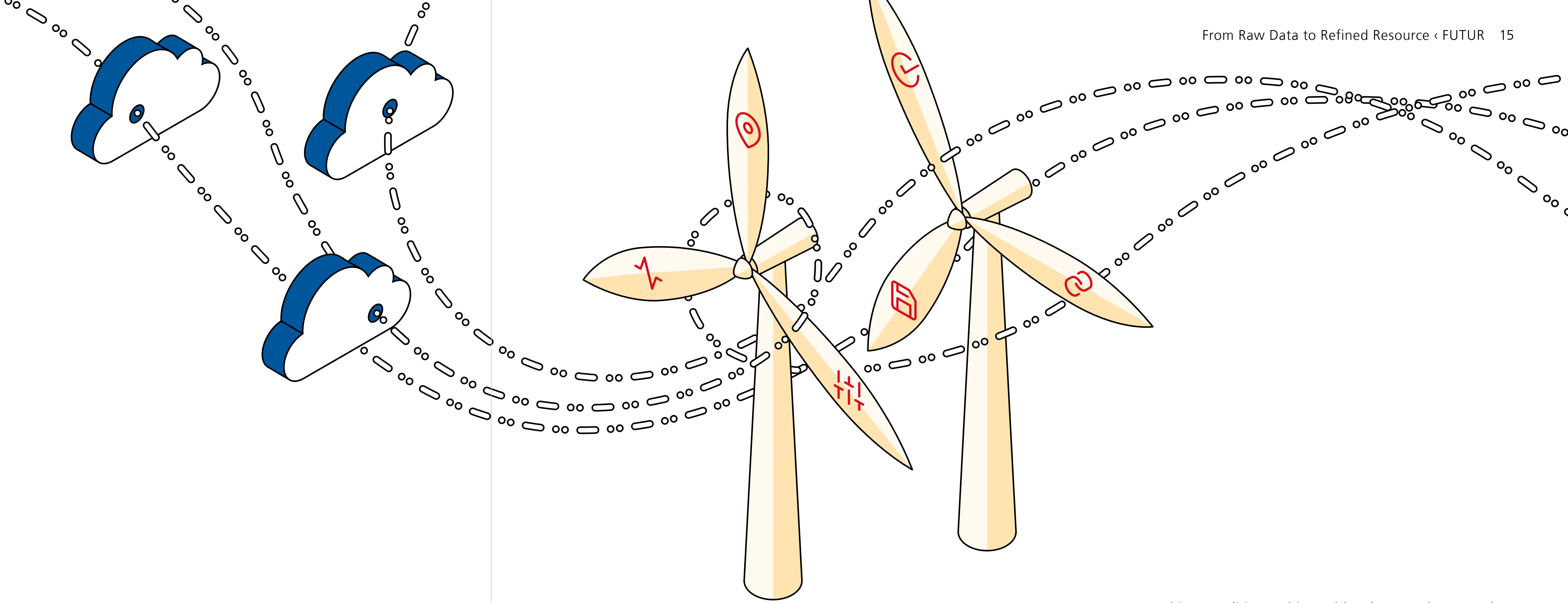
One objective of standardizing data exchange is to ensure network and data quality to enable consistent data processing across data spaces and the applications used therein. They also facilitate cross-company calculation of specific KPIs, such as determining product carbon footprints, in compliance with regulatory requirements. Data in a standardized format is also necessary for automated machine learning and data analytics, allowing IT systems to process them. This makes it easier for companies to analyze networked data, for instance, for machine maintenance or assessing product footprints based on information from the supply chain, production, and potential reuse in multiple life cycles.



DATA SOVEREIGNTY: EXERCISING CONTROL OVER DATA

A fundamental attribute of raw materials is that they undergo many processing steps on the way towards a functional product. This also applies to raw data.
In order for data owners to maintain control over the utilization of the latter, the principle of data sovereignty was established. Data sovereignty refers to the autonomous handling of one's own data, encompassing control over the collection, storage, use, and processing of proprietary data. Often, this concept also extends to digital sovereignty, referring to informational self-determination in the digital age. In addition to political and legislative responses, IT providers at various levels are addressing this principle. They incorporate digital concepts and technologies to ensure that companies can enact their digital sovereignty. Initiatives like Gaia-X and Catena-X play significant roles in this endeavor.

Not all data is the same: They have to be prepared differently for different systems.



There are numerous success factors for end-to-end data flows.

Read more about Gaia-X and the mobility sector in the article »All Hands on Deck« on page 16.

Read more about our research within the framework of Catena-X in the article »Software-driven Smart Dismantling« on page 42.

Gaia-X is a European endeavor aimed at establishing secure and interconnected data infrastructures that prioritize both applicable laws and sovereignty. It is based on an open federation of stakeholders. To support their autonomy as well as their collaborative efforts, basic functionalities are provided, enabling the discovery of available services, data sharing, standardization of data models, and fundamental services like authentication. This approach is applied across various domains, from public administration to industrial sectors, mobility services, and healthcare. For example, the Gaia-X 4 Future Mobility project family examines data supply for automated vehicles, system networks for vehicles, product life cycles, and digital twins for automated driving.

Catena-X builds upon the fundamental principles of Gaia-X. By federated services and a common concept for managing policies on a technical level, it empowers companies to grant access to their data to specific organizations or companies that can demonstrate a particular role through certification. Companies without access do not even necessarily become aware of the data's existence. The policies in Catena-X can also define conditions for data usage, such as restricting data usage to specific regions or time intervals. This ensures that authorized or certified recycling companies, for example, may access data on the materials used in a vehicle and their supply chain when needed for recycling purposes, while competitors cannot access the material composition.

DATA CONTINUITY: ENSURING SEAMLESS DATA FLOW

Data continuity refers to the seamless and consistent usability of data from various sources and applications. These sources include IT systems, platforms, or databases, distributed throughout the entire product life cycle. Key aspects of data continuity encompass the following:

- Integration of diverse data sources, such as data from legacy systems into current IT environments.
- Mapping of different data types, like mapping energy data from manufacturing into life cycle assessment models for product development.
- Access to real-time or live data, for instance, when monitoring and controlling 3D printing processes.
- Uniform data formats and standards, fostering interoperability between development and production systems.
- Data quality and governance, including establishing governance for the handling of product-related data.
- Managing changes, such as defining technical and temporal data validity.

Seamless data continuity is achieved through a smooth data flow within and between companies, supported by unified data formats and models, along with necessary interfaces between IT systems. Analyses conducted in data flow assessments by Fraunhofer IPK have highlighted that data continuity is often seen as an isolated IT challenge. In reality, it should align with digital value creation. This perspective addresses not only formats and IT systems but also value-generating activities, coordinating process flow, and structuring organizational entities in the setup. This approach underscores that data continuity serves as the backbone of value creation.

DATA-DRIVEN BUSINESS MODELS: EXTRACTING VALUE FROM DATA

Data-driven business models have become a decisive competitive factor for manufacturing companies. By intelligently collecting, networking, analyzing, and evaluating data, manufacturers not only optimize their internal processes but also generate added value.

Real-time data collected by sensors and interconnected machines allow factory management and specialized personnel to closely monitor production processes and machine conditions. This enables them to detect and resolve bottlenecks or disruptions promptly. Moreover, data analysis offers opportunities for predictive maintenance. By analyzing sensor data, maintenance needs can be foreseen, reducing unplanned downtime and extending the lifespan of equipment, ultimately leading to improved overall production efficiency and reduced operational costs.

Company management can also utilize the obtained data to develop new business models. Manufacturing companies can offer data solutions as a stand-alone product or cooperate with partner companies to place new service offerings on the market. For example, they can monetize their expertise in data analysis and thus tap into new sources of income. There is also potential for data-based business models in the personalization of products and services. By evaluating customer and usage data, companies can offer individual solutions that are tailored to the needs and preferences of their customers. This not only increases customer satisfaction, but also opens up new sales opportunities through customized products and services. ◆

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All Hands on Deck

Today, those who develop complex products do so using data and collaborative methods. Gaia-X aims to provide the framework for this.

»Alone we can do so little. Together we can do so much.«

Helen Keller

Nowadays, complex products such as cars typically have a significant »digital component«. Important functions throughout their entire life cycle have shifted from the physical world to virtual data spaces. In the automotive industry, products are developed almost completely virtually, entire production facilities are controlled through digital twins, and smart products are capturing an increasing amount of data. New requirements for sustainability and recycling make the use of data essential even after a product's end of life. With a high degree of cross-organizational processes, more and more, this data must be used collaboratively. The decentralized exchange of data is also on the rise due to advances in autonomous driving and the increasing connectivity of vehicles. Furthermore, the use of software from various manufacturers also plays a significant role, as ever more complex service and function chains need to be represented to efficiently process and use data.

All these complex interconnections come with correspondingly great challenges that can be illustrated through a forward-thinking technology that could have a profound impact on the field of mobility: collaborative digital twins.

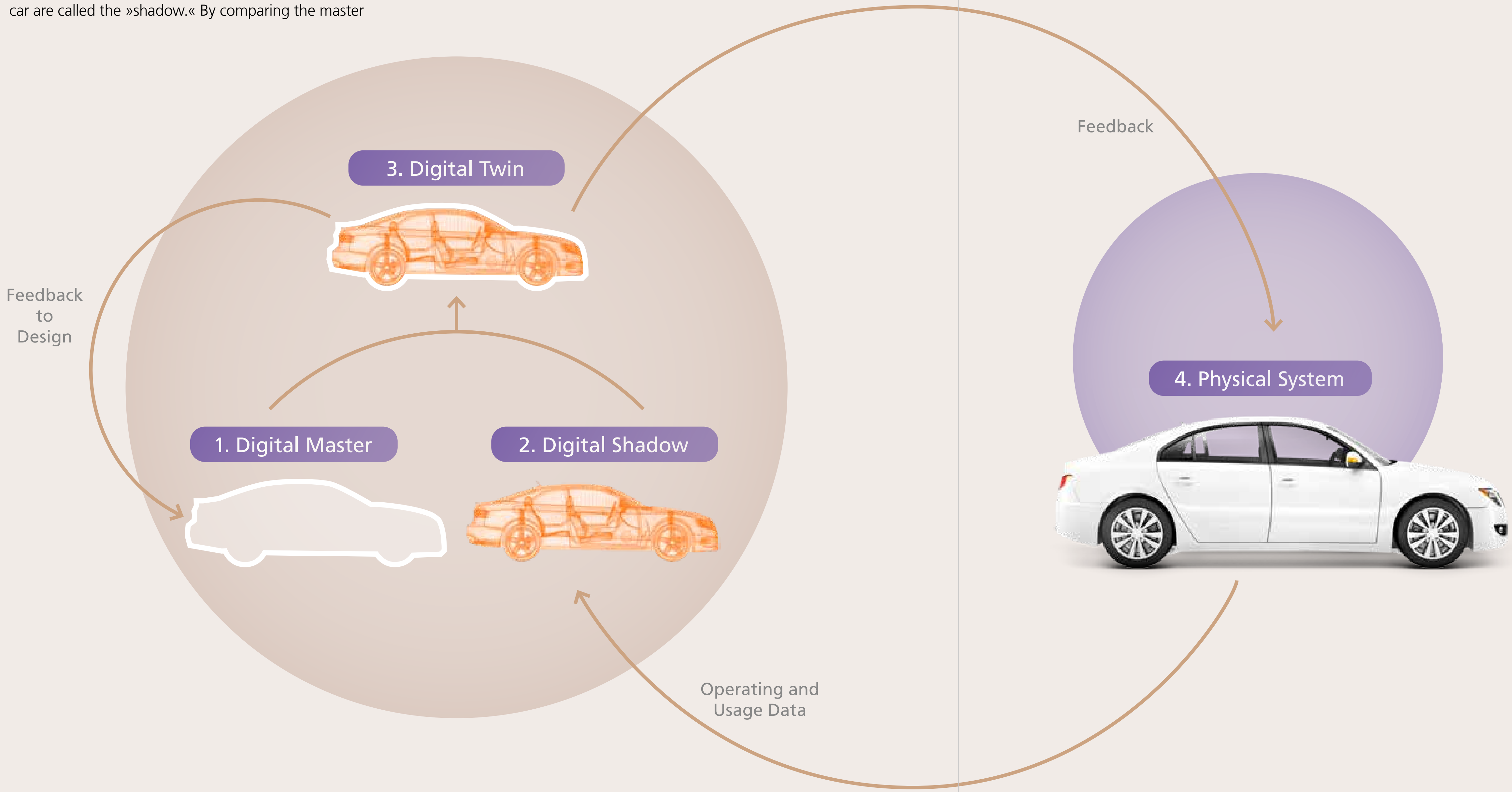
MASTER, SHADOW, TWIN

Digital twins are a strategy for effectively utilizing data and are often an essential part of the digitalization strategy for German and European companies. Digital

New requirements for sustainability and recycling make the use of data essential even after a product's end of life.

twins are virtual representations of a physical entity that combine virtual (master) and real (shadow) data to perform a given function. Let's take your car as an example. There are probably thousands of cars like yours. They were all produced based on the same drawings and production instructions, and they have maintenance cycles based on average usage patterns. The models, simulations, and data used to manufacture all these cars are called the »master.« However, your car is unique. From the moment of production, there were peculiarities that only applied to your car. There might have been assembly variations, or it could have been driven on particularly rough roads or in very hot, cold, or wet regions, requiring early maintenance. These data that represent the reality of your unique car are called the »shadow.« By comparing the master and shadow data of the car, functionalities can be implemented in the »digital twin,« for example, making predictions about the optimal maintenance timing.

Digital twins are essential in the entire mobility sector. They help professionals detect anomalies, assess quality, predict maintenance needs, train autonomous driving systems, and monitor various mobility systems. To achieve this, data from various players and sources, such as vehicle sensors, manufacturer development models, and climate or traffic information, need to be combined,



giving rise to collaborative digital twins that enable cross-company and cross-organizational product development teams to design innovative, efficient, and integrated products. To ensure data sovereignty, protection and ultimately the trust of all parties involved, this must all happen in a well-regulated environment.

UTILIZING DATA TOGETHER THANKS TO GAIA-X

This is where the Gaia-X initiative comes into play. It is developing an open-source framework that enables a federated and secure data infrastructure. This allows data to be exchanged in a trusted environment while ensuring the digital sovereignty of data owners and interoperability across different platforms.

To achieve this, an open-source toolbox with so-called »Gaia-X Federation Services« (GXFS) is being developed. These services represent the minimum technical requirements for establishing and operating a cloud-based, self-managed data infrastructure ecosystem. They include a catalog component to establish common data description standards among data space participants and intelligently link data and services to collaborative digital twins. Additional rules and components for »compliance,« »sovereign data exchange,« and »identity & trust« enable the definition and enforcement of rules for collaborative data usage, such as contract completion or access rights management in the shared data space.

The Gaia-X ecosystem marks the dawn of a new era of cross-industry collaboration. It facilitates the development and implementation of fair and transparent data-based business models, reducing their complexity and costs. The vision of Gaia-X is a thriving digital industrial landscape where the values of data sovereignty, collaboration, and innovation are merged harmoniously. At Fraunhofer IPK, scientists are conducting research in collaboration with companies from the digitalization and mobility sectors as part of Gaia-X, aiming to make this vision a reality. They delve into profound questions such as the development of digital business models, data flow structuring, the creation of shared digital twins, the establishment of suitable IT systems, and the development of ontologies and information models to ensure data compatibility. ◆

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Data Must Move up the Agenda

As Managing Directors of the Business Associations Berlin-Brandenburg (Unternehmensverbände Berlin-Brandenburg, UVB), Alexander Schirp and Sven Weickert are representing the perspective of the local industry within the »ReTraNetz-BB« project. In our interview, they explain how digitalization will change the automotive industry.

Sven Weickert

born in 1969, studied business administration in Berlin. After working in business and academia, he joined the Business Associations Berlin-Brandenburg (UVB). Today, as Managing Director, he is responsible for the areas of economics, education, and digitization.

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Alexander Schirp

born in 1966, studied law in Passau and Rostock. He has been working for the Business Associations Berlin-Brandenburg (UVB) since 1995. Since October 2023, he has been CEO of the umbrella organization as well as the Association of the Metal and Electrical Industry in Berlin and Brandenburg (Verband der Metall- und Elektroindustrie in Berlin und Brandenburg, VME).

| futur | **From a business perspective, what are the most pressing concerns when it comes to the transformation of the automotive industry, and at what level should these be addressed?**

/ SCHIRP / The automotive industry faces the challenge of becoming more sustainable, reducing its ecological footprint, and entering the circular economy. This applies to both production and the operation of vehicles. In addition, there are digitalization issues such as autonomous driving and connectivity. Self-driving vehicles are connected to other cars as well as their environment and require innovative and secure technologies. Additionally, the means of production are changing. Processes and supply chains are being digitized to increase efficiency and reduce costs. In the face of this profound transformation, automotive companies must first understand the changing needs and desires of their customers. Each company needs a clear strategy for investing in research and development, production, marketing, and sales for this comprehensive transformation.

/ WEICKERT / Policymakers must recognize that common standards in regulation and development goals are crucial for the future viability of this industry. At the same time, it is important for policy to advocate for a level playing field in sustainability, ensuring equal global competitive conditions. Achieving climate-neutral production requires massive investments, which must not negatively affect the competitiveness of the German industry.

| futur | **When a vital economic sector like the automotive and supply industry is being digitalized, this entails massive data flows that need to be managed. What strategic importance do concepts such as data standardization, data sovereignty, and data security hold for industrial policies in Berlin?**

/ WEICKERT / Data plays a crucial role in the future of the automotive industry, both in the capital region and globally. The issue offer significant economic opportunities. For manufacturers, suppliers, and infrastructure operators to communicate across borders, they require not only uniform data standards and legal certainty but also high-performance digital infrastructure and robust IT security architecture. These tasks must be at the top of the agenda for Berlin-Brandenburg's digital policy. When it comes to vehicle data, trust and privacy are also significant. Consumers are very sensitive in this regard. Therefore, member companies of the industry association VDA, in addition to existing legal regulations, have developed common data protection principles for connected vehicles. These principles include transparency, self-determination, and data security.

| futur | **Data is generated not only in the process of digitalization but also in research. From your perspective, how do the research partners of the ReTraNetz-BB project, including Fraunhofer IPK, contribute to the transformation of the automotive industry in the Berlin-Brandenburg region?**

/ SCHIRP / Fundamentally, the use of research data must maintain a balance between the interests of science and business. Open access to research data allows for the transparency and replication of scientific results. Publications are essential for scientific reputation. This, however, conflicts with the demands of business, such as the confidentiality of results obtained through industrial cooperation.

More information
about ReTranetz-BB
can be found here
www.ipk.fraunhofer.de/
en/references/retranetz

»When it comes to vehicle data, trust and privacy are also significant. Consumers are very sensitive in this regard.«

Sven Weickert

/ WEICKERT / ReTraNetz-BB, as a funded project, provides research and development results publicly. In addition to various analyses of the industrial ecosystem in the automotive sector, research partners support participating companies in shaping their strategic and technological perspectives. This includes the development of new business models, production processes, technologies, and materials for increased resource efficiency and cost reduction. Research partners also address the critical issue of human resources, developing and offering educational and training programs in the long term.

| futur | **Mr. Schirp, as a qualified lawyer and CEO of the umbrella organization in the capital region, you are well-suited to serve as a contact point for lawmakers. How do you assess the current legal framework for digital transformation, and what legislative gaps need to be filled?**

/ SCHIRP / The legal framework for the digital transformation process goes beyond the well-known General Data Protection Regulation (GDPR). In addition, digitally relevant directives and regulations by the EU affect areas such as IT security, copyright, liability law, and subsidies. The legal framework must prioritize consumer protection, at the same time it must not inhibit the innovative power and competitiveness of German and European industry. State regulation, especially when it comes to new technology, must allow for flexibility and consider innovation potential.

»Fundamentally, the use of research data must maintain a balance between the interests of science and business.«

Alexander Schirp

RETRANETZ-BB

The goal of the ReTraNetz-BB project is to support SMEs in the Berlin-Brandenburg region in the automotive and supplier industry as well as their employees in necessary transformation processes towards climate-neutral production and sustainable mobility. The focus is on promoting existing strengths, defining new themes, developing model measures, and supporting tests and applications. Location advantages are to be developed and demonstrated, external influences to be considered. An interstate consortium of economic development agencies, social and labor partners, educational institutions, and scientific institutions, including Fraunhofer IPK and TU Berlin's IWF, is driving these initiatives.

| futur | **Mr. Weickert, where is the regional industry in terms of digital transformation today, and where is it likely to be in 2030?**

/ WEICKERT / The digital transformation, coupled with the need for ecological transformation, presents a significant challenge for industry. It is becoming a permanent task, known as the Twin Transition, especially as technological development is advancing rapidly. Even if one is well-prepared from today's perspective, new technologies and competitors can fundamentally change the industry tomorrow. One prerequisite for industry's ability to adapt continuously is a functioning industrial ecosystem. Universities and research institutions, deep tech startups, and industrial companies working together are the basis for successful innovation. The capital region is well-positioned in this regard: Science in Berlin and Brandenburg is at the forefront of crucial, industry-relevant digital technologies. Berlin's »Zukunftsorte« and business networks are addressing the right issues, and in Brandenburg, the value chain for electromobility is being established. The concept of »Urban Production« also offers significant opportunities for Berlin. In this context, we believe that by the end of the decade, there will be a record high of 250,000 industrial jobs in Berlin and Brandenburg. ◆

Scrutinize to Optimize

Non-invasive real-time quality control in additive manufacturing processes has long been wishful thinking. Researchers can now collect data and inspect parts during processing without destroying them.

Digital inventories, mass customization and smarter products through optimized designs: The industrial community is well aware of the potential unleashed by additive manufacturing. However, especially in safety-critical applications, such as in the aerospace, automotive and energy sectors, process qualification challenges still get in the way of this technology's mass adoption.

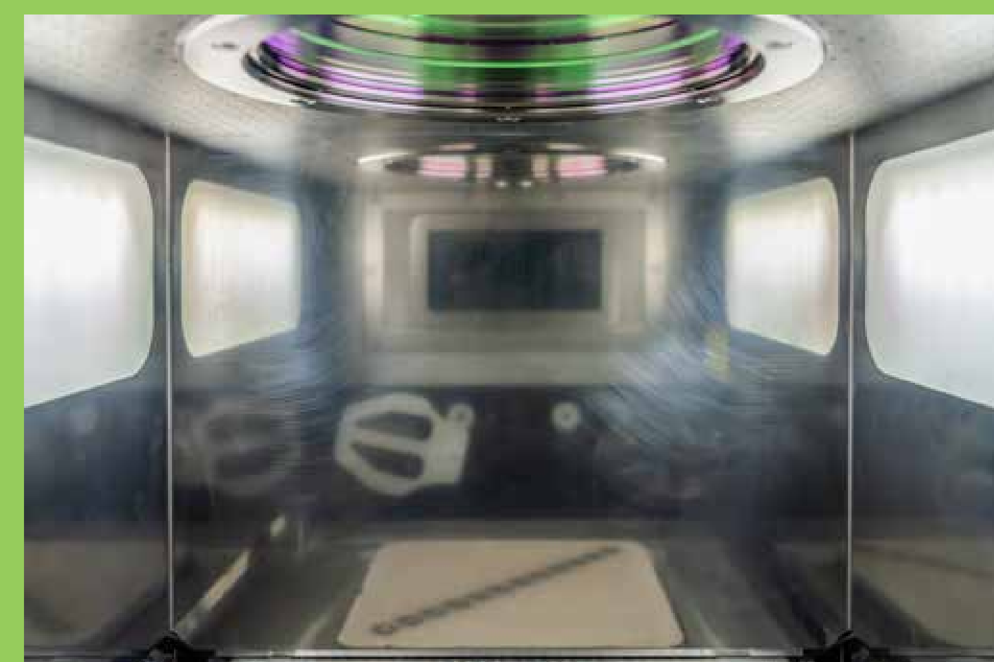
Just to give an idea of how complex it is to develop reliable additive processes, let us analyze the laser-based powder bed fusion process (L-PBF), currently the additive manufacturing technology used most by industry: There are more than 50 parameters that can directly influence final parts quality. From the metallic powder condition and machine calibration state, all the way to the definition of suited laser parameters and scanning strategies – setting up a stable process is still a very time-consuming and empirical task. The fact that simulation models are still ramping up in maturity makes it even more challenging.

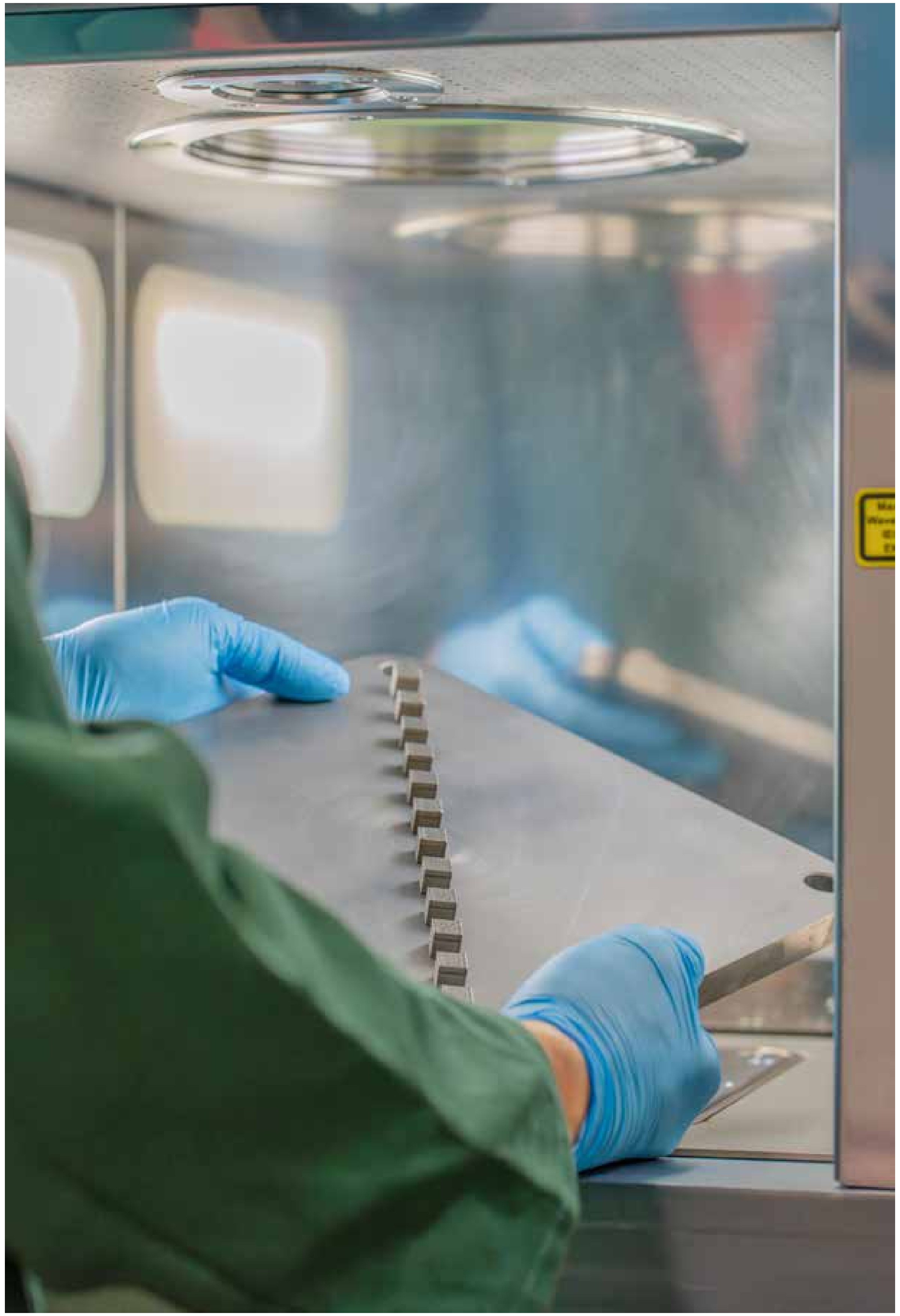
KEEPING A CLOSE EYE ON EVERY LAYER

There are multiple types of defects that can occur in additively manufactured parts, gas porosities and lack-of-fusion being two well-known examples. Depending on their size and location, the presence of defects may cause the rejection of complete parts, which might have taken several hours to be manufactured. Therefore, the sooner process irregularities are identified, the better. Researchers at Fraunhofer IPK are working in the project »PipeNDT« (Pipe is short for »Pipeline«, NDT stands for »non-destructive testing«) to develop a monitoring system capable of already spotting defects while they are forming during the building process. In order to achieve this, process signatures were acquired through the use of high-speed photodiodes for every scan track in every layer, generating several gigabytes of data. The question to be answered was: How to transform this huge amount of monitoring data into actionable quality information? The researchers chose the approach to extensively investigate the internal

How to transform a huge amount of monitoring data into actionable quality information?

Images:
Complex build jobs in metallic additive manufacturing are particularly prone to errors





1

2

Images:
1
An optical quality control during the samples removal often reveals defects, which could have been avoided
2
With digital images from the synchrotron it is possible to analyze sections of the workpiece without having to destroy them. This is useful for investigating part density.
© XPLORAYTION GmbH
3
The experimental set-up in the synchrotron enables the realization of micro tomograms in a high-throughput manner
© XPLORAYTION GmbH

quality of final parts through non-destructive methods in order to generate ground truth data to develop the monitoring model.

UNVEILING INTERNAL SECRETS OF FINISHED PARTS

After the Fraunhofer IPK researchers had manufactured enough samples, they were handed over to the project partners at XPLORAYTION, a company that specializes in hyper-precise imaging technologies and advanced 3D data analysis. They were then taken to a particle accelerator, a so-called synchrotron, to be analyzed by means of X-ray microtomography. This non-invasive technique is the gold standard for assessing a material's bulk integrity, without destroying samples but rather keeping them intact for further use. In the synchrotron, up to one hundred billion times more radiation is generated than in a conventional laboratory X-ray tube. This extreme X-ray intensity allows for faster and better imaging. As part of PipeNDT, the researchers developed an optimized sample changer as well as a high-throughput pipeline to enable the micro computed tomography of tens to hundreds of samples per measurement campaign. With the help of advanced image processing techniques, every single voxel – a three-dimensional pixel – of the samples was analyzed and labelled accordingly, if defects of interest could be spotted. The amount of digital information can also easily surpass several gigabytes for each sample, depending on the resolution at which they have been scanned.

The combination of process monitoring and non-destructive inspection data bridges the gap for a holistic quality control in additive manufacturing.

DATA FUSION FOR QUALITY CONTROL

Combining process monitoring and non-destructive inspection data bridges the gap for a holistic quality control in additive manufacturing. The PipeNDT team developed a method to register information from different sensors. It is comparable to creating a digital ID for every single point of a part, containing information such as which parameters have been used in its manufacturing, what the process signatures looked like and to what extent defects are present in that region. This structured database paves the way for statistical analyses and for the development of machine learning models to predict the quality of additively manufactured parts. Although single defects still cannot be spotted by the monitoring system tested in PipeNDT, further sensors will be used to incorporate additional process signatures into the pipeline. Based on their joint research, Fraunhofer IPK and XPLORAYTION help to increase the maturity of additive manufacturing through innovative and industry-oriented quality control along the whole process chain. ◆

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3

The project »PipeNDT« was supported by the Federal Ministry for Economic Affairs and Climate Action (BMWK) on the basis of a decision by the German Bundestag, within the framework of the Central Innovation Programme for small and medium-sized enterprises (ZIM).

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

A Sustainability Leaderboard

Keeping emissions in focus: Benchmarking greenhouse gas emissions enables quick comparisons of sustainable business developments.

A person flying from Berlin to Munich and back for a business trip emits approximately 308 kilograms of CO_2. A more environmentally friendly option is the train: Using a high-speed train such as the German ICE causes only 34 kilograms of CO_2 on the same route (with an average energy mix, including green energy). However, if a business traveler works on a laptop during the train journey, the carbon footprint changes again. Electronic devices require electricity, as do data centers that keep the cloud and digital twins running. Also, CO_2 emissions depend on the energy mix. But how does a company determine the ecological footprint of its employees? How much climate-harming greenhouse gas (GHG) is hidden in the raw materials, and where can emissions be reduced in the supply chain?

HOW MUCH CO_2 IS TOO MUCH?

The far-reaching consequences of climate change challenge companies to identify and subsequently minimize their negative environmental impacts. In this regard, GHG play a crucial role. Comprehensive reduction of these emissions, to the extent of achieving carbon neutrality, is demanded by both science and politics. But what does this mean exactly, and how can small and medium-sized companies transition to a carbon-free way of doing business? Is my company emitting too much for its size? How do I compare to my competitors?

These questions are the focus of the ongoing »KliMaWirtschaft« project, in which the German Association of Small and Medium-sized Businesses (BVMW) and Fraunhofer IPK are involved. Participating companies are empowered to account for their GHG emissions in a balance document, define climate protection goals, and effectively reduce emissions through a three-part workshop series, online consultations, and a climate protection toolbox. Overall, »KliMaWirtschaft« aims to achieve a measurable reduction of 333,000 metric tons of CO_2 equivalents (CO_2e) within three years.

SEARCHING FOR COMPARABILITY

The Greenhouse Gas Protocol serves as the comparative yardstick, an international standard for accounting and reporting greenhouse gas emissions, which differentiates between three categories known as scopes. Scope 1 deals with direct emissions at a company's site, such as those from oil or gas heating, which can be precisely measured through meter readings or electricity bills. Scope 2 covers indirect emissions, such as purchased grid electricity or district heating. Scope 3 includes other indirect emissions generated along the value chain, including emissions from purchased goods, employee commuting, business travel, and the use of sold devices. Accounting for these emissions is naturally more challenging and often relies on modeling and estimates.

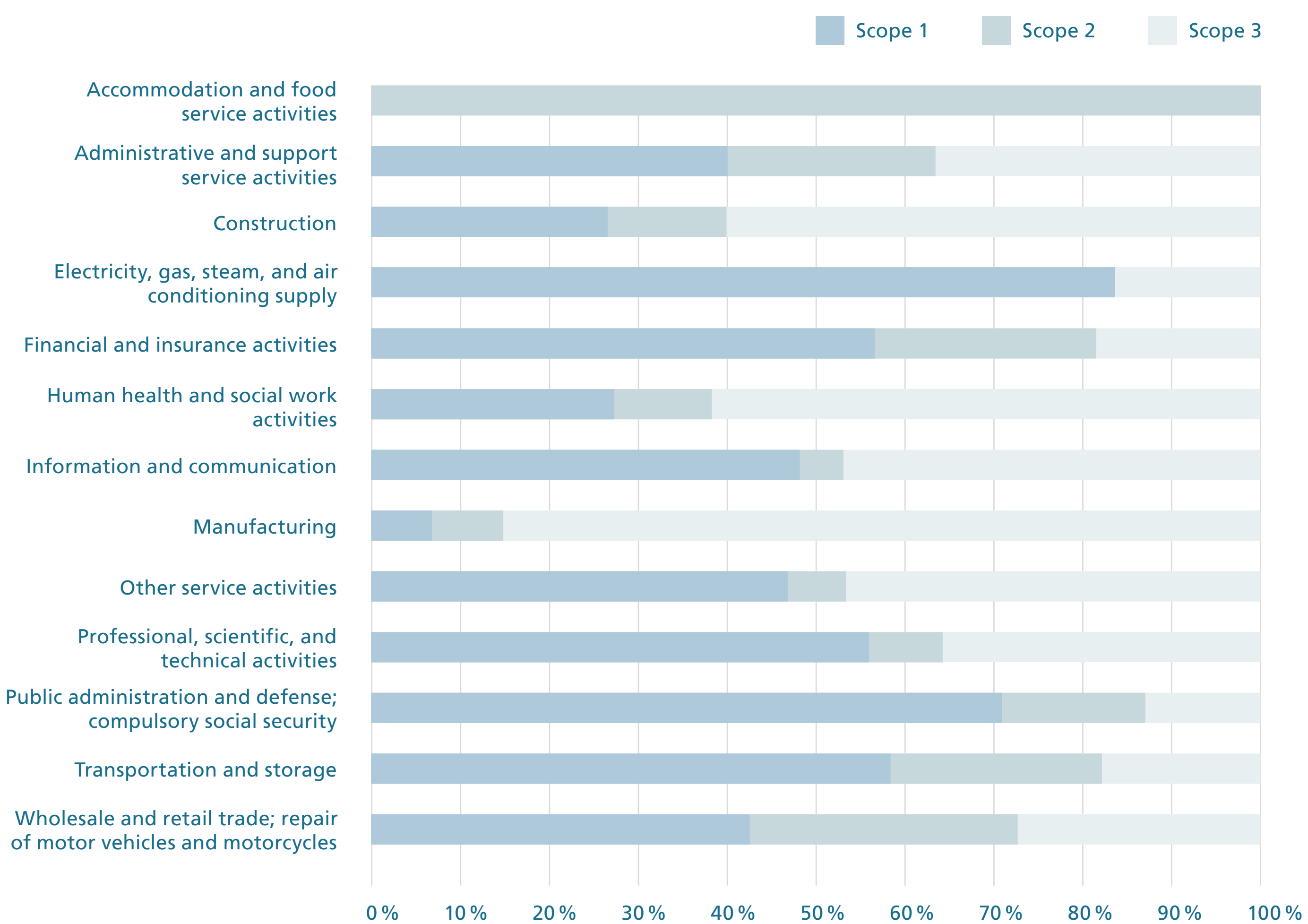
A suitable method for contextualizing and evaluating emissions is called benchmarking. Similar to the sports world, where individual performance is compared with the best, companies want to compare their emission data with market leaders or at least similar companies. This approach not only provides a better assessment of their own reduction goals but also yields valuable insights from the experiences of others in shaping a more sustainable future together.

As a result, experts at Fraunhofer IPK developed an application for the evaluation and analysis of real emission data, based on nearly 70 GHG balance sheets submitted by participating companies, mostly SMEs, in the »KliMaWirtschaft« project. The surprising result is that emissions are primarily found in Scope 3, outside the actual production. This analysis therefore displays how many previously unnoticed GHG emissions companies are responsible for along the entire value chain. It simultaneously underscores that the SME sector as a whole can make a significant contribution to a climate-friendly business approach by taking responsibility for reducing its emissions and implementing specific climate protection measures.

INDUSTRY-SPECIFIC DIFFERENCES IN CO_2 EMISSIONS

It is also worth taking a closer look at the different distributions of GHG emissions in various industries. For instance, manufacturing companies traditionally consume a lot of energy and have a high material turnover. This is reflected in high GHG emissions in Scope 2 and 3. Companies in the service sector, on the other hand, have higher emissions in Scope 1 and 2 due to their primary office activities. Energy supply companies fall slightly off the grid: As primary producers of electricity or district heating that is delivered to end-users, they have both significantly higher GHG emissions and also proportionally high Scope 1 emissions.

Average GHG emissions by industry sectors



> **The SME sector as a whole can make a significant contribution to a climate-friendly business approach by taking responsibility for reducing its emissions and implementing specific climate protection measures.**

More information (in German):
www.klimaschutz-wirtschaft.de/

Participating in the »KliMaWirtschaft« project is still possible for interested companies. CO_2 benchmarking is also available to any company looking to transition to sustainable production. The analysis tool is an excellent starting point, even if the initial goal is just to assess how your business compares to others. ◆

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Supported by:
Federal Ministry for Economic Affairs and Climate Action

Competence for Complexity

In the ever-evolving landscape of product development, product life cycle management (PLM) and product data management (PDM) have become indispensable. In an era where technology and competition continually advance, efficient data management and seamless process management play a crucial role in a company's success. This is especially true in a time when increasing integration into data ecosystems like Gaia-X demands highly efficient and agile development environments.

Fraunhofer IPK defines PLM as a strategic approach that encompasses the entire life cycle of a product, from conception through production to disposal. This comprehensive understanding forms the foundation for improved collaboration between departments, optimized resource utilization, and accelerated market introduction.

For those who wish to deepen their PLM knowledge, Fraunhofer IPK is offering the English language online course »Mastering PLM«, as well as the German language »PLM Professional« training with its partners Fraunhofer IAO and Fraunhofer Academy. These tailored programs provide practical insights into the latest PLM methods and tools. Participants are empowered to master the complexity of PLM and implement innovative solutions within their organizations. The interplay of data, people, and processes is examined to convey a deeper understanding of the necessity of a holistic PLM approach.

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Regine Wolters
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PLM TRAINER

»The PLM Professional course offers content for future-oriented product development that is not addressed in any other training or field of study.«

Dr.-Ing. Kai Lindow
FRAUNHOFER IPK
PROGRAM DIRECTOR AND TRAINER, MASTERING PLM AND PLM PROFESSIONAL

»PLM is great, but a lot of work. We teach PLM professionals how to make the right adjustments within their company.«

Zeno Ispan
LAYTEC AG
PLM PROFESSIONAL ALUMNUS

»PLM shortens time-to-market, minimizes non-value-adding tasks, promotes digitalization and can improve collaboration across departmental boundaries within the company.«

Marcus Klug
ACONEXT STUTTGART GMBH
PLM PROFESSIONAL ALUMNUS

»Since my training as a PLM Professional, I have successfully carried out PLM consulting on the topics of digital twin and lightweight construction.«

Thomas Maiti
DASSAULT SYSTÈMES
PLM PROFESSIONAL ALUMNUS

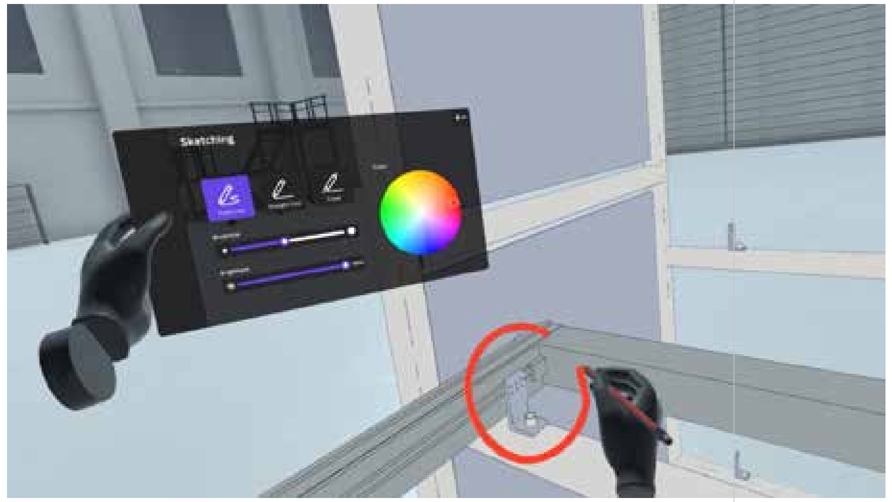
»By training to become a certified PLM Professional, I have obtained an officially recognized qualification that is not offered in this form by our university education system.«

More information
about the English language online course »Mastering PLM«:
www.ipk.fraunhofer.de/mastering-plm-en

Virtual Testing – Real Savings

Faster from idea to prototype: The enVAR software accurately translates designs into virtual environments, enabling better collaboration within teams.

Product development costs have become an existential question for the German and European economy. Whether in mechanical engineering, the automotive industry, the mobility sector, or the construction industry: The later planning errors are discovered, and the more projects are delayed, the more severe the consequences in competition. Researchers at Fraunhofer IPK support companies in minimizing such risks using extended reality methods like virtual reality (VR). They have developed a user-friendly virtual reality platform for testing and adapting designs, prototypes and concepts under realistic conditions. The platform is called enVAR and is based on the principles of immersive technologies.



COLLABORATIVE ENGINEERING THROUGH IMMERSION

Fraunhofer IPK provides solutions to industrial questions regarding the future of engineering and develops holistic methods and technologies for product development. One of the researchers' focus areas are the so-called immersive technologies. Collaborative engineering on platforms such as enVAR allows entire teams to dive into virtual worlds together. Other immersive solutions can be found as industry-related applications in the virtual commissioning of facilities, in security methods, assistance systems, and training environments.

DETECTING WEAKNESSES EARLY

enVAR allows engineers to import data from the product life cycle management (PLM) system into a VR environment and visualize 3D models of their concepts on a 1:1 scale. This can be helpful in identifying weak points at an early stage. Additionally, other team members, even without CAD knowledge, can get a true picture of the project's status. These include, for example, trainees who take job tickets using the integrated note function, or members of management who suggest corrections. Instead of time-consuming explanations of screenshots via PowerPoint, employees can exchange information at eye level and com-

Images:
Fraunhofer IPK's team uses extended reality methods to support its partners

pare work statuses. Once the team agrees on changes, they are integrated back into the PLM system, allowing product development processes to continue seamlessly.

PLAN, ASSESS, OPTIMIZE

The use cases of enVAR include installation inspections, feasibility studies, and needs analysis for resource minimization. Project teams can, for example:

- model the complex interior of a vehicle to minimize space taken by certain components.
- determine the ideal cost-comfort ratio for long-distance trains, from seating arrangement and luggage storage to cable routing and design of economic areas to the installation of sleeping compartments.
- find the right location for shelves, monitors, and seating in a university library.
- virtually lay fiber optic cables in an office complex to precisely determine requirements.

The software is intuitive to use and provides precise results. For example, if pipes need to be laid, the team defines parameters like diameter and minimum bend radius, and these are read into enVAR as a configuration file. In the software, they can choose the corresponding pipe type and place it on the model's surfaces using control points, visualizing where pipes with predefined properties should run. Control points can be moved or deleted at any time, along with the virtual pipes.

Product development teams will be able to manipulate real components in a virtual environment.

Images:
Virtual and physical reality merge with the help of immersive technologies

REAL COMPONENTS IN A VIRTUAL ENVIRONMENT

Fraunhofer IPK is already preparing enVAR for additional tasks, such as virtual collision tests in vehicle development, ergonomic assessments in prototype construction, and visual inspections. Furthermore, the Fraunhofer software could potentially benefit from integrating an augmented reality application, as user interactions and PLM interfaces tested in VR can be incorporated. This means development teams will be able to manipulate real components in a virtual environment. ◆

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No Waste Today

Circular economy: Effective take-back management and recycling enable companies to not only save material costs but also reduce their ecological footprint.

Every year, 11 million tons of food end up in the trash in Germany: yogurts purchased in too much quantity left to spoil in the fridge, or perfectly edible fruits discarded in bulk by supermarkets because their expiration date has passed. The throwaway society is wasteful with resources in other product categories as well. Clothing that is still in good condition and barely worn is discarded because the next cheap fashion items are already on display. Industry also generates a lot of waste: packaging, metals, old appliances. Instead of being repaired, defective IT devices, among other things, often end up in containers – along with valuable raw materials like copper or cobalt.

Although the consequences of such thoughtless resource handling are well known, current production and consumption habits continue to follow the logic of a linear or disposable economy – production, consumption, and disposal or incineration. It is important to note that extracting and processing naturally occurring resources account for 50 percent of greenhouse gas emissions and up to 90 percent of biodiversity loss and water stress. Departing from this approach holds the great potential to decouple economic growth from resource consumption and enable a sustainable future.

CIRCULAR ECONOMY AS AN OPPORTUNITY

The so-called circular economy offers a way out. The idea is to organize products and business processes in loops. One of the sub-projects of the BioFusion 4.0 research project illustrates what this may look like in practice: An orthosis is produced as an assembly aid using 3D printing, which is biodegradable at the end of its life cycle. What is special about it: Old cooking fats are used as base material. Precious resources that would otherwise have ended up in landfills and incinerators are thus reintroduced into the value cycle. The circular economy offers a chance to rethink our economic practices and adopt a pioneering approach to business activity that promotes the protection of climate, the environment, and biodiversity.

However, especially in small and medium-sized enterprises, financial, time, and, most importantly, personnel resources often leave no room for implementing circular economy principles not only on a technological level, but from a holistic, systemic perspective at business level. How can a company design its business model in a circular way?

EXAMINING BUSINESS MODELS

At this point, Fraunhofer IPK provides support. A central part of BioFusion 4.0 is developing business models for the biological transformation – a conceptual framework across all sub-projects of BioFusion 4.0. This includes testing a general approach model and an action plan for the sustainable and circular transformation of existing business models.

This approach model serves as the basis to identifying suitable circular business model patterns for strengthening the circular economy within the context of each individual company. Unlike the very specific business model of an individual company, business model patterns are general instruments that can be applied in any organization through clever adaptation. Examples would include take-back management or producing durable and repairable products. Business model patterns can thus be integrated into any specific business model of a company.

At the outset of a guidance process, the current business model is analyzed together: What is the value proposition – a physical product or a service? What does the company need for it – which resources, activities, partners, and suppliers? Who is the offer aimed at – what customer segments, customer relationships, or competitors exist? What revenue sources are there? What does the cost structure look like?

In a second step, the potential for circular development of the business model is explored through specific questions. For example, in manufacturing, effective take-back management can save on material costs and reduce dependencies on high commodity prices in global markets. These potentials form the basis for the final selection of measures to strengthen circular economy in the participating company.

THINKING SYSTEMICALLY ABOUT CIRCULARITY

A business model pattern catalog developed by experts at Fraunhofer IPK serves as a tool for expanding the circular economy in companies. The catalog is a collection of proven business model patterns and instruments for analyzing and designing a business model based on the following circular principles:

- Rethink
- Reduce
- Reuse
- Repair
- Refurbish
- Remanufacture
- Repurpose
- Recycle
- Recover

Using these so-called R-strategies, suitable circular business model patterns from the catalog are selected in the last step of the guidance process and implemented in a specific value chain of the production process: For example, repairability must be considered at the beginning of the design process.

The pattern catalog helps companies become more circular, making a valuable contribution to Germany's efforts to transform the domestic economy into a circular economy and make the transition to sustainable products and services. Thanks to Fraunhofer IPK's methodology, even small and medium-sized enterprises have the opportunity to shape this transformation at business model level – and ultimately operate more resource-efficiently. ◆

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Image:
Example of closed-loop concepts: Remanufacturing extends the life cycle of old parts
© Circular Economy Solutions GmbH

More information:
www.ipk.fraunhofer.de/biofusion40-en

This research and development project is funded by the German Federal Ministry of Education and Research (BMBF) within the Framework Concept »Research for Tomorrow's Production« and managed by the Project Management Agency Forschungszentrum Karlsruhe, Production and Manufacturing Technologies Division (PTKA-PFT).

SPONSORED BY THE
Federal Ministry of Education and Research

Software-driven Smart Dismantling

The more complex a product, the more challenging the dismantling of its components becomes. Fraunhofer IPK's CE Assistant identifies the optimal strategy in each case.

Lithium, copper, rare earth elements – there is a tough global competition for resources like these, with industrial companies striving for resilient supply chains. This involves the recovery of materials from products that have reached the end of their life cycle. One of the challenges is the lack of essential information about numerous components. What raw materials are contained and in what quantity? What steps are necessary to separate them from each other? What can be recovered and what must be disposed of properly? What machines are required and where are they available? As part of the »Catena-X« project, Fraunhofer IPK, in collaboration with partners, is developing software that allows answers to all these questions. Dubbed the CE Assistant (CE = Circular Economy), it will assist dismantlers in defining the most suitable strategy for each case.

DIGITAL TWIN STORES PRODUCT DNA

The process is based on data collected throughout the entire life cycle of a product. This means that during the product's development, manufacturers, for example, store information about what the object is made of, where the raw materials come from, how many units are planned, and what recycling rates are aimed for. This creates a virtual image of the real product, a digital twin that accurately reflects the intended state. In addition, each individual item in a product line is given an identification number. The data is instance-specific, allowing the CE Assistant to unequivocally assign them at the end of the product's life (EoL).

»LIFE STORY« IN THE DIGITAL SHADOW

Just like human identical twins, real products evolve differently from their digital twins over the course of their lives. For example, a retired used vehicle is likely to no longer contain only original parts after numerous repairs. Furthermore, components age at different rates depending on usage and external conditions. This makes many products at the EoL a black box for dismantling companies. The solution is to complement the digital twin with a digital shadow. This includes all the changes that have occurred to the product in the hands of the user. For this purpose, the CE Assistant must be able to access information from as many manufacturers as possible that could supply replacement parts. This may sound ambitious, but thanks to Catena-X, such a comprehensive »product passport« is already becoming a reality, initially for the automotive value chain.

CRITERIA FOR THE SOFTWARE STANDARD

To ensure that the CE Assistant supports circular economy as desired, the researchers at Fraunhofer IPK have integrated certain criteria. Recommendations for reusing, refurbishing, recycling or recovering of components depend, among other things, on applicable laws and regulations, the need to consider pollutants and whether the components are generally recyclable. Safety-critical components like airbags, for example, should not be reused. Additionally, the CE Assistant considers the mileage, functionality, and estimated remaining lifespan. Another basis for the circular strategy recommended by the CE Assistant is the expected environmental impact according to ISO standard 14044. Lastly, the software calculates, among other things, the potential contribution of each CE strategy to the carbon footprint. For example, the assistant will determine whether a component should actually be refurbished. Under certain circumstances, it may be better for climate protection to manufacture an identical replacement part rather than transporting the component to a special facility.

More information
about Catena-X on
www.ipk.fraunhofer.de/catena-x-en


© LRP Autorecycling Leipzig

COLLABORATE AND LEARN

The software follows a standardized logic, making decision processes reproducible. The advantage is that it can be applied to products from other companies. For this purpose, the CE Assistant transmits its results, recommendations, and calculation paths to Catena-X. In addition, partner companies can learn from the experiences shared via the CE Assistant. For example, if it is discovered at the EoL of a vehicle that connectors are difficult to disconnect, manufacturers can instruct their suppliers to optimize the design. This feedback-to-design approach makes the new generation of products more durable, repair-friendly, and recyclable, reducing the need for primary materials and contributing to sustainability. ◆

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CATENA-X

The aim of Catena-X is to make the value chain around vehicles more sustainable and environmentally friendly. To achieve this goal, 28 reputable research institutions, vehicle manufacturers, suppliers, and other companies have joined forces under the umbrella of Catena-X. Catena-X will enable cross-company data exchange along the automotive value chain. Participants retain full control over their data and decide who can access it at any given time. The consortium includes Fraunhofer-Gesellschaft, Siemens, Bosch, BASF, and Henkel, among others. For the CE Assistant developed as part of Catena-X, Fraunhofer IPK collaborates with LRP Autorecycling Leipzig, BMW, SAP, and tec4U. In the future, the researchers plan to open the software to other industries.

Giants, Sustainably Manufactured

Zero-defect manufacturing is a key to a sustainable economy. GreenDelta's life cycle assessments support companies in this endeavor, even when dealing with massive products like ship engines.

A guest article by Dr.-Ing. Friedrich Halstenberg, GreenDelta GmbH

Transforming industry towards the application of sustainable practices requires extensive systemic changes in organizations, products, and services. To manage these changes, relevant indicators and impact categories must be systematically evaluated based on available information. This is where Life Cycle Assessment (LCA), also known as environmental or ecological accounting, comes into play. It is a proven data-driven method for quantifying environmental impacts.

At GreenDelta, we have developed an open-source LCA software called openLCA. It is used globally by companies, universities, and government institutions to quickly and efficiently calculate various sustainability indicators, such as Product Environmental Footprints (PEFs) and CO_2 footprints, or Environmental Product Declarations (EPDs). While we provide openLCA for free, we also engage in various consulting and software development projects with companies and public institutions, provide training for users, and participate in different research projects.

One of these research activities is the EU-funded project ENGINE (Zero-Defect Manufacturing for Green Transition in Europe). In this project, we are developing a system for designing and producing metal products with minimal defects. The application is demonstrated in the ship engine supply chain. GreenDelta's contribution to the project involves using openLCA to assess the impact of reliability in production and operation on the sustainability of these products. In particular, we focus on the challenge of incomplete and uncertain data, for example in the early stages of system design. These bring traditional LCA methods and tools to their limits because they rely on high data quality. We address this issue by combining LCA and System Dynamics (SD) models.

Combining LCA and System Dynamics (SD) models reveals the consequences of decisions over a specific period. Ideally, the system's behavior becomes clear while only cause and effect are modeled.

© Jens Blank

Dr.-Ing. Friedrich Halstenberg

earned his doctorate at TU Berlin on the topic of »Developing Circular Systems.« Prior to this, he worked as a research assistant at Fraunhofer IPK and at IWF of TU Berlin, where he focused on product life cycle management (PLM) and developing sustainable products and services. At GreenDelta, Dr. Halstenberg is involved in research and consulting projects with a focus on LCA, circular economy, and product development. He works with clients in the machinery, ship drives, plastic recycling, and construction industries.

SD is an approach to understanding the nonlinear behavior of complex systems over time. Data elements like stocks, flows, internal feedback loops, table functions, and time delays are used to simulate causal chains. This reveals the consequences of decisions over a specific period. Ideally, the system's behavior becomes clear while only cause and effect are modeled. Typically, the model's structure is represented in a user interface. While LCA models require the collection of precise data, which is time-consuming and largely dependent on the availability of information, SD models can be created more quickly, focusing on essential data.

Together with 16 other project partners, we integrate these models with extensive material simulation models into a development methodology based on Model-based Systems Engineering (MBSE). This way, the models are interconnected, and valuable information is distilled from various data sources. The overall result supports manufacturers of metal products in developing more sustainable and competitive products. ◆

Spotlight on Data Selection

Data from manufacturing processes is used to evaluate process quality. Often, only a fraction of the available data points is sufficient, but they must be the right ones.

When there is unusually heavy smoke in the workspace, something is likely wrong with the process. This sounds simple and logical. However, when such statements about process quality need to be made within the framework of automated monitoring, the question arises: Which data is suitable to appropriately quantify process quality? How do you differentiate between »normal,« »acceptable,« and »not tolerable«?

Process data has become a valuable asset in the world of production. Those who can interpret it correctly gain deeper insights into processes and can make more informed decisions. Despite the enormous potential, the use of process data is still in its infancy because effectively capturing, analyzing, and interpreting data remains a challenge. For the implementation of data-driven strategies, finding the right balance between benefits and the invested effort is a key to success.

A current research project at Fraunhofer IPK is focused on evaluating process quality in powder bed-based laser beam melting, known as PBF-LB/M. Process deviations such as variations in energy input are to be detected through sensors, whereby the selection of suitable initial data is already a central task.

A CLEAR GOAL IN MIND

When data is expected to provide value for analyses, forecasts, optimizations, or other business goals, every activity in the smart data area should start with the question: What exactly do I want to achieve? And which data will help me reach this goal? This step may seem trivial, but too often, smart data activities fail because the data foundation is chosen to be too extensive. A focused selection not only reduces the amount of data to be managed and processed but also facilitates compliance with data protection regulations. Companies can concentrate on the quality of the data captured to make informed decisions without being overwhelmed by unimportant or redundant information.

Therefore, it is essential to describe the use case precisely at the beginning and identify only the necessary information in this particular case. In the mentioned project, process quality is to be assessed based on the welding fumes generated during PBF-LB/M. Various approaches are available for smoke detection, including optical detectors, laser smoke detectors, thermal methods with heat sensors, or chemical detection.

WHAT CAN THE SYSTEM PROVIDE BY DEFAULT?

An increasing number of equipment manufacturers have started adding extensive sensors and monitoring systems to their machines' factory settings. Hence, the initial considerations should always focus on the machine's equipment: What process data does the manufacturing machine provide by default? Information can be obtained from built-in sensors, control systems, machine performance data, or process parameters and settings. However, only the data sources relevant to the use case should be considered.

The manufacturing machine that the Fraunhofer IPK scientists used in the project, for example, has an integrated monitoring system for recording process emissions in various wavelength ranges using photodiodes. The intention of the equipment manufacturer behind this system is to analyze emissions occurring in the melt pool. However, the information can also be used to identify radiation emitted by the welding fumes. This system serves as the first data source for describing welding fume behavior.

SENSIBLE ADDITIONS

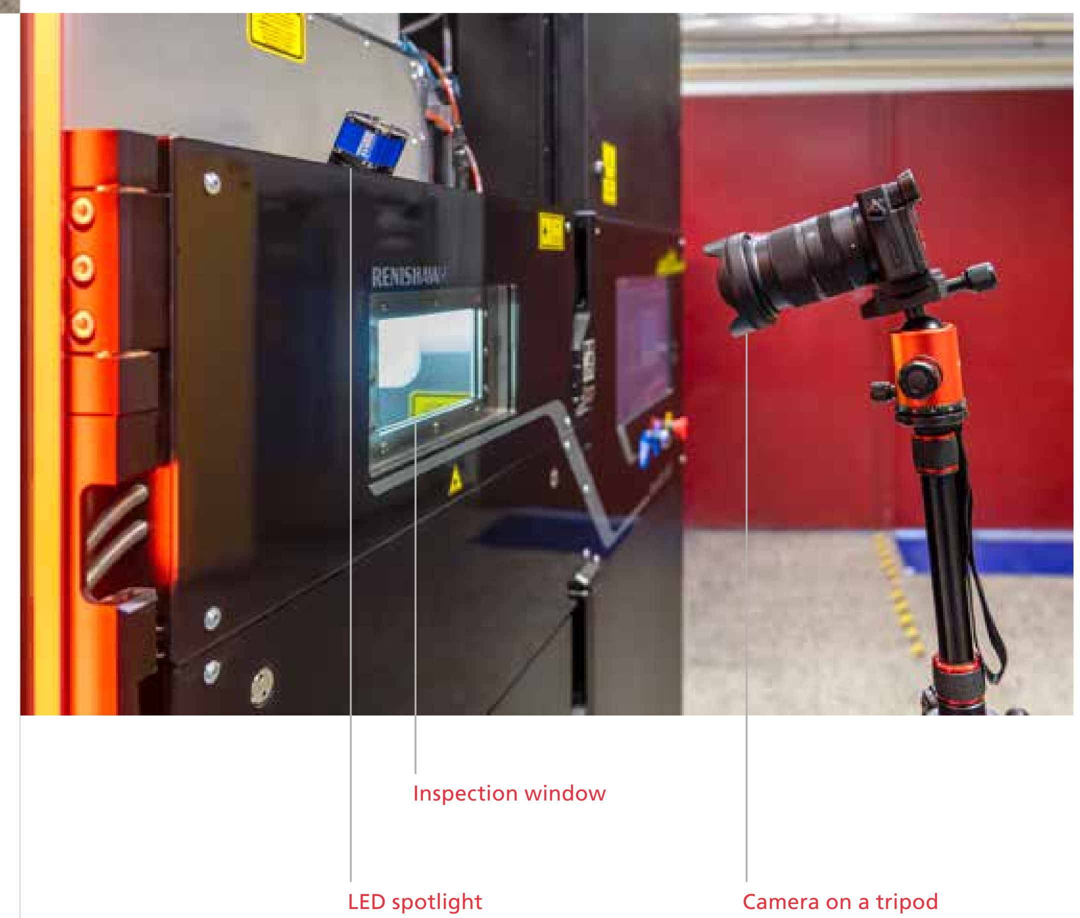
No further information could be obtained from the machine or existing peripherals. Therefore, additional sensors are required to support the analysis. Appropriate solutions must always be chosen specific to the facility, should not influence the manufacturing process, and should be cost-effective to operate. In PBF-LB/M manufacturing, accessibility is a challenge, as measurement devices cannot be placed directly in the build chamber. Systems positioned outside the facility provide a solution.

For a visual analysis of welding fumes, no specialized technology is required today. Advancements in camera technology and image processing now enable standard cameras to serve as sensors. Digital cameras can be placed outside the facility, in front of the viewing window, and effectively capture visible welding fumes.

In addition to capturing process emissions with photodiodes, a light barrier based on photodiodes is integrated into the system. The measurement system is installed in the exhaust duct of the facility. If smoke particles pass through the light barrier, a drop in intensity can be assumed.

In total, there are three different data sources on which the behavior of the process can be characterized based on the welding fumes: radiation measurement, camera, and light barrier. The smart use of these process data measurements as a monitoring system leads to a significant improvement in the manufacturing process. Similar solutions are conceivable for any other manufacturing process, starting with a clear definition of the use case. ◆

Test setup for camera-based inspection



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Quality over Quantity

Big Data is considered the gold standard when it comes to AI. However, high-quality datasets lead to better insights than sheer amounts of data.

Artificial intelligence thrives on data, and especially neural networks are insatiable. If you feed them sufficiently, you eventually get the desired results. Or do you? Nowadays, terms like »small data,« »little data,« or »smart data« are becoming more common. There may not be a fixed definition behind them, but the common approach is to lead machine learning models to useful insights even with small datasets and short training times. To make an AI system »intelligent,« it does not necessarily need abundant but, above all, high-quality data nourishment. In simple terms: The most sophisticated algorithm is useless if data quality is poor.

The main reason for this shift in thinking is the rapidly growing energy consumption of AI models. While neural networks and deep learning are always computationally intensive, their power consumption depends heavily on the quantity and quality of data. New research approaches, including the so-called Green AI, are increasingly focused on methods to improve data quality and the balance between accuracy and (energy) efficiency of models. These developments not only benefit the environment but also companies that have limited training data available and still want to use it profitably.

NAVIGATING THE DATA JUNGLE

But what exactly characterizes high-quality training data? Data quality is influenced by numerous factors, but it crucially depends on the data collection method. For obtaining high-quality data, an accurate capture process is essential. The next step is to find the subset out of the acquired, yet unsorted data that has the potential to become first-rate training data, meaning it contains precisely the information the AI needs for learning. The challenge is to filter out these information features and patterns in exactly the right proportion from a data set.

USED PART IDENTIFICATION BY MEANS OF AI

Researchers at Fraunhofer IPK have addressed this challenge in the EIBA project. Together with technology partners, they developed an AI-based assistance system that identifies old automotive components and assesses their condition, all without a need for QR codes or barcodes. The underlying necessity: numerous (industrial) old parts end up in recycling yards each year. A more environmentally and economically sensible approach is remanufacturing, in which the worn-out component is brought back to its original condition. However, this requires the product to be clearly identified, which is challenging when it is dirty, rusty, or overpainted. An additional difficulty is that many products are only slightly different from each other. The new assistance system makes the evaluation of used parts significantly easier.

QUICK START WITH LIMITED DATA

The task of the Fraunhofer IPK team was to train neural networks and special algorithms for machine vision to recognize used parts. In the data acquisition stage, the researchers chose a multimodal approach that intentionally accesses multiple data sources, because a single image is often insufficient for the AI to identify an object clearly. In comparison to humans, we perceive the object, examine it from different angles, look for characteristic features, and incorporate additional information independent of color and shape. Inspired by this multisensory human perception, the solution developed at Fraunhofer IPK includes stereo cameras and a scale to capture weight and optical properties in 2D and 3D. Additionally, business and delivery data from logistics and documentation processes are also integrated.

Images:
The EIBA assistance system for identifying used parts is multisensory: The sorting workstation has several cameras and a scale.

Since it is time-consuming and costly for smaller companies to generate large data sets in advance – meaning capturing all used parts optically – data collection was integrated into the ongoing operations of the application partner C-ECO, a service provider for the circular economy, using fixed cameras at work stations. About 200,000 image data points were collected this way in a first proof-of-concept. The AI had more than enough training data, but was it sufficient to achieve effective results? What the researchers had not anticipated was the often poor quality of the image data. Many shots had hands, coffee cups, or other utensils in the picture, the part was cropped, shaded, or only the empty worktable was visible.

A significant portion of the data turned out to be not only unusable for training. They could even be harmful to it, because the algorithm tried to learn to recognize objects in images, even when these objects were partially hidden, merged with a messy background, or completely missing. This led to non-sensical correlations in the data, and at the same time, important classes or patterns could not be learned adequately.

FIRST STEP: CLEANING UP THE DATA!

To overcome the new challenges, the researchers underwent a fundamental paradigm shift. They abandoned the principle of »more data yields better results« and replaced it with »meaningful data arrangement yields better results«. However, correcting each image pixel by pixel by hand would be an enormous effort. Therefore, the data experts at Fraunhofer IPK developed a method that utilizes AI and statistics to evaluate image quality. This allowed them to pre-sort the flood of images for their suitability in the training process automatically.

Specifically, this meant that the datasets were cleaned, removing incorrect, duplicate, unimportant, inaccurate, or incomplete values, and bringing them into a statistically representative distribution. A dataset with high information diversity is created when all data classes are included, and each class is represented as well as possible. The challenge lies in finding the right balance between data reduction and information gain: If too many data points are filtered out, the performance of the AI suffers.

AI DATA DETECTIVES: FINDING ERRORS

Clustering is a method for organizing a large dataset into classes without prior knowledge of these classes.

Images:
There are many possible industrial use cases for AI-based image processing

PROJECT SUCCESS IN NUMBERS

AI training data volume was reduced by 60 %.

The AI assistance system correctly identified over 98 % of all used parts.

For each correctly sorted and subsequently refurbished component, 8.8 kg of CO_2 equivalents are saved.

It represents a form of unsupervised machine learning where unlabeled data is grouped solely based on their »spatial similarity«: The assignment depends on how far a data point is from a so-called cluster center. Using this technique, the researchers managed to create groups with identical and similar visual patterns. This allowed them to identify »outliers« and data with redundant information content and remove them from the dataset.

Another applied technique, especially for data cleaning, is segmentation. To accurately identify image objects despite a complex background, certain features are extracted step by step from the data and continuously refined. Accordingly, the researchers initially identified visual differences in color, shape, and texture between the objects and the background. Then, they could separate all essential data points – objects or clear structures – from their (chaotic) surroundings.

SMALL QUANTITY – BIG IMPACT

With the help of the developed automated data preprocessing method, the research team managed to isolate the most relevant image data and reduce the training data set by 60 percent. This not only led to significantly more accurate predictions by the AI assistance system – over 98 percent of the used automotive parts were correctly identified in performance tests – but also reduced energy consumption. In the pre-sorted data, the algorithm can recognize patterns more quickly because it spends less time analyzing irrelevant information. This reduces the training effort and computational power.

Last but not least, the focus is always on the human using the assistance system. The more precise it works, the more motivated they are to feed it with new data. Through continuous digitalization and simultaneous use and evaluation of data, a kind of AI life cycle is created: a cycle in which knowledge about each used part is constantly expanded, thereby continuously improving the AI application. ◆

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More information about our automatic identification solutions for used parts on www.ipk.fraunhofer.de/automatic-identification

AI-tailored Wish Fulfillment

The first draft rarely is the final one in product development. With the help of artificial intelligence, this labor-intensive but essential stage can be accelerated.

Whether it is a gasoline car or an electric vehicle, an SUV or a compact car, a sports car or a family vehicle – comfort is a crucial factor in the purchase of a car. The damping system, consisting of shock absorbers and additional springs, is essential for this. To ideally adapt the latter to the specific needs of certain cars and achieve the best possible comfort, iterative tuning processes and expert knowledge have always been a requirement. Commissioned by BASF Polyurethanes GmbH, a manufacturer of additional springs in the automotive industry, researchers at Fraunhofer IPK have now developed a process that aims to simplify the design of such additional springs using artificial intelligence. The goal is for AI to derive a suitable component directly from the customer's requirements.

As a methodological approach to training an AI, the researchers used the CRISP-DM standard process. After an initial situational analysis, the available data is examined, and specific goals are derived. These serve as the basis for training and testing an AI model.

Additional springs are rotationally symmetrical and can therefore be represented in simplified models with few parameters. Compared to other training sets with more complex historical data, this approach significantly simplifies AI training.

Using the simple models, the researchers made systematic small changes. This allowed them to generate over 10,000 different designs from a single model. The team then simulated how these simplified and readjusted virtual springs behave under various loads. The data obtained from the simulations served as the training basis for a neural network.

In an initial random sample test, it was shown that the AI model is capable of generating components that come close to the specified requirements. In practice, this means that development teams, for example, could »feed« a new customer's specifications into the AI and receive a functional initial design for an additional spring. They could then refine the design with detail adjustments. ◆

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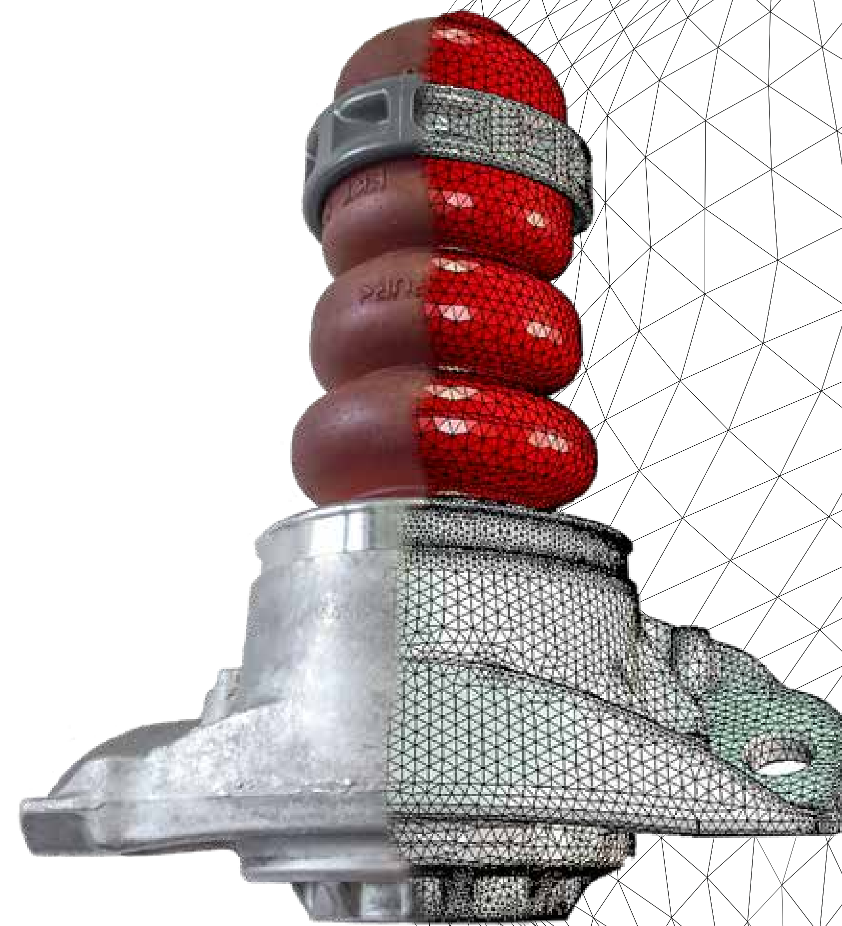

Image:
In addition to shock absorbers, such additional springs are essential for a car's ride comfort. Their design is to be made much easier in the future – with the help of AI.
© *BASF*

Learning from Nature

Within the framework of the research project »BioFusion 4.0«, data-driven solutions for a more sustainable and resource-efficient production are being developed at Fraunhofer IPK – inspired by principles from nature.


1

Images:
1
At the Hannover Messe 2023, Christopher Mühlich (right) and the Fraunhofer IPK team explained the BioFusion 4.0 project live. Pictured here are the then BMBF Ministerial Director Prof. Dr. Ina Schieferdecker and Fraunhofer IAO Director Prof. Dr. Wilhelm Bauer (center).
2 and 3
As a product example, finger orthoses are manufactured from compostable bioplastics using a 3D printing process. They are used as orthopaedic aids, for example to stabilize the finger joints during the assembly of vehicle components.

Even though Fraunhofer institutes are known for their innovation, there is no need to reinvent the wheel every time. Sometimes, it makes more sense to apply well-established principles to new use cases. This is the fundamental idea behind the research project BioFusion 4.0, in which 13 partners from academia and industry, led by Fraunhofer IPK, have come together to develop solutions to bring sustainable biological transformation into industry. To make production more future-proof, digital, and eco-friendly, they collectively explore how biological principles can be adapted to industry and turned into practical solutions.

The project team has so far been achieving impressive results in addressing industrial use cases. These results highlight the crucial role of data in implementing sustainable and resource-efficient production. Interested parties had the chance to a glimpse of the specific solutions being developed within the project at Hannover Messe 2023 and the XVII International Production Technology Colloquium (PTK 2023), among others.

AUTONOMOUS AND CONNECTED

What can modern production learn from natural ecosystems? Ecosystems in nature, where different species of organisms, plants, and microorganisms interact and depend on each other, are highly complex. Similarly, in production, there are numerous actors: people, machines, IT systems. Their interactions play a crucial role in the functioning of the entire system. Following the concept of biological transformation, the BioFusion 4.0 team models these actors in the production process as autonomously acting agents, inspired by nature. They are intelligently networked, communicate with each other, negotiate tasks, and coordinate their actions. Bio-inspired multi-agent systems form the framework of sustainable production and adapt flexibly to changing requirements.


2


3

Researchers at Fraunhofer IPK are using demonstrators to show how manufacturing companies can become more flexible and resilient by means of such self-organized process handling. One of their demonstrators located at Fraunhofer IPK is illustrating the development, production, and life cycle of orthoses – orthopedic aids used, for example, to stabilize finger joints during the assembly of automotive components or for medical purposes. These orthoses can be 3D-printed from biogenic material and fully composted at the end of their life cycle.

The concept of decentralized production control is illustrated through an interactive factory layout simulating the processing of various product variants of said orthosis. The workstations, represented by small screens, are interconnected, forming a multi-agent system inspired by natural ecosystems, in which production tasks are automated and coordinated. Visitors to the demonstrator can see which workstation the system has desig-

This research and development project is funded by the German Federal Ministry of Education and Research (BMBF) within the Framework Concept »Research for Tomorrow's Production« and managed by the Project Management Agency Forschungszentrum Karlsruhe, Production and Manufacturing Technologies Division (PTKA-PFT).

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More information
about the BioFusion 4.0 project can be found on www.ipk.fraunhofer.de/biofusion40-en

nated to carry out the current task on the screens. Using levers symbolizing different product variants, they can approach the selected station. Users can also simulate the failure of individual workstations at the push of a button and experience how the multi-agent system promptly reacts and redistributes production tasks. The progress of incoming orders and the current operational state of workstations can be monitored on a dashboard. The demonstrator shows how companies can improve the adaptability and resource efficiency of their production processes through the biological principle of self-organization.

CREATING TRANSPARENCY WITH DIGITAL TWINS

Analogous to natural ecosystems, there are »product ecosystems« that involve not only physical products and their subcomponents but also digital services, the required infrastructure for their operation, as well as their interactions with other products. Successful natural ecosystems must continually demonstrate their resilience and optimize in harmony with their environment. This means they must respond promptly and self-optimize flexibly to changing environmental conditions. Similarly, digital twins can monitor »product ecosystems« and, based on specific information like real-time data, help them achieve optimized states. In the context of BioFusion 4.0, researchers at Fraunhofer IPK are investigating how the concept of digital twins can support product-specific calculation, tracking, and later optimization of the CO_2 footprint over the entire life cycle.

In a dashboard, relevant data spanning the entire life cycle is represented, again using the example of the finger orthosis and its surrounding product ecosystem. The resulting digital twin integrates various sustainability-relevant data along the product life cycle. For instance, product development or production planning teams can directly view planning data like CAD models, bill of materials, or plan LCA data for different product variants. During production, use, and at the end of life stage, the dashboard displays real-time data such as energy consumption. By intelligently linking planning and real data, a real-time life cycle assessment can be calculated. Deviations and critical values are visible on the dashboard, allowing optimization measures to be derived and implemented on the physical product, following a feedback-to-design approach.

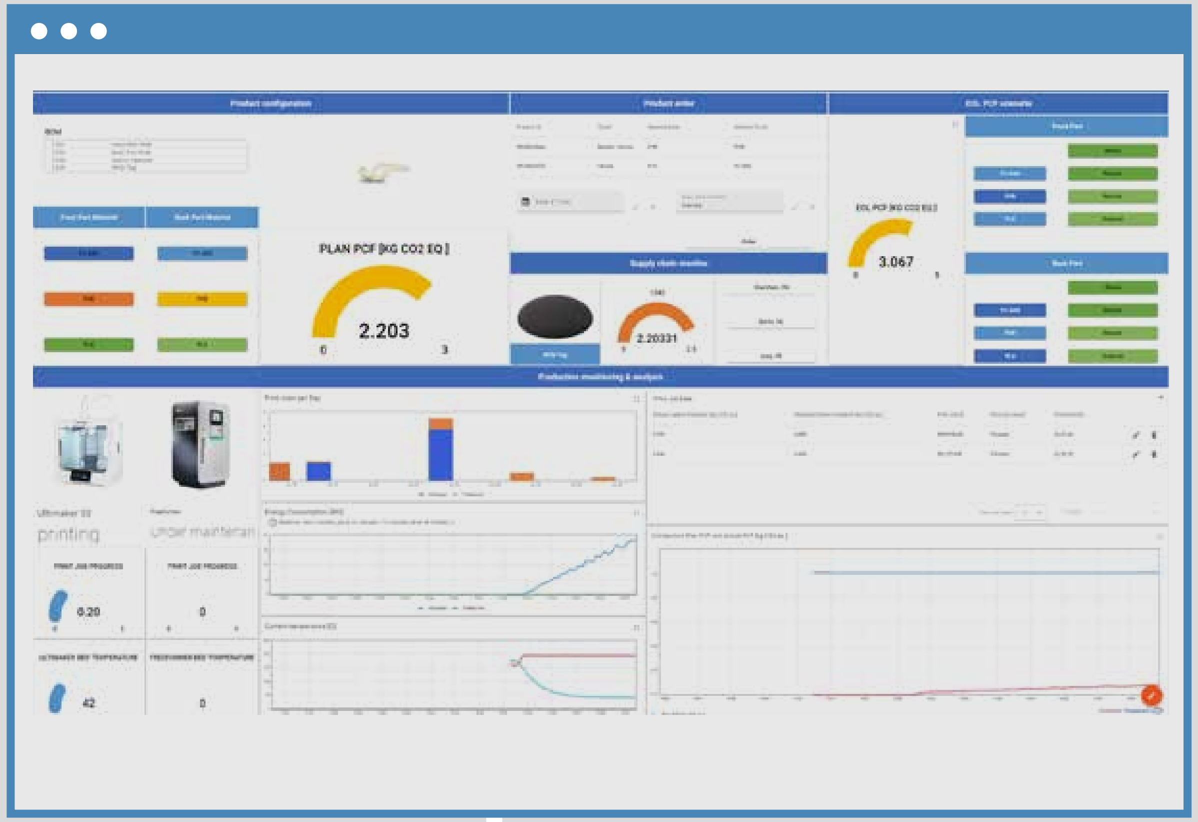
1

2

CONSIDERING THE ENTIRE PRODUCT LIFE CYCLE

The digital twin for sustainability assessment and the self-organizing production process are just some examples of solutions for the biological transformation of industry. Until the official project end in 2024, researchers in the BioFusion 4.0 project will work on many more specific subprojects, the results of which will be showcased at the next Hannover Messe in 2024. The data obtained in the project will serve as a basis for potential business models of biological transformation, intelligent material recycling, bionic integration of connected production systems, bio-intelligent worker assistance systems, and additive manufacturing with biogenic and biodegradable polymers, all aimed at sustainable production in harmony with nature. ◆

Images: 1 and 2
The demonstrator for self-organized production shows an interactive factory layout. The small screens represent individual workstations that coordinate with each other automatically and can then be approached using the levers to carry out production orders.



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Images:
Data is mapped in a dashboard product ecosystem. The underlying digital twin enables the monitoring of environmental impacts along the product life cycle.

5G à la carte

Not all 5G networks are created equal – because industrial applications need to be tested under industrial conditions. To this end, PTZ Berlin is providing a campus network.

In 2022, the Berlin Fraunhofer institutes officially launched a joint, real-time 5G communication infrastructure. In the Production Technology Center (PTZ) Berlin's central test area, a 5G cell was set up, consisting of a baseband unit and eight antennas. The network is going to be equipped with an open core (Open5GS). This core will run at Fraunhofer HHI in the Fraunhofer Edge Cloud and will be connected to the infrastructure at PTZ Berlin. This kind of network, a so-called standalone network (5G-SA), is the standard for use in industry, for example in warehouse logistics. In contrast to public 5G networks, these do not rely on an existing 4G network (5G-NSA, Non-Standalone). This setup allows for testing use cases for industrial 5G standalone networks at PTZ Berlin under realistic, industry-like conditions.

The scientists at PTZ Berlin can make use of the extensive available machinery to work on their research tasks. Additionally, customer-specific hardware can be connected to the 5G infrastructure to develop proofs of concept for particular use cases. For specific questions regarding 5G parameters, such as optimizing upload and download bandwidths for specific applications, researchers from Fraunhofer IPK, along with 5G experts from other Berlin Fraunhofer institutes, can provide targeted consultations.

Currently, a demonstrator is being developed at Fraunhofer IPK, in which an autonomous vehicle with a built-in robotic arm is remotely controlled through the Fraunhofer Edge Cloud. This project will demonstrate the extent to which the present communication infrastructure meets the high demands of industrial environments, including low latency and low packet error rates. ◆

Images:
A 5G radio cell with eight antennas was set up in the PTZ Berlin's central test area, operating, among other things, an autonomous vehicle with a robotic arm.

In the Berlin Center for Digital Transformation, four Fraunhofer Institutes, namely Fraunhofer FOKUS, Fraunhofer HHI, Fraunhofer IPK, and Fraunhofer IZM, are conducting joint research on technologies and solutions that address the increasing digitalization and networking of all aspects of life.

More information
about the Berlin Center for Digital Transformation can be found here:
www.ipk.fraunhofer.de/lzdv-en

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PTK 2023

Rethinking Production: Production as a driver for an industrial society in transition – this was the motto of Fraunhofer IPK's and IWF of TU Berlin's conference in Berlin from September 14 to 15. More than 200 guests from business, science and politics came to discuss the major challenges Germany is facing as an industrial location across all sectors.

The conference focused on the specific topics and tasks associated with the digitalization and decarbonization of the industrial sector and presented innovative technologies, methods and business models that can be used to achieve sustainable and CO_2-neutral production. Renowned keynote speakers, including Dr. Ansgar Kriwet, Member of the Management Board Research and Development at Festo SE & Co. KG, Prof. Dr. Helmut Schramm, Head of Production BMW Motorrad and Head of the BMW Group's Berlin plant, Dr. Hubert Lettenbauer, Managing Director of Carl Zeiss MultiSEM GmbH and Dr. Timm Neu, Associate Office Lead @ Software Innovation & Development Berlin, Volkswagen AG, explained current strategies that their companies are using to manage the transformation. Speakers from mechanical and plant engineering, the automotive and supplier industry, electrical and energy technology as well as aerospace presented successful practical examples of resource-conserving and emission-free production as well as current Industry 4.0 solutions in six specialist sessions. Fraunhofer IPK and IWF of TU Berlin also offered practical insights into their current R & D work with technology-oriented transfer paths through their test fields. The conference was supported by Berlin Partner für Wirtschaft und Technologie GmbH, BWA Deutschland, CONTACT Software, Global Production Engineering, IWF e. V., PreZero Deutschland and the Verband der Metall- und Elektroindustrie in Berlin und Brandenburg e. V. (Association of the Metal and Electrical Industry in Berlin and Brandenburg).

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