DRIVEN

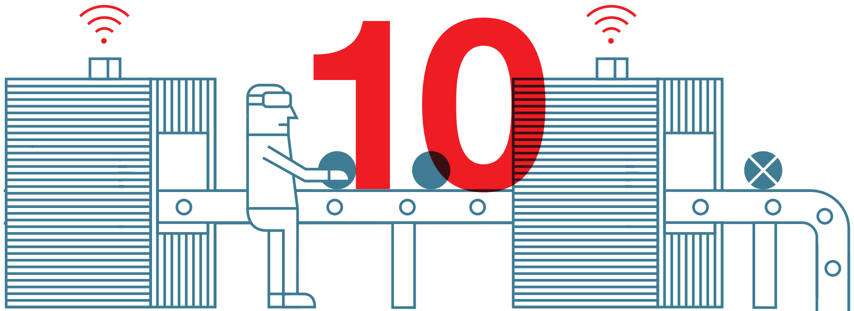
by maxon

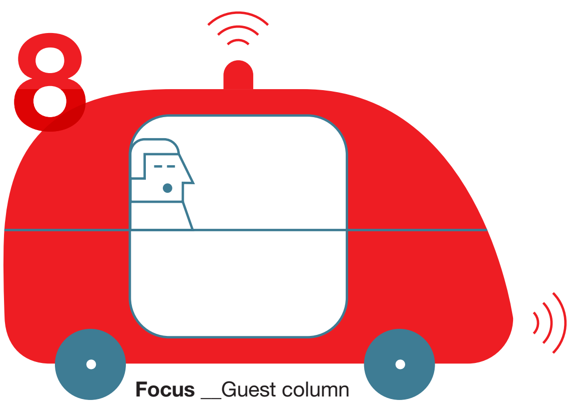
Think tank

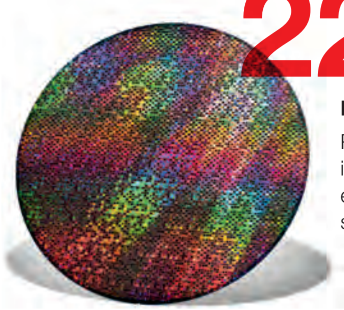
___ **The dawn of a new industrial age.** p.10

___ **How to build an exoskeleton for the Cybathlon.** p.30

Contents







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Eugen Elmiger,
CEO maxon Group

Paving the road for the factory of the future

When the fridge talks to the TV and the mobile phone, then digitization has clearly reached our private homes. However, what about companies? How will Industry 4.0, the Internet of Things, and artificial intelligence change the way we collaborate with our customers? Which services will we be offering in the future? Will there still be people working in the factories? These exciting questions are being addressed in the current issue of driven, which you are holding in your hands. Understand the technical terms used to describe smart factories, and learn why some technologies are longer in the coming than initially hoped for.

In this issue, you can also read how a team prepares for the exoskeleton competition at the Cybathlon, and we introduce our ceramics department in greater detail. Finally, there's the second part of the in-depth technical article on inductance in iron-core DC motors.

Happy reading!

The disassembled runner-up

Here it lies helpless: Sweaty Junior, the humanoid robot built by Offenburg University of Applied Sciences (GER). When assembled however, it will achieve great things: The second place in the 2019 robot soccer world cup in Sydney. Sweaty is equipped with 15 maxon drives, some of which have their own cooling to eke out the maximum in performance. They actually sweat, which gives the robot its name.

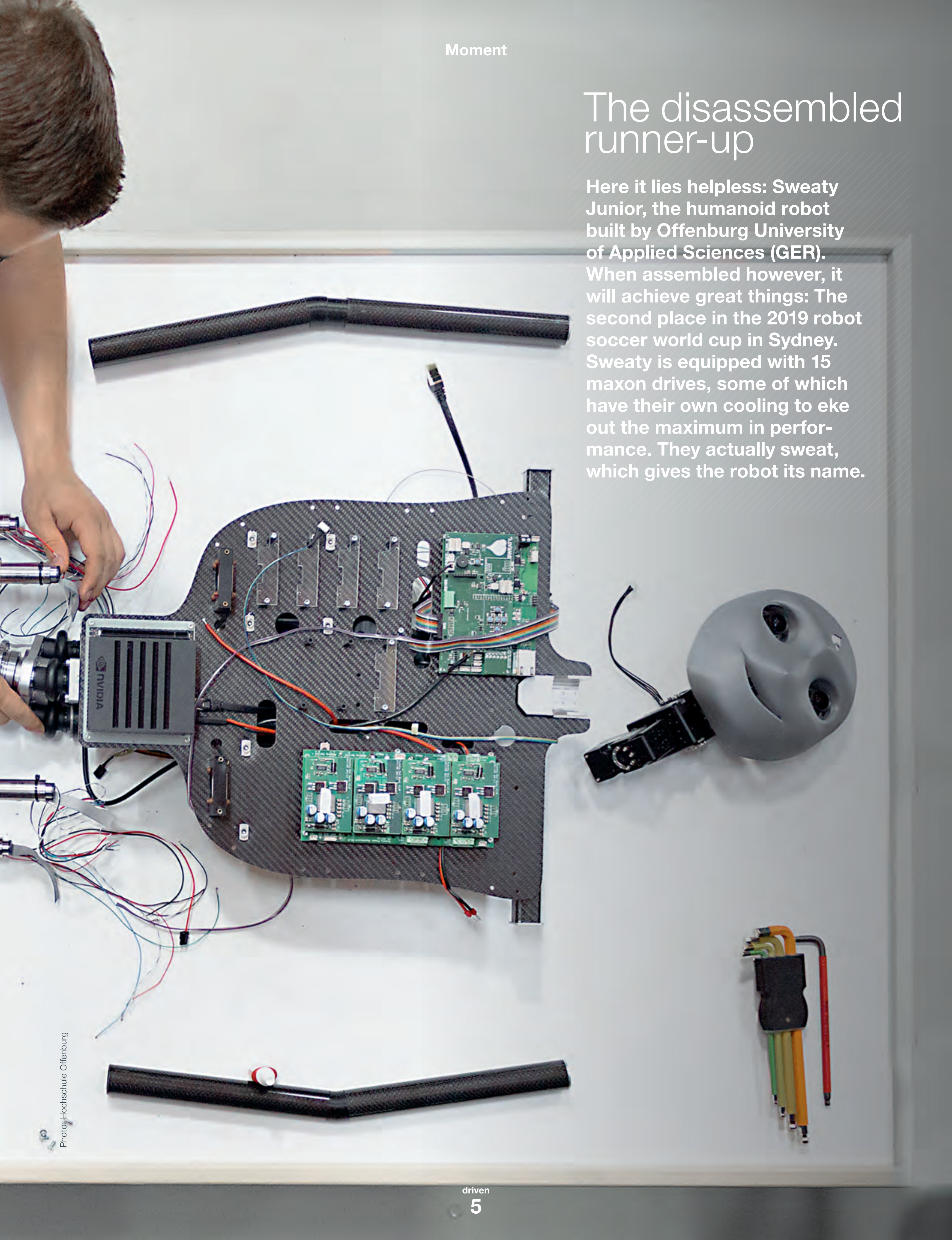


Photo: Hochschule Offenburg

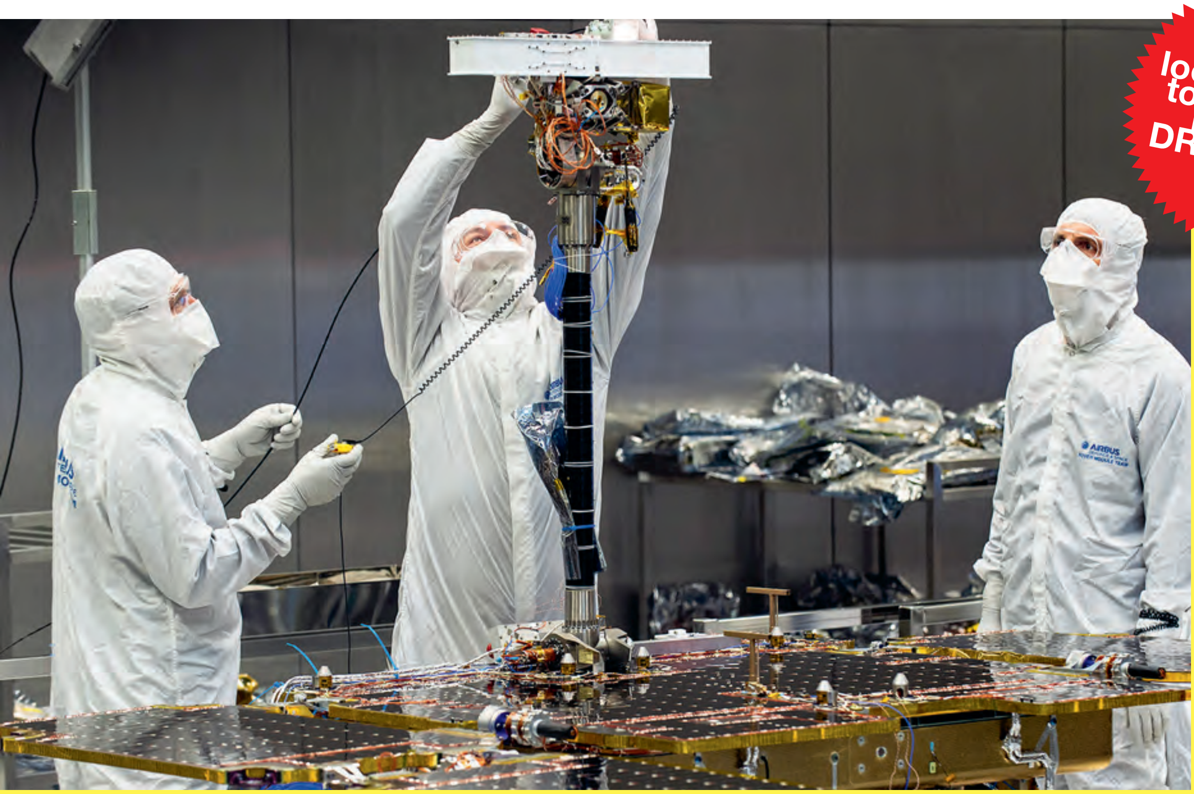
UPDATE

MARS TICKER

maxon and Mars are closely linked. More than 100 of our drives have been used on the Red Planet so far, and their number is growing. Here's a brief overview of the status quo of the various ongoing and upcoming missions involving maxon.

Mars2020

The successor of the Curiosity rover has received a few updates, including better wheels and a drill head for taking soil samples. Inside the robot, a miniature robotic arm (equipped with maxon *flat motors*) moves samples taken by the drill to an inspection and sealing unit. The sealed samples will be dropped off in a location where they can be picked up and carried to Earth on the one of the next missions. In late summer, NASA assembled the robot – which is still looking for a name – and mounted the helicopter unit that is planned to perform the first ever flight on Mars. The helicopter uses *six DCX drives*. The mission is scheduled for launch in July/August 2020. At the time of this writing, everything is on track.



You may look forward to the Mars issue of DRIVEN 1/20

ExoMars

The rover "Rosalind Franklin" was fully assembled in 2019. Afterwards, ESA took it from Great Britain to France for final, comprehensive testing. Later on, it will be installed in the landing module to wait for the launch, which is planned to take place in Kazakhstan in July 2020 – provided the Europeans manage to solve the current issues with the landing parachute. The next time window for a Mars mission won't open before 2022. More than *50 maxon drives* are installed in the ExoMars rover, powering wheel drives, drills, measuring instruments, solar panels, and camera masts.

BIKEDRIVE Air

Electric tailwind

It's that one rise in the city, the little hill on the way to work, or the last incline before reaching the top of the pass, where cyclists wouldn't mind a little bit of a tailwind. Just this effect will soon be achievable with a new e-bike drive system. maxon is currently working on a lightweight mid-mounted motor which is installed almost invisibly in the frame – ideal for racing bikes or fixies.

For more information please see:

maxonbikedrive.com

maxon motor becomes maxon

maxon under a new banner

Last summer, maxon motor dropped the word “motor” from its name. The company now presents itself as “maxon.” This has several reasons. On one hand, the company is in a process of transformation from a manufacturer of motors and components into a specialist for precision drive systems with a focus on five core markets (medical technology, aerospace, industrial automation, transportation, as well as e-mobility and robotics). On the other hand, maxon is changing its corporate structure to position itself as a powerful group, with a worldwide presence and the ability to respond to specific local demands. The new name and the visual rebranding reflect this transformation.

New maxon ambassador

Welcome, Sébastien Buemi!

In early September, a fast guest visited the maxon headquarters: Swiss formula E driver Sébastien Buemi, who is also a formula 1 test driver and has won the last two 24 Hours of Le Mans events. Racer Sébastien Buemi (second from the left) knows what precision and efficiency are. After all, he has already won 13 Formula E races and was the world champion in 2016. Now he also is a maxon ambassador. When the Formula E starts into its next season this winter, Buemi will be wearing the maxon logo on his racing suit. He says: “I’m proud of working with a Swiss high-tech company and being part of the maxon family.” Of course, the joy is mutual. maxon Group CEO Eugen Elmiger says: “Sébastien and the Formula E in general are a great match for us. After all, we are increasingly becoming a systems provider, and the e-mobility market is particularly interesting in this regard.”

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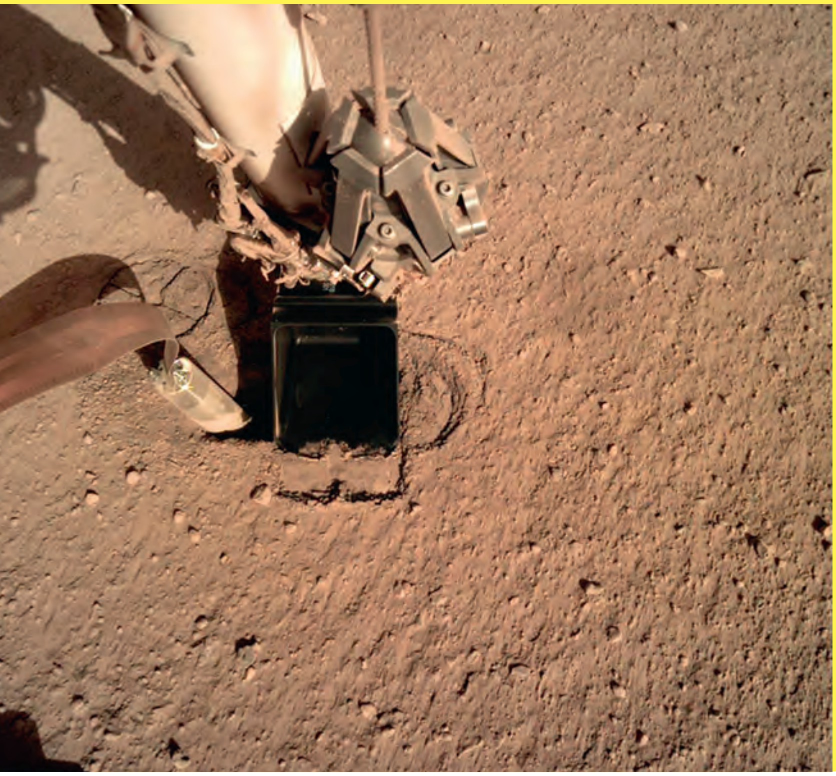


InSight **As planned, the stationary NASA robot landed on Mars in November 2018 and successfully unfolded its solar panels with the aid of maxon motors. Things didn’t go quite as smoothly for the heat sensor, which was planned to burrow five meters deep into the ground. Hammering began in late February 2019, but the process needed to be stopped only a few days later. Since then, the mission managers have been trying to solve the problem. One thing is certain: The burrowing unit (called “mole”) is working flawlessly, powered by a *maxon DCX motor*. However, the friction of Mars’ soil is not as strong as initially thought, in part due to the planet’s lower gravity. That’s why the mole stopped making progress after only 35 centimeters. In late summer 2019, NASA decided to support the mole with the robotic arm. With success: Shortly before the editorial deadline, the mole started digging again.**

Photos: Airbus/M. Alexander, NASA

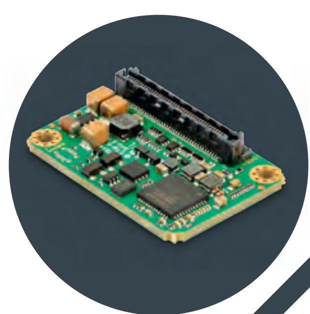
New products

IDX 56 L
up to 2 Nm
of torque

IDX industrial drive

All included in the package

In a short time, maxon developed a new line of compact drives designed especially for applications in industrial automation and automated logistics. These IDX drives consist of a powerful brushless EC-i motor combined with an EPOS4 positioning controller. A planetary gear can be added if necessary. The drives stand out for their high efficiency, maintenance-free components, and a high-quality industrial housing with IP65 protection. IDX drives also have configurable digital and analog inputs and outputs to enable a wide variety of functions and operating modes. Their intuitive software enables easy commissioning and integration into any kind of master system.



EPOS4
Micro 24/5 CAN

EPOS4 Micro 24/5 CAN

When space is at a premium

Our EPOS4 positioning controllers are now also available in a Micro version. As the name suggests, the benefits of these motion controllers are their small size and attractive pricing. Their functionality is virtually identical to that of other platform products. This makes the EPOS4 Micro 24/5 particularly interesting for robotics applications where space is at a premium, as well as cost-sensitive multi-axis applications. The controller is initially available in a CANopen version, with the EtherCAT version scheduled to follow in the spring of 2020. As with the entire EPOS product line, users benefit from free additional options for easy commissioning, such as the EPOS Studio user interface, comprehensive documentation, as well as practical examples.

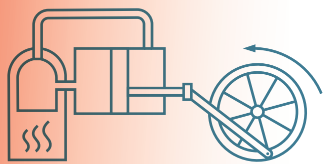
The maxon online shop has more than 5,000 products, selection aids, combination tools, and comprehensive product information:

shop.maxongroup.com

"It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change."

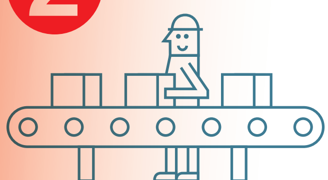
Charles Darwin | English Naturalist and Geologist

1 industrial revolution



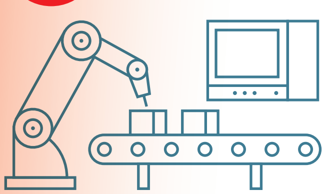
Toward the end of the 16th century, mechanical machines using water or steam power start to replace muscle power.

2 industrial revolution



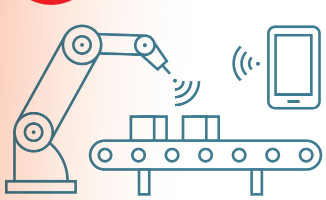
The railway, the telegraph, and especially electricity enable the introduction of modern mass production at the end of the 19th century.

3 industrial revolution



In the 1970s, analog devices begin to be replaced by digital computers. This enables the further automation of production.

4 industrial revolution



In 2010, the fourth industrial revolution begins, characterized by the increased interconnection of machines, robots, and sensors via the Internet.

Illustrations Anita Allemann

The think tank

Will the smart factory – intelligent and digital – fully abolish the need for people in production? Or is this just a vision that lags far behind the actual reality?

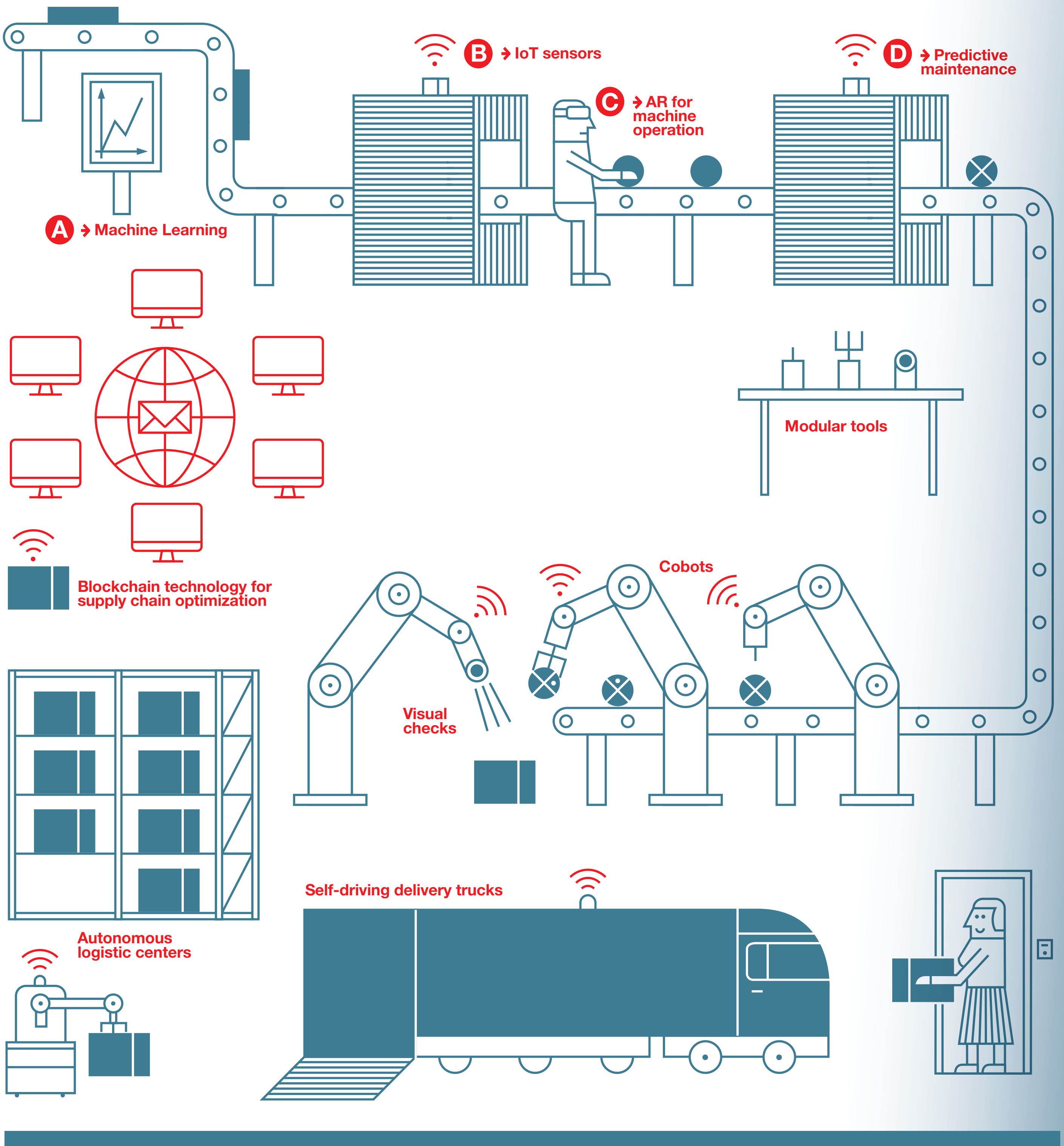
Powerful computers, large data sets, and miniaturization have already caused a rapid change in industry. These days, products are being developed and tested digitally. Machines continuously supply data about their status to cloud-based systems, which optimize their energy consumption and enable the prediction of failures.

At the same time, many industrial production systems still have a long way to go before they could be considered automated. It takes more than a few robots to make a smart factory. It requires the interplay of many key technologies, as well as standardized processes.

One thing is certain: The fourth industrial revolution is here to stay, and it will change the way how we develop, make, and service products. Those who don’t get on board will lose out, sooner or later.

Smart factory

The smart factory is a concrete application example of Industry 4.0 and IoT. In the intelligent factory of the future, products, tools, and machinery are connected and communicate in real time. Because manufacturing processes are coordinated automatically, human intervention is rarely needed.
For example, when a customer orders a custom product over the Internet, the order is forwarded directly to the factory and executed. Machines equip themselves with the necessary tools and materials, continuously monitoring the production process and adjusting it where necessary. The machines coordinate the sequence of orders and send updates to customers continuously. They also detect early on when the next maintenance or repair is due.



Industry 4.0

The term "Industry 4.0" represents the **digitization of industrial production** and encompasses the entire value-added chain. Components are being integrated into intelligent networks in order to make the economy more flexible and efficient, thereby starting the fourth industrial revolution. **"Industry 4.0" is a marketing term that has its origins in an initiative by the German government.** The term was first introduced at the 2011 Hannover Messe and is now being used worldwide. **In the US however, the term Industrial Internet is more common.**

A Artificial intelligence

Systems capable of learning are referred to as artificial intelligence (AI). A good example would be a robot that repeats a motion sequence based on a simple program until it has found the perfect solution. This kind of learning from experience is especially interesting for companies that primarily produce customer-specific unique parts. AI also enables production systems to optimize themselves continuously, without outside intervention. This is referred to as machine learning.

B Internet of Things

The Internet of Things (IoT) is the main prerequisite for Industry 4.0. IoT refers to the networking of products, machines, platforms, and people over the Internet or local networks. The term is commonly used when talking about wearables like fitness trackers or smart watches. That's only a small part of it though, because the number of products and applications connected to the Internet is rapidly increasing. This opens up new possibilities, including possibilities for industrial applications: Products supply information about their status or their environment to the network. This information is aggregated into a digital representation of the entire production chain, enabling machines to provide the right tools and components automatically.

C AR and VR

In augmented reality (AR), users observe the real world through their smartphones or special goggles. The device shows users additional information (text, graphics, visualization, etc.). The technology is already being used for games, navigation apps, or interior design planning software. In virtual reality (VR) on the other hand, users fully immerse themselves into a virtual world, usually with the aid of VR goggles.

D Predictive maintenance

The collection and evaluation of data enables better and better prediction of faults and failures. Components can be replaced before they fail, resulting in significant cost savings. However, this requires that the components send information continuously. This information is compared with values collected from experience as well as quality data, which allows predictions to be made about the service life.

5G network

5G is a mobile communication standard (fifth generation) that enables faster data transmission. 5G has shorter latency, enabling it to **respond in real time**, which makes the technology **interesting for the Internet of Things**, where machines and products communicate with each other.

Cloud-ready communications

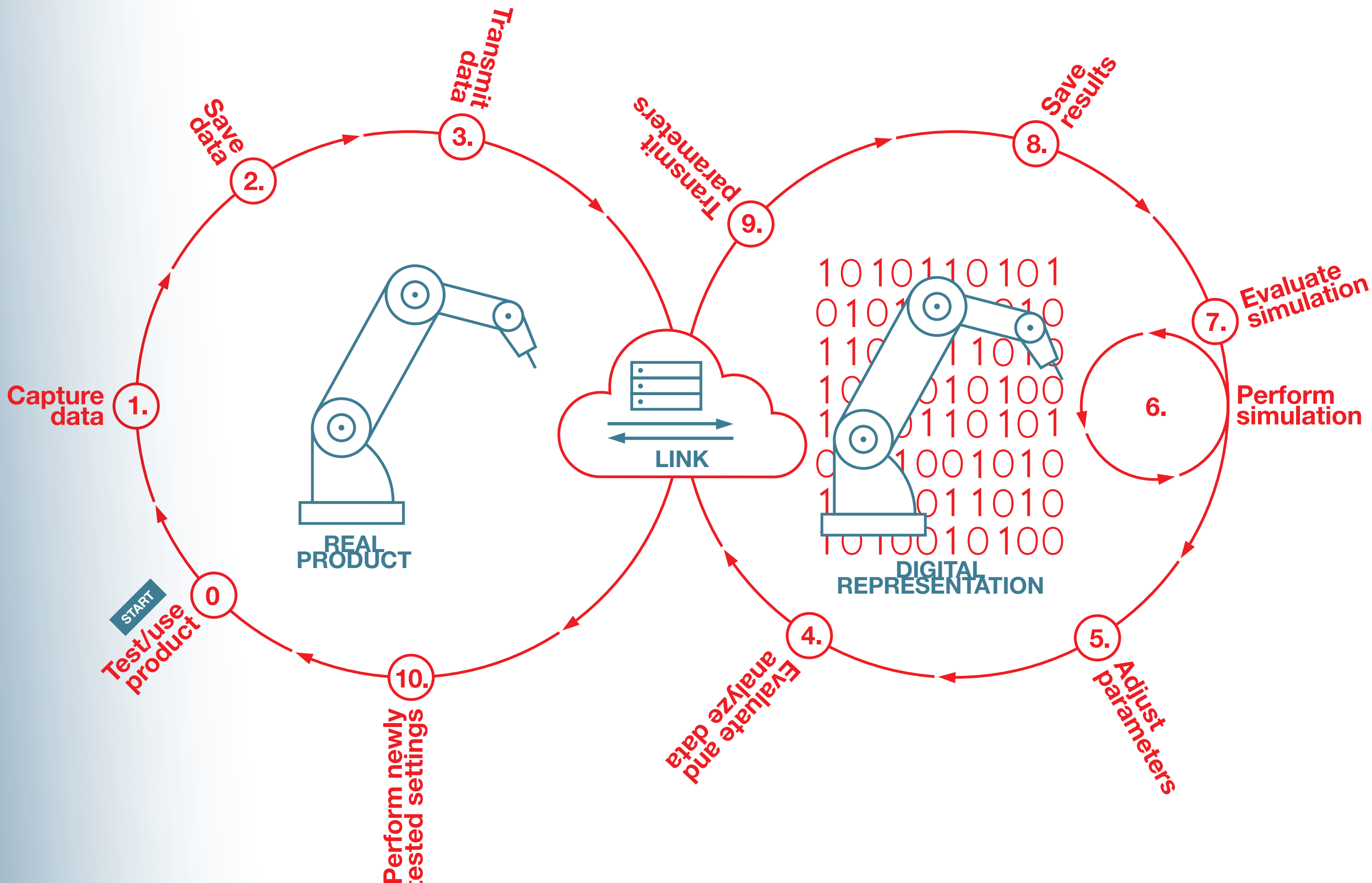
Bluetooth and WLAN in industrial automation? That was still unthinkable only a few years ago. However, times have changed.

Devices need to communicate in order to exchange data. The concept is familiar to us from our everyday lives: Smartphones communicate with a pair of headphones via Bluetooth and connect to cell towers using radio technology; notebooks use WLAN to connect to a router, and a fiberoptic cable leads from the router to the wall box. Clear rules are required for these data connections to work. These rules are defined in what is referred to as network protocols. Like consumer electronics, industrial automation also requires network protocols so that the various devices “understand” each other. Here’s where things get a little different from everyday data applications.

When you access the maxon website from home, it doesn’t matter if the site loads one tenth of a second faster or slower. In industrial automation and multi-axis synchronization however, every millisecond counts: Even a small delay in the data transmission can throw an entire system out of sync. That’s why industrial applications need data connections that are faster and more reliable. CANopen and EtherCAT are well-known examples. They’re also used in maxon systems. People often talk about “real-time data exchange” in this context. The expression “real time” may lead to the misconception that the communication between devices is fully instantaneous. That would be physically impossible. Any exchange of data takes time, even if it’s only a microsecond. Instead of “real time”, “extremely low latency” would be a better description for the design goals in industrial automation.

In CANopen and EtherCAT networks, the data exchange happens via cables. Why not use wireless, like WLAN or Bluetooth? “Way too unreliable and prone to errors,” used to be the standard answer experts gave to this question until a few years ago. Today, this is no longer strictly true. The use of wireless technologies like WLAN and Bluetooth, both of which have made great progress in recent years, is becoming more common in industrial automation. This is not least because, in an industrial setting, the storage and exchange of data isn’t just local but extends into the Internet. “Cloud computing” is the key word here. That’s also why everybody is talking about 5G technology these days. For an individual smartphone user, the new mobile communication standard offers few noticeable benefits. For many other applications revolving around Industry 4.0 and the Internet of Things (IoT), this modern transmission technology is the way of the future.

One of many application examples of the digital twin technology



Digital twin

People talk about digital twins when machines, products, or entire processes are represented virtually, i.e. mirrored. This offers a chance to simulate and validate the product as early as the development stage, before an initial prototype has been built, and to accelerate the market launch. Even entire systems or factories can be virtually mirrored and simulated. Commissioning takes place digitally in advance, which allows potential malfunctions to be identified and corrected early. To increase performance in the factories, the digital twin can be continuously supplied with sensor data from the production system and the products in real time (see Internet of Things). The current state of the machine is represented digitally at all times. Through incorporation of artificial intelligence, the smart factory is able to schedule maintenance and optimize processes independently.

Digitization needs to pay off

Industry 4.0 has been a hot topic at maxon since the drive specialist introduced configurable drives. Now we're continuing to drive digitization – but not at all costs.

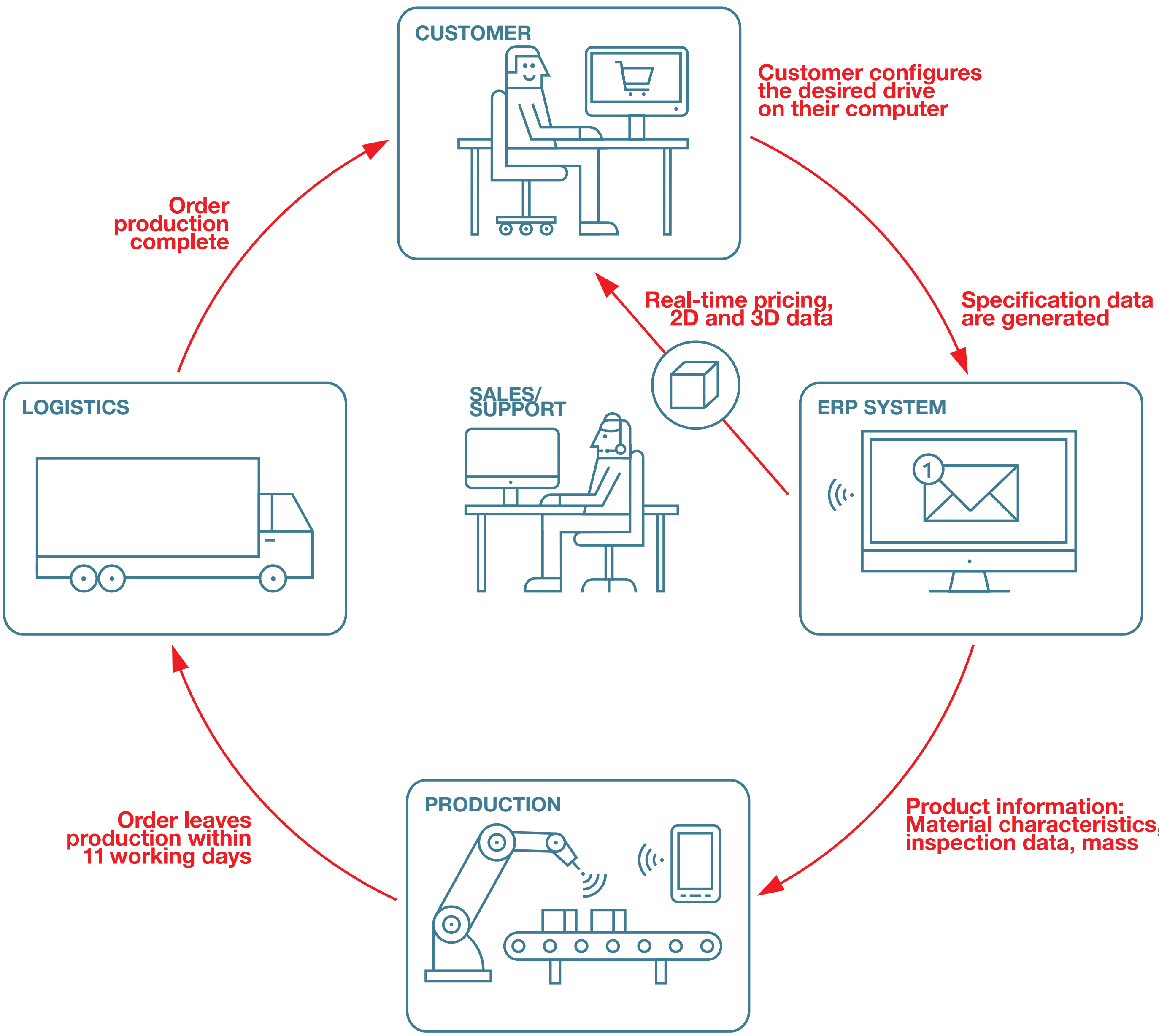


Illustration: Anita Akllemann

Automation and digitization are important topics in the maxon Group. One example is the online configurator introduced in 2013, which enables customers to compile a specific drive on their computer and send the order directly to production, very much in the spirit of Industry 4.0. Accordingly, maxon Group CEO Eugen Elmiger says: "A batch size of one is standard for us."

When someone configures a drive online, consisting of motor, gearhead, and encoder, they see the price in real time. As soon as the configuration is complete, the customer gets access to the 2D and 3D construction data. This digital model can immediately be integrated into the customer's application. At the same time, the properties of the order are entered into the maxon ERP system, which generates production data and sends them to production, where many work steps are automated. Machines equip themselves with the necessary tools and materials. The order leaves the factory no more than eleven working days later.

For now, each production step is reviewed by an employee – for quality reasons. However, the machines could soon be able to perform the tests themselves. Possibly, the entire portfolio of maxon drives may become available for online ordering in the future. Maybe customers will put on VR goggles to meet online with maxon engineers to compile a drive system and digitally integrate it into the application, long before the first prototype is created.

Efficient material flow due to AI

Sascha Buchschacher and his Configure To Order team are thinking about which technologies are interesting for maxon and which direction the drive specialist will be taking in the years to come. He is fascinated by the possibilities offered by digitization. However, he remains pragmatic: "In theory, you can automate nearly anything – but it needs to make sense business-wise." After all, the investment in each case is substantial.

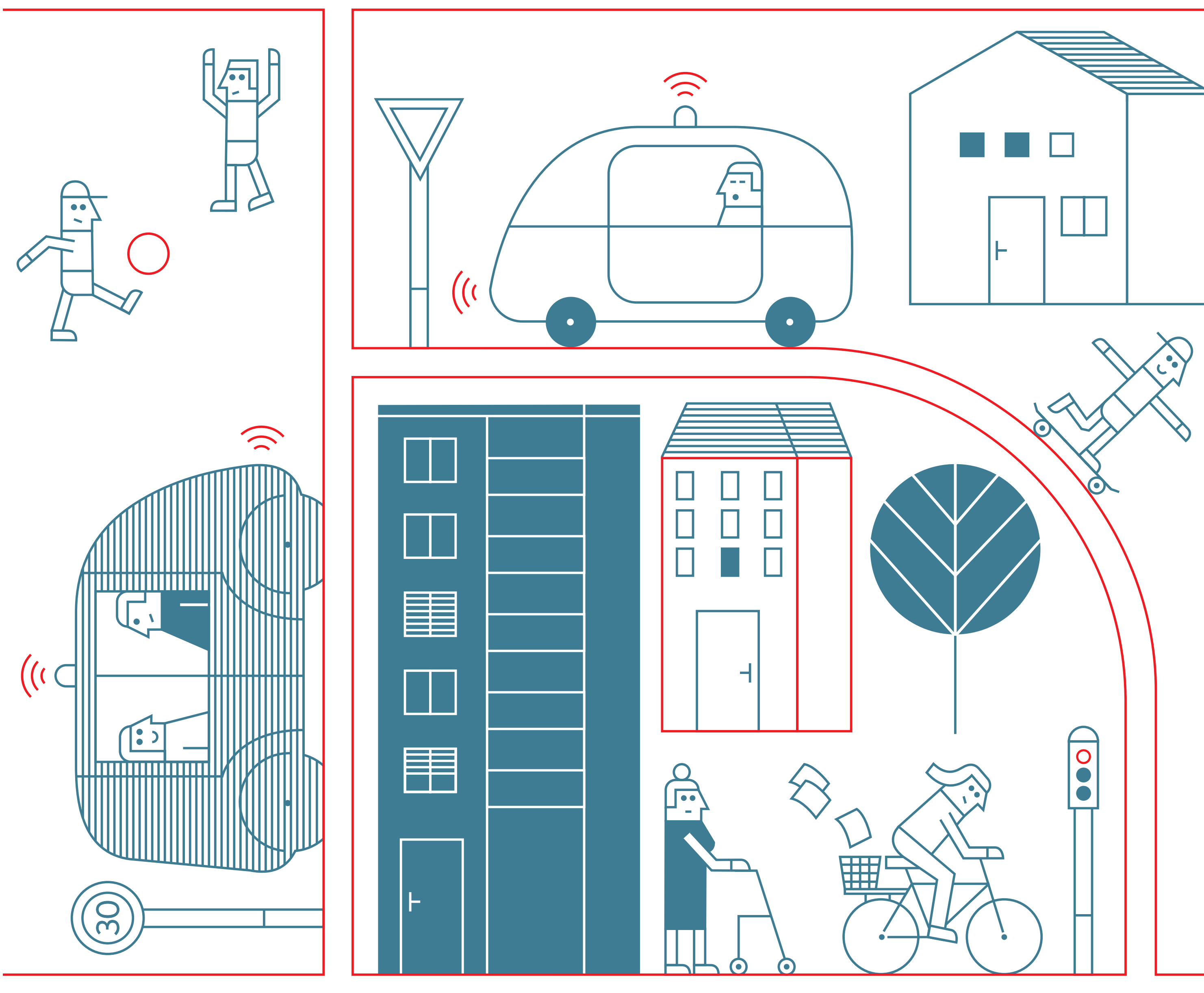
Sascha Buchschacher does not expect industrial workflows to change overnight. "However, we need to lay the foundations for the factory of the future – today." This means establishing stable, unified processes worldwide, installing a workable system architecture, and, most importantly, building a suitable culture within the company. Then it will be possible to implement a variety of digitization projects. As he sees it, there are many ways in which maxon and its customers will benefit from new technologies. Why not use artificial intelligence (AI) to optimize the supply chain and material flow through integration of a variety of data like tariffs, laws, framework agreements, and more? "That would be an interesting application. However, for AI to really yield results, we need a lot of data in high quality, as well as a way of aggregating it for processing."

It's conceivable that the Internet of Things will generate additional services. If maxon drives and controllers are connected to the network and supply information, parameter changes allow conclusions to be drawn about the condition of the drive. A motor can be replaced before wear results in machine failure. Maybe customers won't purchase motors in the future but instead pay per operating cycle. However, implementing such technologies requires high-performance networks and reliable cloud systems. According to Sascha Buchschacher, these aren't yet available. One thing is certain: Digitization will change engineering, production, and the entire way in which we work – but not overnight.

maxon employees in the DCX production line, where drives that have been configured online are manufactured in a semi-automatic process.

Human in the loop

Autonomous vehicles are the most important application case for the Internet of Things. However, the technological development is much slower than it was hoped for. The reason: human behavior.



Text Thomas Ramge

Three or four years ago, the road map for the introduction of robotic cars seemed clear. The main innovators of autonomous mobility just oozed confidence: Waymo, Uber, and Ford announced that large fleets of robotic taxis would soon be roaming American cities. Urban mobility was to become cheaper and safer, as well as greener, due shared use of electric vehicles.

Since then, the data-rich and financially powerful US companies have managed to put only a few trial projects on the road, usually in sunny regions and for customers who don't have to pay. Usually there is still a human in the driver seat to monitor the system. If that person is watching a TV show on their phone while a woman pushes her bicycle across the road, fatal accidents are a possibility. This is what happened in March last year in Tempe, Arizona.

Autonomous vehicles only on highways?

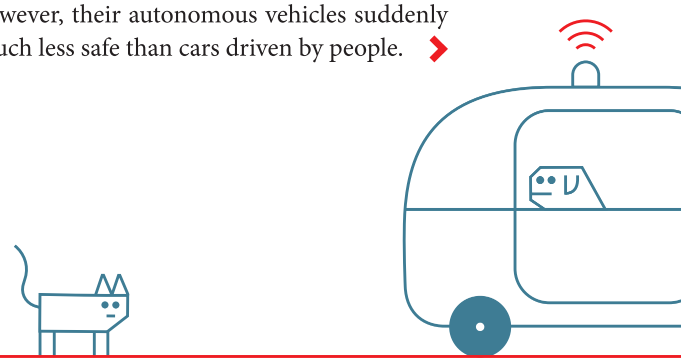
Today, the only remaining optimist is Tesla founder Elon Musk. He still promises that in 2020, the next version of the Tesla autopilot will turn Tesla drivers into Tesla passengers. However, Elon Musk is Elon Musk. His announcements are frequently driven by the logic of capital markets, rather than technological development cycles. All of the other potential vendors of self-driving cars have been toning down their rhetoric: Everything will take longer than expected, probably much longer. The doubters in the industry already suspect that we will see only a very limited version of autonomous mobility, such as buses that cover defined routes at slow speed, or automated driving on highways in fair weather. The cause of these setbacks is not so much technological but rooted in human nature: irrational behavior.

Autonomous mobility systems have made great progress in recent years. Due to improved sensors and LIDARs (a kind of laser-based radar), fast chips, and image recognition processes based on machine learning, the systems have become much better at assessing the traffic situation and selecting the correct decision-making routines in familiar situations. However, intelligent driving machines have a much harder time predicting human behavior than initially thought: While this behavior is mostly rational and in accordance with the rules, it sometimes isn't.

Pedestrians cross a red light, cyclists take the wrong direction in a one-way street, and drivers make turns at corners where they aren't allowed to. Of course, autonomous vehicles can hit the brakes in such cases. However, people will begin to behave in rationally irrational ways toward autonomous vehicles in the future. They will cut in right in front of the robot, because they know it will just quietly brake instead of swearing and honking the horn at them. There is no technological solution to this problem yet.

Robots lack human intuition

We people are pretty good at reading human signals. When we see the gestures, facial expressions, or posture of a person, we usually know whether that person is about to cross the street. Yet even the best image recognition software is unable to interpret these subtle signals, even more so in dim light. It's unclear whether – and if yes – when computers will be able to do so at the same level as a human. If the vehicle in front of us suddenly slows down, we understand that the driver may be looking for a parking space, even if he does not set the turn signal. We know that we should keep distance. There are far more of these special situations – developers of autonomous driving systems refer to them as "micro maneuvers" – than one would think. They increase complexity to a point where current computers are unable to keep up. The state of the art is: Waymo, Uber, etc. could build vehicles that are safe because they always brake – but that would be impractical. Once designers abandon this policy of excessive caution however, their autonomous vehicles suddenly become much less safe than cars driven by people.



Thomas Ramge is a non-fiction writer and lecturer. His work has won multiple awards, including the Axiom Business Book Award 2019 (Gold Medal, Economics), the getAbstract International Book Award 2018, and the German Economics Book Award.

Other technologies also don't deliver on their promises

New technologies usually enter the world with a swagger. At first, they're always long on promise and short on delivery. Then everybody is disappointed, and the technology needs to recover lost trust in the long term. This hype cycle can be observed time and time again in the IT industry. Some technologies take much less time than others to overcome initial difficulties and become reliable and productive. The Internet itself may be the most disruptive example for this in recent history. 3D printing on the other hand is still a long way from achieving the vision of decentralized production in batch sizes of one. In the 1950s, nuclear physicists believed that fusion technology would be supplying the world with cheap energy no later than in the 1970s. These days, barely any serious researcher dares to prognosticate when the first commercial fusion reactor might come online.

In autonomous mobility, the current situation is that about 80 percent of the technological problems have been solved. However, the remaining 20 percent might be the hardest. Self-driving cars remain the biggest hope in the Internet of Things. When traffic and data flows converge perfectly, the world becomes a better and safer place for everybody. More than a million road fatalities worldwide are a moral imperative to drive the development of self-driving cars with the best research we can muster. Due to our own irrationality and lack of discipline, we humans remain the greatest obstacle. Machines need to learn how to deal with this.

Thomas Ramge's two latest books (in German) are "Mensch und Maschine – Wie Künstliche Intelligenz und Roboter unser Leben verändern" (Reclam) and (with Viktor Mayer-Schönberger) "Das Digital – Markt, Wertschöpfung und Gerechtigkeit im Datenkapitalismus" (Econ). In these, he explores how artificial intelligence and robotics change our lives and looks at data capitalism and how it affects the market, value creation, and social justice.

“When digital transformation is done right, it’s like a caterpillar turning into a butterfly, but when done wrong, all you have is a really fast caterpillar.”

George Westerman | Principal Research Scientist with the MIT Sloan Initiative on the Digital Economy

More articles about industrial automation on our blog:

www.drive.tech

In the vacuum workshop

In the semiconductor industry, cleanliness and precision are absolutely critical. Swiss vacuum specialist VAT therefore partnered up with maxon to develop a drive system for wafer processing.

Three of these pinlifters move a wafer in the vacuum chamber.

Photos: MirageC/Getty Images, VAT

The term "vacuum valve" typically doesn't generate a lot of excitement, even among technology aficionados. What could there possibly be that's of any interest? However, things do get interesting when you visit VAT, a globally active company with headquarters in Haag, eastern Switzerland. VAT is a global leader in industrial vacuum technology. Simply put, a vacuum valve is a valve that opens or closes access to a vacuum system. If the word "vacuum" makes you think about packaged food in the supermarket, then you're on the wrong track. Industrial vacuum chambers are primarily needed in applications where even the tiniest speck of dust or droplet of water would ruin an entire production step. This takes us right into the thick of things: the high-tech industry. Smartphones, flat screens, solar panels, processors – without vacuum systems, these and many other products would be impossible to manufacture. VAT accordingly ships most of their systems to Asia, home of the big players in the microelectronics and semiconductor industry.

An elevator for wafers

The production and processing of what is known as "wafers" is a key production step in the microelectronics industry. Wafers are thin, round plates made of a semiconductor material, such as silicon. These plates are the basis for integrated circuits. If one considers that modern processors, including those of smartphones, contain billions of transistors, then it's easy to see why the production environment for semiconductor substrates must be free of all foreign particles. The easiest way to achieve this is by performing these production steps in vacuum chambers. The problem is: The stronger a vacuum, the stronger the air pressure from outside. Professional vacuum chambers are exposed to enormous forces. A normal valve wouldn't stand a chance against such pressure. VAT valves, however, are up to the challenge.

In recent years, the company went even a step further to offer complete systems for various production steps in vacuum chambers, in addition to individual valves. One of these systems is called Pinlifter. The Pinlifter is a kind of elevator for silicon wafers. The wafer rests on three pins, and each of these pins can be moved vertically using a motor. This creates a kind of three-legged elevator (three pinlifters) with which a wafer placed on it can be moved upward in a vacuum chamber and aligned precisely for further processing. Here's where maxon comes in. As a high-precision mechatronic drive system, the Pinlifter is the result of a months-long collaboration between VAT and maxon. The drive unit of the Pinlifter consists of a brushless EC-flat motor with an optical encoder, a brake, and a spindle. Keeping the length of the drive unit to a maximum of 40 millimeters was a special challenge.

Marco Apolloni, head of engineering at VAT, looks back: "We initially explored about six different concepts, with different potential suppliers for the motor, brake, encoder etc. Four of the concepts followed a components-based approach, while the others looked at systems, with the entire drive being provided as a tested unit (incl. housing, spindle, motor shaft, insulation parts). "Due to the strict requirements with regard to precision and size, only the systems-based approaches made it into the final round, as these concepts eliminate many risks and support the development of an optimal solution," explains Marco Apolloni. "maxon stood out for its technical expertise and its ability to deliver the complete solution from a single source."


ID10: Baker
ID5: Ginter
ID1: Gerhardt
ID0: Ball
10
5
adidas

Robots on set

These intelligent robotic cameras that automate live transmission are used on stages, racetracks, and playing fields, operate autonomously - and provide a perfect TV experience.

The camera pans evenly to follow the figure skater, smoothly zooming in as she pulls away and slowing down as she changes direction. A skilled hand with the camera? Yes. However, the hand isn't human. The camera movements are generated by an intelligent robotic system.
The system is backed by technology developed at Seervision, a spin-off from ETH Zurich that produces systems for automated video production that are capable of learning. The core of such systems is their image-analysis software, which is capable of recognizing and classifying people and makes sure that the cameras follow their movements. An expansion of the algorithm to other subjects is in planning.

Collaborative on a human-equivalent level

The software is quite sophisticated. Using what is referred to as Visual Position Tracking, the system sets multiple reference points for each item in the image. These are used to generate movement patterns that are supplied continuously to the controller. The movement patterns are used to continuously and dynamically optimize the field of view. In addition, various image design modules make sure that the requirements for professional image composition are being fulfilled. Conrad von Grebel, Business Developer and co-founder of Seervision, explains: "Our software adjusts camera movements in real time. What's unique about our process is that the cameras operate at a human level of proficiency." The system still allows the producer to intervene at any time. "If I command the software to do a closeup, I can adjust it manually when needed." This makes the technology a perfect symbiosis between an autonomous system and human artistic skill. It works with all commonly used cameras and a web browser.
The number of cameras used in a typical TV production ranges from three to eight in studio setups, to more than 50 during the soccer world cup. This can quickly become quite costly. However, Seervision is not primarily focused on cutting cost: The company wants to give film producers a tool that makes their work more plannable and improves the quality of live transmissions. This results in changes in ❯

Using a large number of reference points, the Seervision system detects people in an image and automatically adjusts the field of view to their movements.

"Our cameras operate at a human-like level of proficiency. This makes them unique in the world."

Conrad von Grebel, Business Developer and co-founder of Seervision

the nature of tasks: The camera operator becomes a multi-camera coordinator who is in charge of the visual language and thus is responsible for the style of the transmission. The benefits include more attractive and immediately adjustable camera angles and movements, as well as the minimization of human error.

The software is continuously learning

The varied functions of the system are based on artificial intelligence: For programming the software, the experts in Zurich continuously analyze existing film material to develop the world's first artificial neuronal net for video productions – a concept that originated in brain research. The software independently learns from the data of past productions to optimize processes of visual recognition and comprehension and to determine the field of view and the movements of the camera. The developers even plan to use artificial intelligence to automate the cutting process.
Seervision equips its camera robots with brushless EC 45 flat motors and EPOS4 compact positioning controllers from maxon that move the camera noiselessly with a precision of 0.0002 degrees. Additional drives mounted on the lens ensure optical accuracy and control the camera focus. Interesting: The original idea of automatically filming a university lecture gave birth to a technology company. Seervision has been part of the maxon Young Engineers Program since 2016, won the Swiss Technology Award in 2018, and has been nominated for this year's Digital Economy Award.

Photos: Luca Meister, Seervision AG

A two-axis pan-tilt unit contains two maxon drives. The Seervision system also contains a connected software rack and a web-based user interface.

"A result of global collaboration"

The IDX is a new compact drive consisting of a motor, gearbox, and controller. The responsible sales engineer Sébastien Gissien explains why maxon is taking a different approach with this product and which markets will benefit from the new drive.

Interview Stefan Roschi

With the IDX, maxon is presenting a new series of compact drives. What's behind it?

IDX drives are based on familiar maxon technologies, like EPOS4 electronics and the EC-i family of motors. The whole unit comes with a housing to protect against water and dust (IP65)

That's all well and good, but aren't there such drives on the market already?

Of course. However, our IDX has a number of strengths to offer, of which I'm quite proud. For example, we achieve the same level of performance as our competitors, with a product that's about 25 percent smaller. The drives are also easy to integrate in any control architecture using an EtherCAT or CANOpen field bus. This is helped by the proven EPOS Studio software, which enables customers to commission an IDX drive in a very short time. Not least, our goal is to offer the IDX series via our online configurator as soon as possible – and this is something that's exclusive to maxon.

Sébastien Gissien is the head of sales at mdp – maxon France.

What prompted the development of the IDX?

The idea for a new compact drive was born two years ago at maxon France. We conducted a survey among our customers and other interested parties to learn about their expectations with regard to such a drive. We then formed an international project team based on these expectations. As such, the IDX is the result of a global maxon collaboration: The brushless motor is from South Korea, the gearhead from Germany, and the matching EPOS4-based electronics are from Switzerland, where a project team integrated all components into an overall system.

What are the intended applications for the drive?

Basically, the IDX series is suitable for any application that requires low-voltage BLDC motors. We're looking at several interesting developing markets. These include shuttles and AGVs (automated guided vehicles) for intralogistics, the packaging industry, agricultural robots, but also production machines with X, Y, and Z-axis movements.

Why the intralogistics market in particular?

Intralogistics is a rapidly growing market with high requirements to productivity and efficiency. Our team has integrated these requirements and developed a product that is powerful, easy to use, and affordable.

When do customers ask for an integrated compact drive for their application?

By way of example, let's look at an AGV whose wheels need to be driven. The more compact the drive, the smaller the entire vehicle. This means that more AGVs can be used when space is limited, which in turn leads to higher productivity. With a pick&place machine, a customer can use compact drives to drastically reduce the amount of cabling and thereby the design complexity.

Is the IDX capable of making a contribution to the digital factory?

Yes. The drive is equipped with two temperature sensors, one in the motor and one in the electronics. Customers can use the real-time feedback for predictive maintenance.

Are there already applications in which IDX drives are used?

We are successfully using the drives in our own production lines in Switzerland. There are also some tests with AGVs and logistics shuttles.

What are the reactions?

The initial feedback has been very positive. Key customers who are already testing the IDX are looking forward to the launch of mass production.


femron
TRUMPF

Me and the machine

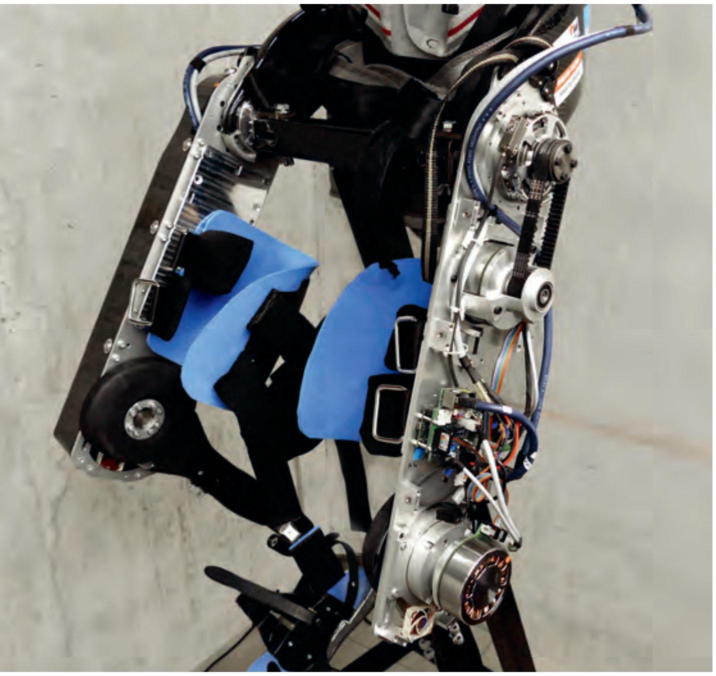
Paralyzed people can learn to walk again with the aid of electromechanical exoskeletons. However, it's not easy. It takes a lot of engineering and hard training.

Does the human control the machine, or does the machine control the human? This old question invariably comes to mind when we're thinking about exoskeletons, i.e. electromechanical aid systems that enable paralyzed people to walk again. To Silvia Rohner, project manager of the Varileg Enhanced team, the answer is clear: "How well an exoskeleton works in practice depends primarily on the pilot." A paralyzed person needs to get used to the robotic support and learn how to use it for best effect. "Some people rely more on strength, others more on technique. Either way, it takes a lot of training." In May 2020, we will see which approach is best when pilots from all over the world, using different exoskeleton systems, compete against each other on an obstacle course during the Cybathlon in Switzerland (see page 32).

Team Varileg Enhanced takes part in the Cybathlon and has set itself the goal of mastering all obstacles on the course. Silvia Rohner: "We want our pilot to succeed in the competition."

Improvements still necessary

At the first Cybathlon in 2016, there already was a Team Varileg from ETH Zurich. It had little to do with the current one, however. The current exoskeleton was developed new from the ground up, as a student project that started in the summer of 2018 and ended in the summer of 2019. Since then, a mixed team from ETH Zurich and the HSR University of Applied Sciences Rapperswil has been working on the completion of the robotic system. The goal: Having the competition exo ready in time for the Cybathlon. "There is still a lot of potential," says Silvia Rohner. While the mechanics are excellent, the software needs to be put in a future-proof architecture. The actuator control also needs improvement. The team wants to



A view of the inside of the Varileg Enhanced exoskeleton: Two maxon EC 90 flat Power Up motors drive the legs on each side.

finalize these changes before the end of winter so that the pilots can start training. One of them, Thomas Krieg, is a former bobsledder and has a strong athletic ambition. He has made great progress since his first walking attempts with the exoskeleton, saying: "I'm getting better and better at handling the machine, and I'm confident that we can master the challenges of the Cybathlon." The most difficult obstacle will probably be the inclined plane. That's because his exoskeleton lacks the additional degree of freedom in the hip joint, so that the entire weight will be on the crutches and Thomas' arms.

Additional motor power

In order to save weight and keep the system simple, the technicians limited the Varileg Enhanced to two degrees of freedom. There are two brushless flat motors from maxon on each side to move the hips and knees. To keep the exoskeleton as narrow as possible at the hips, the motor and gearhead were mounted in parallel, connected by a V-belt. At the knee joints, the gearhead is installed directly on the motor. At up to 600 W of power, the motors of the Varileg Enhanced are twice as strong as those of the predecessor model. This power is needed, says Silvia Rohner. "When climbing stairs, very large forces are generated. We don't have a lot of reserves."

There are many ways to build an exoskeleton. Time will tell how successful the Varileg Enhanced team will be with its concept. At any rate, Silvia Rohner is looking forward to the Cybathlon. "It will be interesting to see the other teams' solutions and get an idea of the technologies used elsewhere in the world."

The Cybathlon is just around the corner

On May 2-3, 2020, the second Cybathlon event takes place in Zurich. Again, people with physical disabilities compete on obstacle courses – supported by state-of-the-art technical assistance systems. The teams and their pilots compete in six disciplines: brain-computer interface (BCI) race, functional electrical stimulation (FES) bike race, powered arm prosthesis race, powered leg prosthesis race, powered exoskeleton race, and powered wheelchair race.

maxon supports the event as a Presenting Partner and will be on site. Among other things, the drive specialist will be supporting the participating teams with technical advice. For more information, please visit **cybathlon.com**

Photos: Stefan Schneller/ETH Zurich; Varileg Enhanced

Series: Brushless motors with grooved windings part II

Saturation at high torque and current

How does the motor data of multipole brushless motors with grooved windings – i.e. with an iron core – deviate from ideal, linear characteristics?

Urs Kafader,
head of
technical training,
maxon

As opposed to classic ironless maxon motors, maxon flat motors and EC-i motors have windings with iron cores. The result is a higher magnetic flux in the winding, which makes the motor stronger.
In the last issue of driven, we discussed how high inductance delays the current response. At high speeds, this creates deviations from the simple linear characteristics of motors with ironless windings. Part 2 is a simplified discussion of the effects of magnetic saturation at high currents. The iron core is only able to amplify the magnetic flux to a certain limit. Above this limit, no further amplification of the magnetic flux in the winding takes place. As a result, the motor's stall torque deviates from a simple linear extrapolation of the gradient. It should be noted that currently (2019), maxon presents all motor data without taking saturation into consideration.

Magnetic flux density of a coil

The magnetic flux of a conventional winding is proportional to the number of turns multiplied by the current passing through the wire. A higher current means a greater flow density, resulting in higher motor torque. This proportional relation between current and torque is expressed by the motor's torque constant, kM.
If one places soft magnetic iron in an external field (e.g. generated by a coil around the iron core), the iron magnetizes, i.e. the internal magnetic moments gradually orient themselves in the direction of the external field. This magnetization generates additional magnetic flux, as well as additional torque in the motor. This effectively means that the motor's torque constant becomes bigger.
Figure 1 This simple illustration shows low motor currents and low magnetization of the iron core. We also have a torque constant kM, which represents the linear dependency between the current and the torque in the motor.

Saturation

At higher currents, the iron core in the coil's magnetic field becomes saturated. Saturation means that all of the internal magnetic moments in the iron are fully in alignment. Increasing the strength of the external field (more current) has no additional effect on the magnetization; only the flux in the coil itself increases. In other words, getting more torque out of the motor requires a much higher current. Or, the same increase in the current only generates little additional torque. The torque constant decreases.
Figure 2 Saturation occurs at high currents. It is not considered in the motor data in the maxon catalog. High currents also mean that deviations from the specified values occur only in short time operation. Only two parameters are affected: startup current and stall torque.

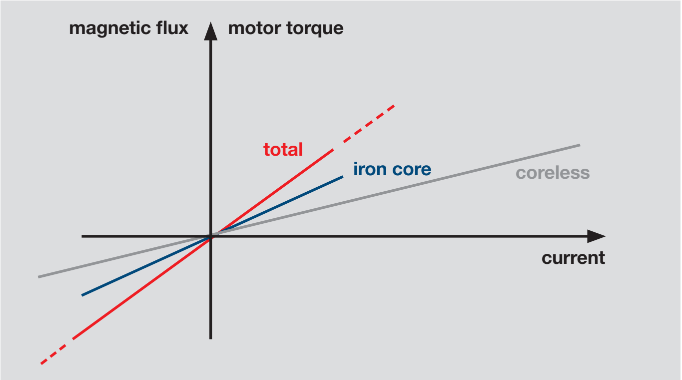


Figure 1 The blue line shows the additional magnetic flux due to the magnetization of the iron core at low currents. The total magnetic flux is represented by the red line whose gradient – i.e. the motor's torque constant kM – is greater than for ironless motors.

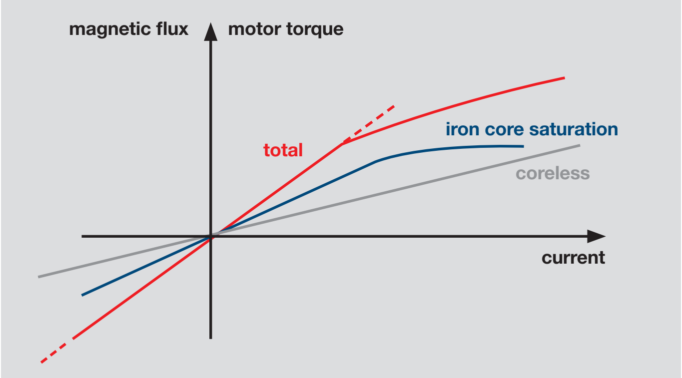


Figure 2 Saturation of the iron core (blue line). In case of higher external fields due to the winding current, the iron core no longer contributes to magnetization. The total flow and the motor torque increase less steeply.

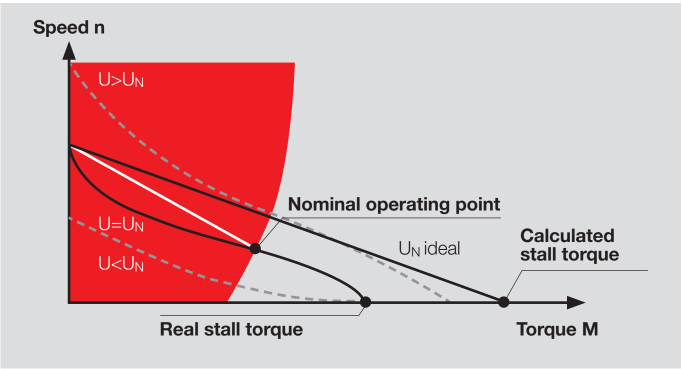


Figure 3 Diagram and remark on saturation: "The specified stall torque is equal to the linearly calculated load torque (without magnetic saturation effect) which causes the shaft to stall at nominal voltage. With EC-flat and EC-i motors, this torque often cannot be achieved due to saturation effects."

maxon EC motor type	Nominal current	Startup current	max. current, ESCON/ EPOS	Current for 20 % reduction in k_M	Saturation effect
EC-i 30, 50 W std	3.64 A	63.1 A	30 A	ca. 23 A	Only at controller's max. current
EC-i 40, 50 W std	2.8 A	47.9 A	15 A	ca. 21 A	almost none
EC-i 40, 70 W HT	2.73 A	60.9 A	15 A	ca. 20 A	kaum almost none
EC-i 52, 180 W HT	6.11 A	225 A	30 A	ca. 60 A	almost none

Table Comparison of the nominal current and the startup current with the maximum current of matching controllers. It also specifies the current at which a significant deviation in the torque constant was observed.

Practical considerations and summary

How important are saturation effects in reality? All affected motors have a very flat gradient. Accordingly, their stall torque is very high compared to the nominal torque. Reasonable amounts of overload torque do not exceed the nominal torque by more than factor five. In addition, peak torques are frequently limited by the maximum currents of the controller (e.g. maxon ESCON or EPOS).

The **Table** compares different current values of grooved multipole EC-i motors. We can see (cf. **Figure 4**): The startup currents are much higher than the maximum currents delivered by standard controllers. In real applications, the specified startup currents – and the corresponding stall torques – cannot be reached. However, the maximum currents from the controller may still severely overload the motors. Saturation only becomes a significant effect at currents and torques in excess of what is reasonable.

What can we learn from this? Most applications do not supply enough current to get even close to creating a saturation problem. Saturation is not a significant problem unless you have a power supply and controller capable of delivering these large currents. Whether or not the motor likes to operate under such a high overload is a different question.

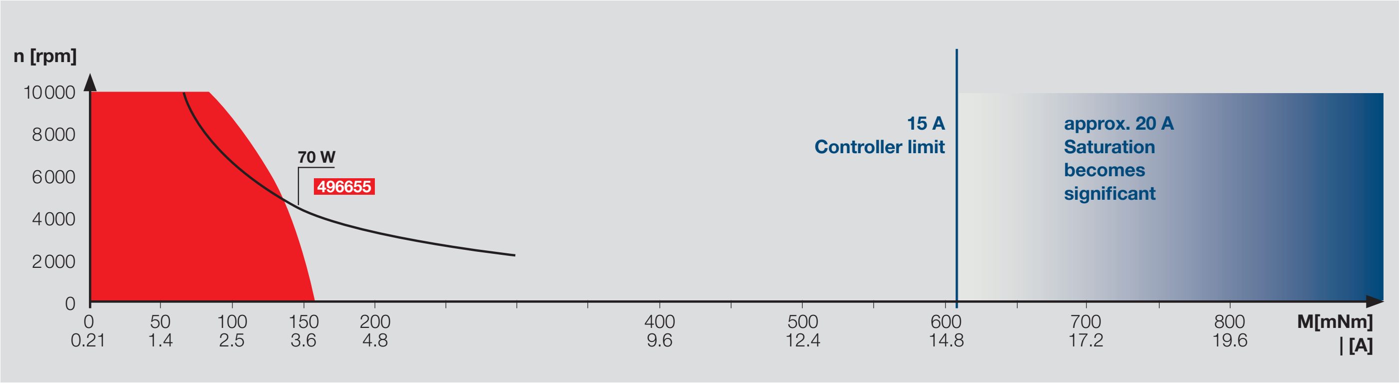


Figure 4 Expanded operating range diagram for EC-i 40, 70W High Torque (the third motor in table 2). Observe that in theory, the stall torque without saturation is about 60 A. That's about three times further to the right than the entire diagram reaches.

Solution from the POWDER KEG

Ceramic is an excellent material for reinforcing a gearhead. That's why maxon started its own powder injection molding unit 20 years ago. Some of the ceramic parts produced there are even used to enhance music lovers' listening experience.

The greatest pride of the department gets its own room. Andreas Philipp, head of maxon's powder injection molding department, beelines for the newly built walls, opens the door, and points at the one machine in the room – a laser device for hard-machining ceramic parts. This latest purchase is capable of cutting ceramics with an accuracy of 2 micrometers, Philipp explains. The machine is able to machine spring elements with a wall thickness of 17 micrometers while simultaneously performing precise measurements.

Ceramics for longer service life

Not many people know that maxon has its own injection molding department for ceramics and metals. After all, the company is known mostly for its micromotors. However, maxon also develops and produces controllers, encoders, and gearheads. Gearheads – or at least gearhead components like gears, axles, or planetary carriers – sometimes need to be reinforced for certain types of application. Ceramics are especially suited for these kinds of upgrades because the material is more resistant to chemicals, high temperatures, and wear than steel. Ceramic axles significantly extend a gearhead's service life, especially for drives used in start-stop operation. That's why, about twenty years ago, maxon began manufacturing its own ceramic parts for gearheads.

From a spindle to a pair of headphones

About 45 employees are currently working in the injection molding department, among them developers, application engineers, quality experts, and production employees. They belong to maxon's specialized gearhead production site in Sexau, southern Germany.
About half of the parts made by the department are used in maxon drives. Customers especially value ceramic spindles for linear drives because of their running characteristics and wear resistance. "We are the only company able to offer customers a motor, gearhead, and ceramic spindle from a single source," says production manager Walter Kuhn.
However, maxon doesn't make ceramic parts just for gearheads. Its products also include miniature jets for industrial automation, pawls for watches, and even headphone casings. The latter have been produced at maxon for years and have a positive effect on sound

quality, according to the vendor. Unlike metal casings, they are also scratch resistant and maintain their sheen for a long time.

The development and production of precision ceramic parts doesn't come cheap. The processes are complex, and hard machining requires diamond tools or, as mentioned above, laser machines. That's why ceramics are usually selected only for very specific requirements that can't be fulfilled using traditional materials. Or, as Andreas Philipp puts it: "Ceramics are used where all other materials have failed."

Two days in the furnace

The production process begins with a granulate, also known as feedstock. It contains a certain amount of adhesive so that the material can be pressed into molds in the first place. After the parts have left the injection molding machine, they can already be machined lightly. However, they don't yet have much in common with finished ceramic products. They are called green compacts, and they are brittle and much larger than the final product. A few more steps are required before they obtain the outstanding characteristics of industrial ceramics. First, the adhesive is removed in a chemical process. Next, they are sent to the furnace to sinter for two days at up to 1500 degrees Celsius. During this process, they shrink by up to 30 percent.

This loss of volume is hard to calculate, especially when the tolerances are in the micrometer range. That's why many parts are reworked after sintering.

Fast production of prototypes

The basic principles of powder injection molding have remained largely the same over the past few years. Some things have changed, however. According to Andreas Philipp, the processing of green compacts will be reduced. Instead, simple basic forms are molded and then machined with high-tech equipment until they have the perfect shape. "This way, customers get a prototype much earlier," says Andreas Philipp. Small batches can also be ready for shipping faster. What hasn't changed is the fascination with powder injection molding, which can be felt throughout the workforce. "Every job is different, nothing is routine. Ceramics are extremely challenging materials. That's what makes them so interesting."

Left: Production manager Walter Kuhn (left) and Andreas Philip, head of the powder injection molding department, standing next to injection molding machines and holding ceramic spindles. Right: Final polish to give the ceramic parts a smooth surface.

Left: Production manager Walter Kuhn (left) and Andreas Philip, head of the powder injection molding department, standing next to injection molding machines and holding ceramic spindles. Right: Final polish to give the ceramic parts a smooth surface.

Starring

DCX 22 DC motor with GP 30 HD gearhead

Encoder and brake Brushless EC 40 with GP 41 gearhead

RE 13 DC motor with GP 13 gearhead

→ ExoMars Rover, p. 7

EPOS4 Compact positioning controller

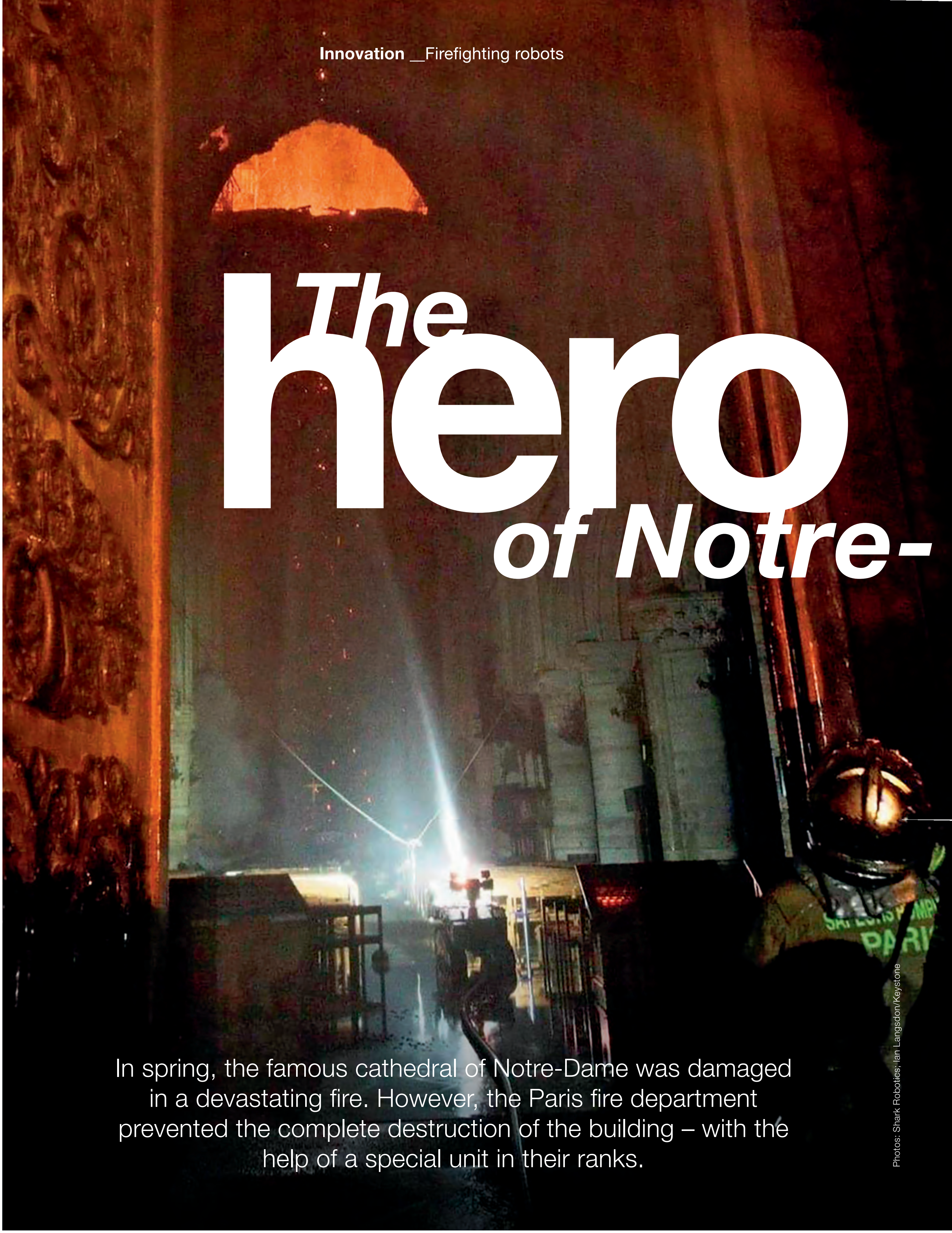
→ Camera robot, p. 24

Brushless EC motor EC-4pole 22

→ Soccer robot Sweaty, p. 4

Brushless EC flat motor EC 90 flat

→ Exoskeleton, p. 30



The hero of Notre-

In spring, the famous cathedral of Notre-Dame was damaged in a devastating fire. However, the Paris fire department prevented the complete destruction of the building – with the help of a special unit in their ranks.

Photos: Shark Robotics; Ian Langsdon/Keystone

Colossus is about 1.6 m long, 78 cm wide and 76 cm tall. It weighs 500 kg empty.

Dame

April 15, 2019, 07:50 p.m.: In front of the eyes of an aghast public, the spire of Notre-Dame cathedral in Paris collapses. To firefighters, this isn't just a cultural tragedy: The collapse means that the structure of the church is further destabilized by the flames. From this point on, entering the cathedral to fight the fire from within is very dangerous. The incident commander decides to send the robot Colossus into the cathedral.

Colossus was built by the French company Shark Robotics. The company employs 20 people and builds high-tech robots to assist or even replace humans in especially dangerous environments. Their robots are capable of moving in rough terrain. Equipped with an articulated arm, they assist firefighters or help with defusing explosives or removing other dangerous objects.

A modular system as a recipe for success

Colossus was developed in collaboration with the Paris fire department. It's not just suitable for fighting fires, but also for rescuing people after the collapse of a building, or for removing biohazards. Since the tasks vary so much, Shark Robotics decided to use a modular design. A base unit is equipped with tools suitable for the mission.

In addition to a fire hose, the robot can be equipped with a 360° pivoting HD camera, for example. The robot can also be equipped with sensors that measure parameters like temperature or radiation exposure and detect the presence of toxic substances. Colossus can also take point, carrying a smoke extractor to make a seat of fire accessible to human firefighters. The gripper arm enables it to clear a path into an area. Not least, Colossus can be equipped with a stretcher, a rescue cage, or a ram. These applications put high demands on the quality and resilience of the materials. That's why Colossus is completely made of steel and aluminum alloys that are also used in aerospace applications. Two 4,000 W motors and six batteries make sure that it is able to work continuously for up to twelve hours. It is completely sealed against dust and water and resists powerful heat radiation.

3,000 liters of water per minute

During the fire of Notre-Dame, the fire hose of the robot was used to keep the inner walls of the church and the structural elements of the building wet and prevent the fire from spreading. Via a supply hose, the robot was provided with almost 3,000 liters of water per minute – without the slightest danger to human personnel. Colossus is operated via a remote-control module with a display.

Designing a robot like this is a technological challenge. For this reason, Shark Robotics contacted mdp – maxon France. For the gripper arms of the robot, the designers were in search of motors that are compact, powerful, and efficient. "Our robots need highly resilient motors that are suitable for extreme operating conditions," says Jean-Jacques Topalian, managing director of Shark Robotics for R&D. "The decision to use maxon was an easy one for us: The company has an excellent track record, and its motors have already proven themselves in hostile environments."

Shark Robotics currently uses 19 different maxon products and obtains the motors directly from the drive specialist's website. Oh, since we mentioned hostile environments: The same electric motors are built into the European rover that will start roaming planet Mars in 2021.

Finished work?

Text Stefan Roschi

Routine jobs will soon be a thing of the past. Robots and AI will be taking over. At least, this is what most futurologists agree on. Sounds great if you're a robotics specialist or a programmer, but less great if you're a person with a routine job. What are people going to do with their lives? Paint? Or start a vegetable garden?
Retrain, adapt, develop, says one half of the experts. The story repeats with every industrial revolution: Old jobs vanish, new ones emerge. From the village blacksmith to the assembly line worker: It's always been this way. No need to panic.
Then there's the other half, who think that digitization can't be compared to other industrial revolutions because the pace and extent of the change are much greater. Not just routine jobs are being automated, but also professions that used to require a high level of education: lawyers, doctors, journalists. Some news articles are already being written by programs (even though this text was still done by hand). While there will be new jobs, there won't be enough for everybody. Most people will be working creatively or in charity – maybe supported by a basic income from the government.
One way or the other, most researchers believe that our concept of work will need to change completely in the coming decades. Fixed working hours, permanent jobs, and time keeping will vanish – as will the boundary between one's job and personal life. Our work will no longer be measured quantitatively. It's much more important that we contribute to the group – whatever that may ultimately mean.
"Adapt and change!" is the battle cry from the Darwinian corner. The future is digital. If we're not technicians yet, then should quickly buy a beginner's programming set from Lego – at least for our kids. For good measure, let's also take an online class on how to make a vegetable garden.

Illustration: iStock/ilyaliren

Contest

How many people work in maxon's powder injection molding department?

Win one of three outdoor solar chargers made by Goal Zero.

E-mail your answer to:
driven@maxongroup.com

The deadline for participation is February 28, 2020
Winners will be notified. maxon employees are not eligible to participate.
There will not be any correspondence in regard to the contest. All decisions are final.

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www.drive.tech

Why not take a look at our blog?

The maxon corporate blog **www.drive.tech** has many exciting reports, videos, and technical articles in which maxon experts offer their knowledge. Get excited, learn new things, and discuss with our bloggers.

Take this article about a robotic precision coffee maker, for example.

Sugar coating

It's one of the last production steps before rotor and stator become a brushed DC motor: A robot covers the rotors with a thermoset material that fulfills several roles. It transfers power between the winding and shaft, acts as an insulating material, and protects against external influences.