The maxon motor **magazine**

driven

Invisible daily helpers

Drive systems accompany us around the clock

A great job: Female engineers talk shop

A great guy: Looking for Roboy

Editorial

Drives in everyday life: **invisible helpers**

Eugen Elmiger, CEO, maxon motor ag

Many engineers encounter precision drive system in their jobs – and perhaps you do too. But even if you are not an engineer, you come across our DC motors, gearheads, and controllers on a daily basis.
For example, in public transport like trains, buses or planes. Even when you get into an elevator, hidden drives open and close the doors. These invisible helpers seldom are noticed, yet they have become of utmost importance in our everyday activities.

The current edition of driven highlights many interesting applications from day-to-day life. We also show what the renowned Roboy robot has been up to the past few years. And we spoke to female maxon engineers about their experiences and impressions in a work environment dominated by men.

Happy reading!

20.5

meters per second. The world's fastest passenger elevators can be found in the Shanghai Tower. With 632 meters, this skyscraper is the world's second tallest building, and its lookout platform at 561 meters is the highest in the world. The platform is served by three express elevators that move at an incredible speed of 20.5 meters per second. By the way, there is a total of 106 elevators in the building. maxon products often ride in elevators – invisibly. Our high-precision drive systems open and close the doors. Would you like to learn more about our fast drive systems? We look forward to hearing about your projects and are happy to support them with our knowledge and our products. Contact us: **contact.maxonmotor.com**

Photos: NASA, maxon motor ag

Mars rover

Once again, NASA relies on maxon technology

maxon motor is on board again for NASA's fifth Mars rover mission. The Swiss drive specialist is delivering brushless flat motors to the Jet Propulsion Laboratory (JPL), which builds the Mars 2020 rover for NASA.

Swiss-made motors in the sample caching system
The maxon drives are being used for mission-critical tasks. The plan is for the rover to take dozens of soil samples, seal them in containers, and place them in cache locations on the ground, where a future mission may retrieve and return them to Earth. Nine BLDC motors from Switzerland are responsible for the rover's handling of the samples. The drives can be found in the sample caching system, including the end-effector (sample tube holder). The sample handling arm moves the sample containers from station to station within the sampling system. Additional motors are used to assist with obtaining the samples and seal the containers.

Close collaboration with JPL
For this project, maxon motor supplies brushless flat motors from the standard range (EC 32 flat and EC 20 flat combined with a GP 22 HD planetary gearhead). The drives were modified specifically for the Mars mission in close collaboration with JPL. They need to survive a dynamic entry, descent, and landing, as well as the harsh daily conditions on Mars with sandstorms and temperatures ranging from –130 to +70 degrees Celsius.

Switzerland

maxon builds new Innovation Center

Drive specialist maxon motor is investing about CHF 30 million in the expansion of its headquarters in Switzerland. The company is erecting a new building, the Innovation Center. Construction has already begun and will be completed in summer 2018. The six-floor building will be the home of the expanded medical technology department, including production facilities with several clean rooms. Tiny micro drives for insulin pumps, medication dosage systems, or surgical robots will be made here.
The Innovation Center will also provide additional space for the company's research and development of groundbreaking drive systems and controllers. The new building at the headquarters will offer space for 350 employees. More than 2400 people work at maxon worldwide.

The Innovation Center, which will house the Medical department, is being built at the Swiss headquarters of maxon motor in Sachseln.

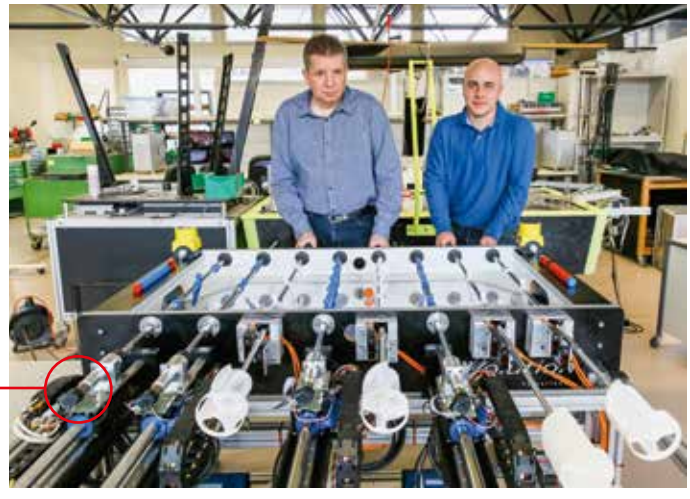
Robotic

Table soccer robot beats human players

The robot locates the ball by means of a camera installed below the transparent surface of the soccer table.

At the Swiss Federal Institute of Technology in Lausanne (EPFL), students are playing table soccer for more than just fun: They are building a robot that operates all four rods of the soccer table and plays autonomously. The project has been continuously improved by bachelor and master students for several years. The robot is now faster, more precise, and more powerful than ever before. It is so good that it can even beat human players – with a simple tactic: It locates the ball, stops it, and shoots at the goal. The soccer table has a transparent playing surface so that the computer always knows where the ball is. A camera takes 300 images per second that are immediately evaluated. The evaluation data is used to control the rods, which are powered by fast motors. The EPFL students are using four brushless maxon DC motors with gearheads and motor controllers. They are planning to make the robot even better by teaching it to play strategically. They want it to analyze the position of the opponent's players, find gaps in the defense, and predict the ball's trajectory. The engineers are also dreaming of a robots-only tournament.

maxon EC-4pole
Ø 22 mm, 120 W, brushless



Photos: EPFL, maxon motor ag

NEW PRODUCTS

ENX EASY

The first steam-sterilizable encoder in the world

With the ENX EASY, maxon motor is offering a sterilizable encoder for drive solutions for the first time. It is available in an incremental (1024 counts) and absolute version (4096 steps), both designed for 1000 autoclave cycles. As of now, the ENX EASY can be ordered online in two sizes, which can be combined with matching BLDC motors and planetary gearheads. The encoder can be integrated into the brushless drives ECX 13 and ECX 16 SPEED without any increase in length. With the addition of a GPX 13 or GPX 16 SPEED gearhead, customers receive a fully sterilizable drive combination that opens up an entire new range of possibilities in medical technology. Its compact and robust design is ideal especially for power tools. The encoder also makes accurate positioning possible, improving motor control at low speeds.

ENX EASY 13
sterilizable

Brushless DC motor ECX 16 SPEED, with GPX 16 SPEED planetary gearhead and ENX EASY encoder.

EPOS4 Compact 50/5

EPOS4

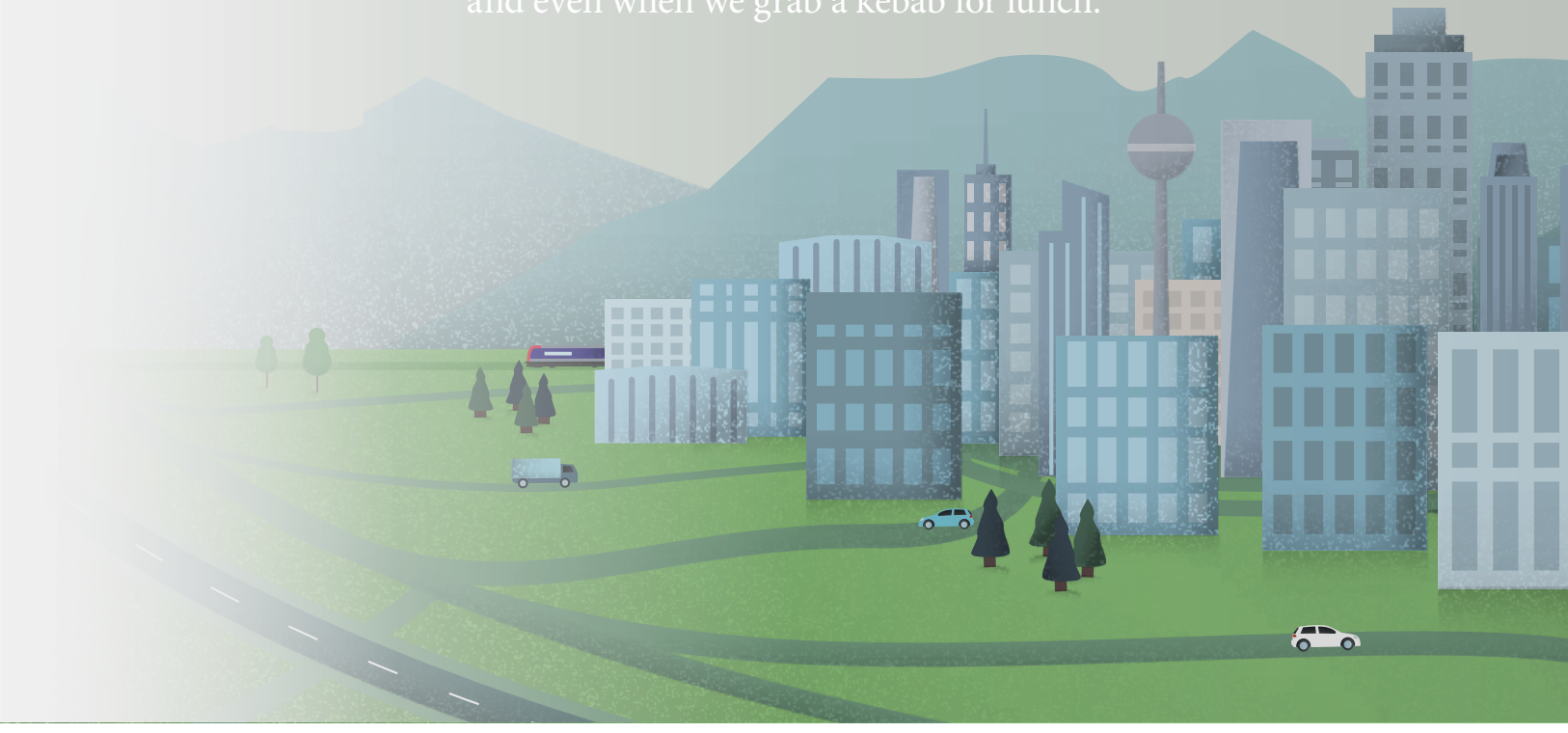
Compact positioning controller in metal housing

The EPOS4 positioning controller from maxon motor is now also available in a robust metal housing. For the time being, this applies only to the 50V/5A version. Other models will be added however. The housing of the EPOS4 is equipped with card slots for expansion modules with Ethernet-based communication interfaces (e.g. EtherCAT or absolute rotary encoders). With this design, maxon stays true to the successful modular concept of this controller series, which was introduced to the market a year ago. EPOS4 controllers are suitable for controlling both brushed and brushless DC motors. They stand out for their high power density and excellent value for money. A range of additional services is provided to the customers free of charge, for example an intuitive user interface, libraries, and many application examples.

Illustration: Pia Bubles

Extraordinarily commonplace

Although we rarely notice them, electrical drives are everywhere around us – at home, on our commute, at work, and even when we grab a kebab for lunch.



At home

It is six o'clock; the alarm rings. Outside, a new dawn breaks. The window shades of the family home open automatically, powered by a drive system. One by one, the members of the Mayberg family join the others at the breakfast table. Mike (8) and his sister Mia (4) are eating their cereal. Their parents Max and Marissa browse the newspaper and plan their day while their household robot makes coffee. Marissa is a design engineer in the automotive industry and works part-time, 3 days per week. Her husband Max is a dentist. The family lives in a modern house in the suburbs.

Blinds

Today, it is no longer necessary to open or close window shades manually. Actuators now do this job. Blinds open and close at the press of a button, or triggered by a sensor. This kind of application often uses brushless flat motors. Their compact size makes them well-suited for the task, and they have the necessary torque.

DCX 22 S
Ø 12 mm, 9 W,
precious metal brushes

Shower system

Marissa Mayberg loves to take a relaxing shower in the morning. She uses an innovative massage brush to stimulate blood circulation. It is made by the Swiss company Aglaja, battery powered, and can be installed in almost any shower. The brushes rotate, adapt to the body, and can be adjusted horizontally and vertically by means of a remote control. It is even possible to configure personalized massage programs. The brush rotation and the automatic height adjustment are each handled by a DC motor with a planetary gearhead.

Photos: Aglaja, Leica, Hermann, Aldebaran, Starship Technologies, Kronos, maxon motor ag, Illustration: Pia Bublies

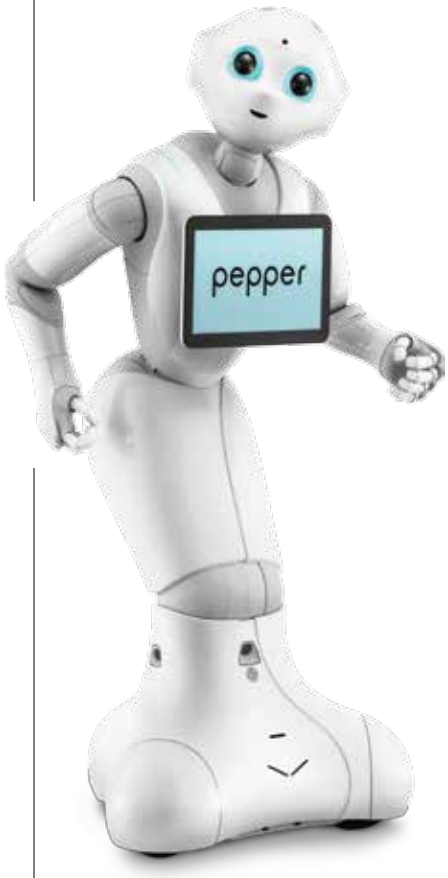
Digital cameras

Digital SLR cameras are able deliver extremely sharp photos. Besides the skill of the photographer, the technology of the camera and the lenses also plays a key role. The central shutter in the lens is a vital component for creating high-end photos. It is triggered by springs that are tensioned by a very small motor-gearhead unit.

maxon A-max 12
Ø 12 mm, 0.75 W,
precious metal brushes

Model railroad

For model train enthusiasts, every detail counts. Everything has to look precisely like the original – just on a scale of 1:45. It therefore takes several weeks before a gauge 0 locomotive is assembled and ready to take to the tracks. Then it has to do its job reliably. In their basement, the Maybergs have a model environment that is accurate down to the last detail. On the weekends, Max and his son Mike run their trains on an interval schedule – driven by reliable DC motors that are easy to control and powerful, yet pleasantly silent.



Social robots

Long gone are the times when robots did only chores. Social robots such as Pepper not only recognize human gestures and words, but also respond to them. When Mike and Mia are feeling down, Pepper animates them to dance and sing. The robot also helps the kids with their studies. The communicative robot is equipped with several brushless DC motors.

Delivery robots

Packages, pizza, toothpaste, milk and eggs, delivered to your doorstep by robots – this will soon be reality. In the near future, robotic vehicles will autonomously deliver packages when the customer desires – around the clock. A start-up from Estonia is already operating several robots across the world as a test project. Their wheels are driven by maxon components.

Record players

Over the years, Marissa and Max have accumulated a remarkable record collection. She likes classical music, he prefers jazz. In the living room, they keep a top-shelf record player with high-quality components. This of course includes a quality motor. The steadier and more evenly a turntable spins, the better the sound. This is why many manufacturers of high-end record players use DC motors by maxon. DCX motors, which can also be configured online, are particularly popular.

Out and about

Max grabs his e-bike, puts Mia in the bike trailer, and cycles into town to do some shopping. He deftly moves through the narrow streets, unperturbed by the morning rush hour. Marissa drives Mike to school in her car on her way to work.

Safely crossing the road

An aid installed at the traffic light makes it easy for blind people to determine whether the light is green or red. Underneath a little box, a pin powered by a maxon motor rotates when the light is green. Pedestrians can feel the status with their fingers.

Transporting patients

Special gurneys simplify patient transport. The gurneys can be adjusted electronically. This makes it very easy to move patients into and out of an ambulance. Each gurney is equipped with two customized brushed RE40 motors.

Bikedrive: More power for bicycles

The Mayberg family lives on a hillside. Last year, Max bought a new mountain bike. When he realized that cycling up the steep incline with Mia in the trailer took him to his limits, he got his bike retrofitted with a maxon Bikedrive, an electric drive with a powerful rear wheel motor, battery, and PowerGrip. Now the hill is no longer a problem.

Illustration: Pia Bublies

More safety in public

Surveillance cameras secure public places, historical buildings or airports. At busy intersections, traffic monitoring by video camera is indispensable. DC motors are usually behind the cameras' ability to swivel.

Less exhaust fumes from trucks

CO_2 emissions are an increasing burden on the environment. It is crucial that we find solutions to reduce these emissions. In many trucks, exhaust gas treatment for diesel motors is implemented with an injection pump driven by maxon products.

Wind protection for convertibles

The morning is sunny and warm; Marissa has opened the top of her convertible. Automatic wind deflectors reduce the turbulence inside the car. This protection is activated by a customer-specific maxon drive system.

Craving for kebab

In the kebab shop at the corner, the vendor slices the freshly roasted meat off the spit with an electrical kebab knife – and again, maxon technology helps to make it work. The main requirement is heat resistance, but that is no problem for drive systems that run smoothly even on Mars.

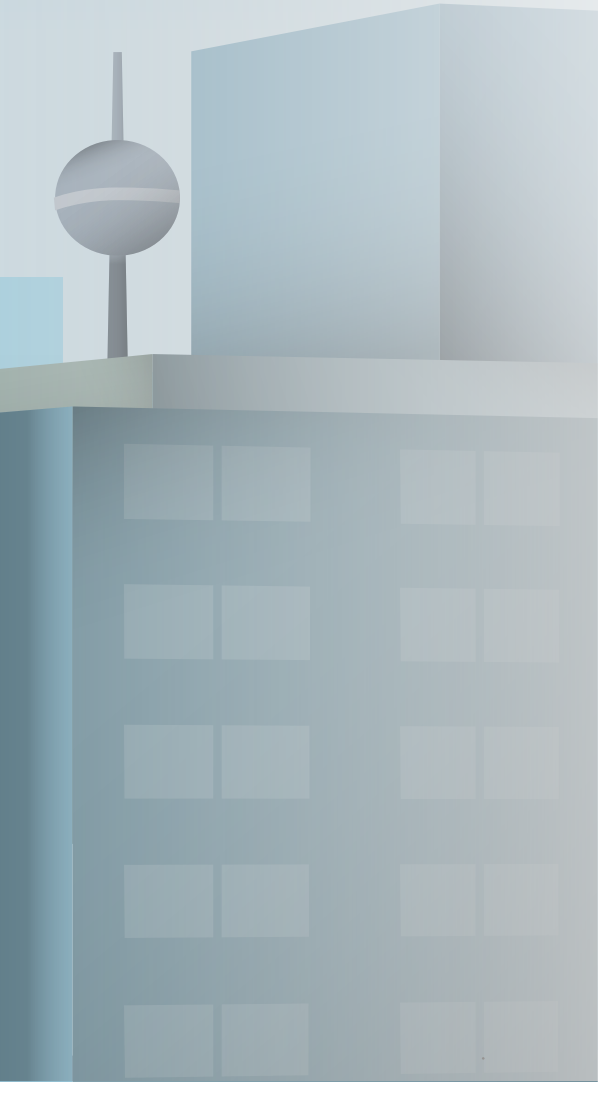
These feet were made for walking

Invisible yet vital: Prostheses make life a lot easier for many people, like this young woman who wears a prosthetic leg. The C-Leg from Ottobock contains high-precision motors that give the wearer more stability and add quality of life.

At work

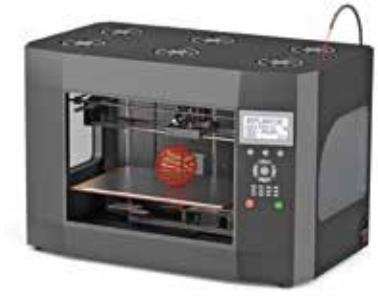
Marissa arrives at the building where she works and looks up. She is standing in front of a high-rise in the city center. Above her, on the eleventh floor, some of her colleagues have been at work since 7 a.m. – the early birds.

Marissa gets into the elevator that takes her up. The doors open smoothly, driven by small hidden motors. In the corridor, she takes out her ID card and holds it up to the reader terminal at the office entrance. The door unlocks with a soft noise. A new day at work is about to begin.



Safety systems

High-security locks can be found all over the world. Many companies use them to keep out unwanted guests. The doors can be opened with a keycard or fingerprint. The locking system uses tiny DC motors with diameters of 10 to 20 millimeters, combined with a gearhead or as direct drives. These drives have to perform reliably for thousands and thousands of operating cycles. Their ironless windings make them very energy efficient.



EC 60 flat
Ø 60 mm, 100 W, brushless

3D printers

As a design engineer, Marissa closely works with other specialists. Their new concepts have to be presented in an aesthetically pleasing and user-friendly form. In her R&D department, things always move fast. The engineers test different shapes and materials for each project. For some time now, Marissa has been using a 3D printer to quickly make prototypes of workpieces and covers. The printer creates layers of liquid or solid substances which are then hardened. It takes only a few hours until the shapes programmed on the computer are finished and ready for testing. The high-precision axis control in the printers is handled by brushless DC motors in combination with encoders and fast positioning controllers.

Elevators

The invisible door opener

Elevators are among the things in our daily lives that we take for granted. We press the button, the cab arrives, we enter and are taken to the desired floor quickly, safely, and reliably. Yet hidden from the passengers' eyes, there is quite a lot of technology involved in the elevator shaft, in the motor chamber, in the control box, and in the cab itself. A motor installed in the cab is responsible for opening and closing not only the door of the cabin, but also the door to the respective floor. The demands on this motor are high: It has to be small yet powerful, energy-saving, reliable, and, most importantly, intelligent.

Direct drive saves space

Together with the Swiss elevator manufacturer Schindler, maxon motor has developed a drive system that moves the doors and meets the listed requirements: The maxon Door Drive is available in two power levels. The more powerful version uses a belt drive and is able to move doors of up to 400 kilograms. The smaller and newer version is a direct drive. This saves space and is suitable for doors up to 120 kilograms.

Intelligent controller

This system solution consists of a brushless DC motor with a diameter of 90 millimeters and a MILE encoder integrated directly on the print. It is combined with a customer-specific positioning controller based on the EPOS2 series. Encased in a housing, the Door Drive can be mounted directly to the lift cab. And this is where its real work starts. There are many different types of elevators, with differently sized cabs, different materials and, depending on the country, different safety standards. After a calibration procedure, the controller of the Door Drive detects the size and weight of the doors, autonomously calculates the optimal parameters, and corrects them if necessary. This greatly simplifies the elevator technician's work. In just a few steps, the Door Drive configuration is complete, and the drive is ready for use.

Valuable data

The advantage of the flat motor's narrow design is that the cab can be made bigger. The drive also saves energy. Nevertheless, it delivers sufficient torque to smoothly move the doors. Last but not least, its integrated controller is intelligent. In continuous operation, it collects valuable data that the technicians can access at any time. This means that besides doing its main job, the drive also functions as an assistant behind the scenes.

Mechatronic systems

The complete drive solution for elevator doors consists of a brushless flat motor (90 mm diameter), an integrated MILE encoder and a customer-specific positioning controller based on the EPOS2 series.

Roboy moves similar to a human and responds to his environment. Now the next generation is arriving: Roboy 2.0.

Wanted!

He is 4 years old and 1.40 meters tall, with a rather large head. He speaks fluent English and German. However, he can't walk. He was last seen in Munich.

Roboy, the little robot: Born in 2013, the humanoid robot with the large round eyes made his first appearance at the "Robots on Tour" exhibition in Zurich. Since then, the 1.40 meters tall robot has been traveling the world to explain the concepts of artificial intelligence to humans, visiting Shanghai, Washington, Brussels, and many other places. He took part in about 70 events over the past few years, including the word's largest convention for artificial intelligence in Beijing (China). He visited the Human Brain Project, the EPFL, iCub at the IIT in Genoa, as well as the Biorobotics Lab in Pisa. The first "Hack Roboy Day" took place in December 2016. It is an event where students who usually didn't have anything to do with Roboy had the opportunity to get to know the robot from the technical side.

Roboy's permanent address is at the Technical University in Munich. An entire team of students is committed to the robot's further development and integration into the Human Brain Project of the European Union. The project's goal is to build robots that don't just move like people, but also think like us. To this end, scientists design and test new brain models for robots.

Roboy 2.0

His muscles are what makes Roboy so unique. In many ways, the robot resembles humans anatomically. Roboy uses a tendon-operated drive technology that gives him the ability to move like a human and react to his environment. The little robot was developed in the Artificial Intelligence Laboratory

(AI Lab) of the University of Zurich, which at the time was under the leadership of robotics guru Prof. Rolf Pfeifer. The laboratory does not exist any more, and the professor emigrated to Shanghai in 2014.

As a main project partner, maxon motor supplied various brushless DC drives that enable Roboy to move in a controlled manner. All in all, 48 maxon drive systems are installed in the robot. Roboy remains a development platform for humanoid robots. However, the robot will never be able to stand or walk, which is why a new large project is being planned.

Roboy 2.0 will be a complete relaunch of the little robot – and the new version will be able to stand. This will involve a new development of the legs and all components like software, drives, and more.

In 2018, the robot will be able to stand on his own legs and interact with us humans. Kelly Antonini, Roboy coordinator: "Roboy 2.0 will be better and smarter, and even more like a human."

Roboy excites people around the globe and showcases what artificial intelligence is capable of.

Roboy was…

… designed and built in 9 months
… born in Zurich in 2013
… designed as a tendon-operated robot
… created using a 3D printer (skeleton)
… equipped with 48 maxon motors

Roboy is…

… the first prototype in a whole series of robots
… a research platform for students
… a soft robot
… an ambassador for a new generation of robots
… the first humanoid robot in the Human Brain Project (HBP)

Roboy on Tour…

In the past few years, Roboy took part
… in 70 events worldwide: China (Shanghai and Beijing: IJCAI, the world's largest conference for artificial intelligence), USA (Washington DC: Swiss Embassy), Korea (Busan: ITU Telecom World 2014)
… at diverse exhibitions: Parma, Stuttgart, Munich, Nuremberg, Lucerne, Frankfurt, Lausanne, Genoa, Pisa, Brussels

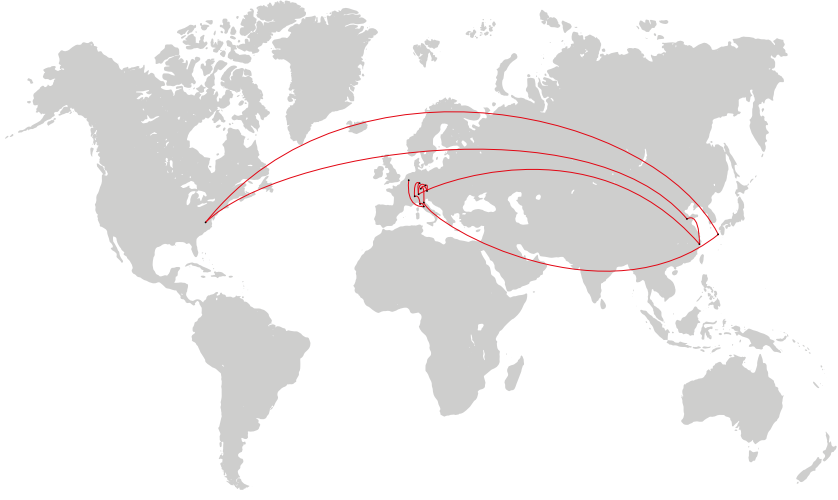


Photo: Devanthro Society

Young Engineers Program

drive.tech
by maxon motor

YEP

maxon supports engineers and start-ups

The drive specialist maxon motor has founded the Young Engineers Program (YEP) to support innovative projects with discounted drive systems and technical advice.

Who is it for?

Students of technical disciplines and start-ups that use electrical drives in their projects.

Benefits?

- Motors, gearheads, and controllers from maxon at reduced prices or even free of charge
- Technical support from the experts at maxon
- Promotion of the project on maxon channels (customer magazine, website, social media)

And now?

- For more information and a registration form please visit ***www.drive.tech***
- An expert panel at maxon motor decides whether the project will receive support and in what form.

On ***www.drive.tech,*** engineers can also find out about other YEP projects. The website includes case studies that describe different applications in drive technology and blogs written by maxon experts.


HB-IAE
Arbalète

Petra Bründler (left) is a development engineer at maxon motor. She primarily works on motor controllers.

Lynn Braunschweig is a project manager in maxon's aerospace unit, where she is in charge of Mars projects.

"The motor either turns, or it doesn't."

Women are still vastly outnumbered in engineering professions. Why is that? And what can be done about it? Two female maxon engineers talk about their experience and share some advice.

Petra Bründler (development engineer) and Lynn Braunschweig (technical project management) work in different units at the maxon motor headquarters in Switzerland. Their jobs are in no way connected. Yet there is something they have in common: They are both women working in a male dominated field.

How did you come to choose a technical profession?

Petra: I've always liked science, math, and logic. In my vocational training in electronics, I enjoyed the mix of classroom education and work at the company, and between mental and physical tasks.

Lynn: My mother is an emancipated, strong woman, a math teacher and good at making and fixing things. When I was little, I always wanted to be like her. It was she who introduced me to the world of technology. Later, I had to choose between becoming a lawyer or an engineer, and I decided to study mechanical engineering.

What fascinates you about your current jobs?

Lynn: I'm a project manager in the aerospace division and currently in charge of brushless flat motors that are used on Mars. Of course I wanted to become an astronaut when I was little, like so many children. Yet even though I'm not flying into space myself, at least my motors do.

Petra: As a developer of embedded software, I like to completely immerse myself into this abstract world of classes and objects. It ma kes me forget everything around me. But I also like the teamwork. We find the best solutions when we put different approaches and ideas together.

Lynn: For us, teamwork is also key. Every day I am dealing with a wide range of technical disciplines and processes and have to adjust to new situations. It's important to keep the big picture in mind while at the same time considering the details in the technical departments. Every day is different, and I keep learning new things.

Petra: Another thing that I like: In my job, I get lots of puzzles to solve, and usually I am rewarded with quick feedback: The motor either turns or it doesn't.

Women are still vastly outnumbered in engineering professions everywhere in the world. Does that affect you in any way in your everyday work?

Petra: As a woman in a technical profession, you stand out. People remember you. If anything, that's usually an advantage. It makes it easier to start a conversation and make new contacts.

Lynn: A few times I felt that as a woman, I wasn't taken as seriously as a male employee with similar experience and training. However, I didn't experience that as a negative thing.

Engineers Lynn Braunschweig (left) and Petra Bründler in the Swiss Museum of Transport next to a model of the ExoMars rover.

Quite the contrary: It motivated me to work harder and prove myself. At maxon, the share of women is relatively high. But still, we could use some more female engineers and project managers, or generally more women in leadership positions.

In your opinion, what is the problem that causes such few women to work in technical professions today?

Lynn: It's maybe just one aspect among many, but I feel like math is a little overrated when it comes to technical professions. It's a shame when young girls decide against a career in technology just because math isn't their strong point. In many jobs, logical, networked thinking is just as much of a requirement, if not more.

As a woman in a technical profession, you stand out. People remember you.

Petra: Maybe many girls don't even think about choosing a technical profession, as it isn't such an obvious thing to do. In the media you keep reading about unequal pay, worse career prospects, and inflexible working hours. I'm sure that scares some away. On the other hand I must say that I never felt any negative impact myself.

How do we get more girls and women excited about science and technology?

Petra: High-school teachers could suggest try-out job training in these fields to girls with a knack for technology. However, I can imagine that in the future, more women will be found in technical professions anyway due to the general blurring of gender roles. I hope that the current focus on this topic in the media is a first step in that direction.

My advice to women: Take a risk!

Lynn: Not just teachers could contribute more, but all parents with daughters. For example, they should involve them when doing maintenance on a motorbike or fixing something in their free time. Companies, on the other hand, have the responsibility to create modern structures with flexible hours, home office options, and part-time jobs.

Do you have any personal advice for women who are considering a career in technology?

Petra: If you like technology and are having fun with it, then there isn't much that can go wrong. Just do it! Women shouldn't be too intimidated by the fact that it's a male-dominated field. My personal experience hasn't been anything but positive.

Lynn: To any young woman, I can only recommend choosing a career in technology. Take a risk! I'm also convinced that the next generation of women will find it easier to combine their careers and personal lives.

Photos: Philipp Schmidli / maxon motor ag

RMS: Measuring thermal load

Motor heat is undesirable in any application – but how exactly does one calculate thermal load? Expert Urs Kafader of the maxon academy explains the basics.

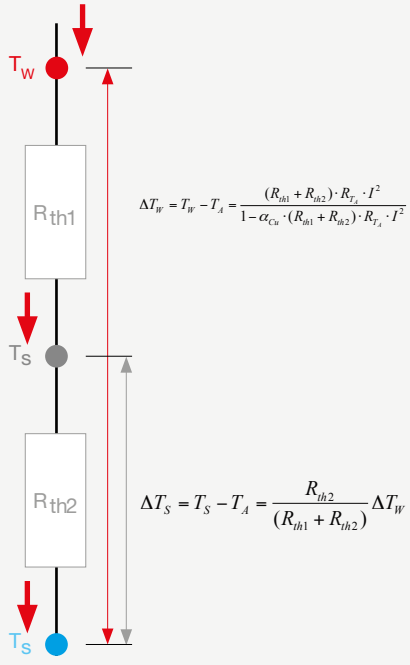


Figure 1

Estimating the increase of winding (TW) and housing temperature (TS) for continuous operation (neglecting heat from eddy current losses) in relation to ambient temperature (TA).

R_{th1} thermal resistance, winding-housing
R_{th2} thermal resistance, housing-environment (may be influenced by installation conditions)
R_{TA} electrical terminal resistance at the current ambient temperature
I current load
A_{Cu} temperature coefficient of the electrical resistance of copper (about 0.004 K-1)

The denominator in the first formula considers the temperature dependence of electrical resistance. In equation 2, the thermal resistances act as "voltage splitters" for temperature.

How hot does a motor get? For continuous operation under constant load, the temperature is easy to estimate. After a sufficient amount of time has passed, a thermal equilibrium sets in that can be calculated by means of the thermal resistances of the motor, R_{th1} and R_{th2} (see figure 1). First the heat build-up in the winding is calculated based on Joulean power loss, then the heat generation of the motor as a whole (the stator) is determined.

Load in cyclical operation

What are the calculations as per figure 1 for cyclical operation with a sequence of different current loads? Do the load cycle and the short breaks repeat multiple times? Will there be a thermal equilibrium eventually, and what will that temperature be?

The thermal load in cyclical operation is based on the effective value of the current or torque, which is independent of the current direction and takes into account the disproportionate heat build-up under high load. The value is referred to as RMS (root mean square) – a name that already describes the calculation perfectly: Take the root of the temporal mean of the summed squared loads. As a formula for current, this looks as follows:

$$I_{RMS} = \sqrt{\frac{(t_1 \cdot I_1^2) + (t_2 \cdot I_2^2) + (t_3 \cdot I_3^2) + (t_4 \cdot I_4^2) + \ldots}{t_{tot}}}$$

This RMS current value is inserted into the formula for calculating the winding heat in figure 1. You could also use the torques instead.

Example: Heat generation in the motor of a hand-held device

A sterilizable ECX SPEED 22 L motor (36 V winding) is to be installed in a medical hand-held device. The temperature should not increase by more than 20 °C over 10 cycles. Because surgeons holds the device in their hands, it should not become hotter than 40 °C on the outside.

These are the load specifications for the operating cycle:

Phase 1:	50 000 rpm,	10 mNm,	15 s on	5 s off
Phase 2:	1500 rpm,	25 mNm,	60 s on	5 s off
Phase 3:	600 rpm,	16 mNm,	30 s on	60 s off

Number of cycles: 10

Can the thermal requirements be fulfilled?

Let's begin with some considerations for the load duration. Including breaks, a cycle takes almost 3 minutes, or 10 cycles for half an hour. The motor has a thermal time constant of slightly over 8 minutes, so that the thermal equilibrium is almost reached at the end of 10 cycles. This allows us to apply the calculations for the temperature equilibrium for a worst-case evaluation. This is additionally justified by the fact that we are only concerned about the housing temperature, which changes only slowly based on the time constant mentioned above. At one minute, the longest load phase lasts only a fraction of the time constant so that the temperature fluctuations in the housing will be very small.

With regard to the required torques it should be mentioned that all values are significantly lower than the motor's nominal torque of about 33 mNm. The motor is therefore only under a light load, with a low expected heat build-up. The speed is high only during the initial 15 seconds, so that heat generation due to eddy currents is negligible.

Photos: maxon motor ag, Fotolia

If we let the motor run with the specified load cycle, then this is thermally equivalent to continuous operation with the RMS value (effective value) of the load. Inserting the torques into the formula results in:

$$M_{RMS} = \sqrt{\frac{(t_1 \cdot M_1^2) + (t_2 \cdot M_2^2) + (t_3 \cdot M_3^2) + (t_4 \cdot M_4^2) + (t_5 \cdot M_5^2) + (t_6 \cdot M_6^2)}{t_{tot}}}$$

$$\sqrt{\frac{15 \cdot 10^2 + 5 \cdot 0^2 + 60 \cdot 25^2 + 5 \cdot 0^2 + 30 \cdot 16^2 + 60 \cdot 0^2}{175}} = 16{,}3 \text{ mNm}$$

The motor has a torque constant of: 6.11 mNm/A, for an effective current load of: I = 16.3 mNm/6.11 mNm/A = 2.67 A.

When this value is inserted into the equation for the heat build-up of the winding in figure 1, the result is 15 Kelvin. Due to the ratio of thermal resistances, the housing heats up a little less than that, by about 14 Kelvin. For an ambient temperature of 20 °C, the resulting housing temperature remains slightly under 35 °C. Both values, heat generation and final temperature, are within permissible limits. This remains true even if one considers the temperature variations within a load cycle, roughly estimated at ±3 Kelvin.

maxon ECX Speed 22 L
Ø 22 mm, brushless, sterilizable

Urs Kafader has been supervising the technical training at maxon motor for 20 years. He runs training sessions on the technology and use of maxon products for employees at the maxon headquarters in Sachseln, for the international sales network, and for customers. He holds a Ph.D. in physics as well as an MBA in production science. He began his career at the Laboratory for Solid State Physics at the Swiss Federal Institute of Technology, Zurich.

With its vertical measuring method, PetroMarker has embarked on a new course for finding raw materials.

Hidden
resources

The surface of the ocean conceals many secrets – unexplored depths, grotesque life forms, and precious resources. To find these resources, a Norwegian company has developed a technology for scanning the bottom of the ocean in greater detail.

Photos: PetroMarker

PetroMarker is able to collect data at depths up to 5000 meters under the seabed. Measuring the electrical resistance of the bottom layers provides clues about the location and size of oil reservoirs.

At a depth of 1000 meters, it is ice cold and dark. No natural light penetrates here. At first, only silhouettes are discernible in the glare of the underwater robot's floodlights. Then strange, three-legged objects appear on the bottom of the ocean.

They are receiver stations for electromagnetic waves transmitted into the seafloor, to visualize its geological strata and find resource deposits.

When oil companies want to find out whether drilling at depth is worth the cost, they often rely on Controlled Source Electro Magnetic (CSEM) technology. This technology exploits the differences in the electrical resistance of different bottom layers to provide clues about the location and size of oil fields.

The CSEM technology uses a very strong power source to generate an electro-magnetic field, as well as several receivers to record the fields. These tripod receivers are placed on the sandy bottom and pick up electromagnetic signals that have been changed by the layers through which they passed.

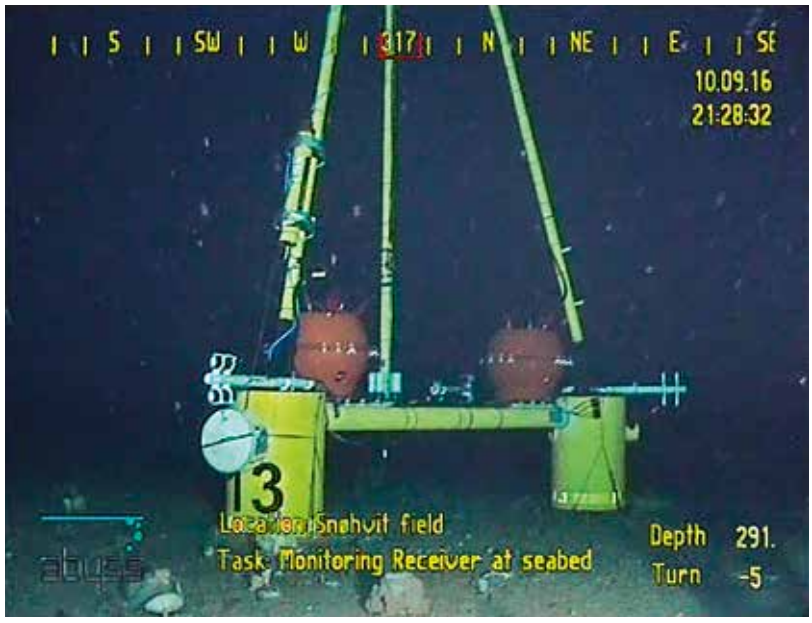
5000 meters below the seafloor

In 2016, the Norwegian company PetroMarker placed 25 new tripods in the North Sea. The special thing about this new measuring method is that, unlike other measuring methods, the company uses a vertical transmitter and receiver to find resources under the bottom. This enables a much more detailed resolution and data measurement up to 5000 meters under the seafloor, the company claims.

The tripods are about 4 meters high and made from a combination of glass fiber and special foams. Due to the sensitive electronics, metal parts cannot be used. This far below the surface, the pressure is extreme, and the salt water is aggressive.

Underwater drives for vertical alignment

A prerequisite for the exact capture of electromagnetic data is that the antennas are aligned perpendicular to the seafloor – or as close to perpendicular as possible, as the seafloor isn't always flat. To this end, the company has developed new receivers that enable a vertical alignment of the antennas at the center of the tripods with high precision. This is where the underwater drives from maxon motor come in. They are installed at the lower end



At the center of the tripods (receivers), the antennas are aligned as vertically as possible on the seabed.

of the receiver antenna to align it vertically as needed. The maxon drive solution excels through its compact design and low weight. The centerpiece of the oil-filled underwater drive system is a motor-gearhead combination, comprising a brushless DC motor (BLDC) and planetary gearhead.

The system is completed by a controller (EPOS) and a compensator. The units are encased in plastic to protect them from corrosion. Several modifications were required to meet the specifications for this application: The EC-i 40 motor and the GP 42 planetary gearhead are customized, and the compensator isn't off-the-shelf either. A dual seal, imitating typical submarine technology, ensures that the system is able to resist the enormous water pressure. The control electronics of the underwater drive are housed in a pressure-neutral glass ball that is able to resist the pressures of up to 600 bar – one of the challenges of this extreme application. Carsten Horn, Aquatic Solutions project manager at maxon motor Sexau: "This is an extremely interesting project where the new maxon underwater drives are used. The successful field trial of the tripods in the North Sea proves that maxon's technology works exceedingly well."

PetroMarker's successful trial shows: The maxon underwater drives work.

Small and ready **to conquer the world**

A Canadian company succeeded in building the world's smallest and most accurate industrial robot arms. Their first device is small enough to be held in one hand.

Photos: Mecademic

As so often, the story begins with a brave start-up. Mecademic was founded in 2013 by Jonathan Coulombe and Ilian Bonev. The two met at the ÉTS engineering school in Montreal – where Bonev is a professor – while Coulombe was finishing his Bachelor's degree in electrical engineering. Together, they developed an academic robot (dual-arm SCARA) for colleges and universities before taking a step further and reorienting Mecademic towards industry's needs. Their goal was to develop an industrial robot that is much smaller, more precise, and easier to operate than any of the existing models.

This six-axis robotic arm is only half the size of its predecessor as the world's smallest industrial robot. It can be programmed and operated via a computer.

Ultra-compact design

Two years later, Mecademic finally made it. Their six-axis robot arm, the Meca500, has a precision of 5 micrometers and is only half the size of a regular small industrial robot. It weighs less than five kilograms, with a base about the size of your palm, and has a payload of 500 grams. Most importantly however, the controller is fully integrated, which saves even more space and drastically simplifies integration. It only takes a 24 V power supply, a computer, and an Ethernet cable to program and operate the Meca500.

Creative design with flat motors

Jonathan Coulombe, Mecademic's CEO, is proud of the final product: "It was quite a challenge to fit all the components into such a small package." The drives also needed to be sufficiently small, while still being powerful and compliant with high quality standards. "They simply have to be the best in terms of precision and long service life. After all, they must run for several years in continuous operation and need no maintenance." That's why Mecademic decided to use brushless flat motors from maxon. These DC motors are renowned for their compact design and high torque. In the Meca500, they are combined with zero-backlash gearheads and high-resolution encoders for precise movements and durability.

Continuously improving

"Our goal is to create a new market for extremely compact industrial robots that compete with fixed automation solutions. The Meca500 can be used as a standard component for machine builders, as in a laser machine or a medical device, or in assembly lines." says Ilian Bonev. The Meca500 is only the starting point for a whole line of compact robots. "We want to offer the smallest and most precise robots for industrial users to pave the way for new products, applications, and discoveries." A second robot model is already in development.

In collaboration with Schunk, the young company also developed an electric gripper that is completely integrated with the Meca500 robotic arm. Mecademic is responsive to customers' demands, and firmware updates are given to clients based on the features they request. With these updates, the Meca500 will soon be able to function as a collaborative robot, with a function to prevent collisions (with an environment known in advance) and a zero gravity mode for hand guiding.

The drives need to be precise and durable to withstand continuous operation.

With the Meca500, various advanced and versatile applications are possible, from animal surgery to precision assembly for watchmaking and jewellery. Of course, the robot arm is also able to perform traditional tasks, such as pick-and-place and inspection, especially in the electronics and life science sectors.

Meca500 robots are already in use in Europe and North America, with many more to come.

Colossus with feet of analog technology – a reverse steam locomotive in the digital new world

Author: Michael Funk

What a steam locomotive looks like? Everybody knows that! There is a big boiler in front, followed by the cab and a tender. Even the digital new world isn't going to change that. Indeed, this bastion of smoking nostalgia can only be conquered by analog means…

The air is heavy with the smell of lubricant oil. I am strolling through the California State Railroad Museum in Sacramento, as a huge black monster appears before my eyes. Surrounded by a labyrinth of magnificent old locomotives, I admire the pioneers who completed the First Transcontinental Railroad in 1869, marveling at their achievements. However, there is something wrong with one of the machines.

Unobstructed tunnel vision

The locomotive answers to the name "Southern Pacific 4294" and was built in 1944. It has a reverse design, with the cab in front. The cramped control center of the venerable

Photos: Keystone / Jack Rice, Neil916, Michael Funk

machine can be reached via a narrow ladder. In the cab, an older gentleman awaits me. He used to ride this iron horse across the western United States. His name is Bill, and he volunteers at the museum in his retirement. Children love listening to the old dinosaur when he proudly explains about his cab-forward locomotive. He still knows every single one of the numerous levers and valves by heart.

Since their initial opening, the tracks of the Sierra Nevada were a nightmare for train drivers. Tunnels alternated with snowy overhangs, trapping the steam and smoke from the machine so that it ended up in the eyes of the crew instead of rising skywards. Just around the time when petroleum engines became usable for railways, somebody built a steam locomotive with the cab in front of the boiler, for unobstructed tunnel vision.

The reversal of cab and boiler – it was quite literally a revolution, but did it actually herald a new age? Bill laughs: "The real revolution came later, when they started using electric motors."

Even a brief tour of the museum leaves no doubt about what he means: The changed design of later locomotives, railway cars, and overhead lines is just too obvious.

What past revolution will I be talking about when I reach dinosaur status? Maybe serving robots, or my first model railway from a 3D printer?

An elevator takes me to the second floor. I watch the elevator doors as they open and close, then repeat their mechatronical choreography shortly afterwards. We take this for granted. Along an endless skyline of locomotives and railway cars, I let my eyes pass over 150 years of technological history. A surveillance camera mimics my scan of the room, just as if it wanted to beat me to a selfie. What for? Who steals a multi-ton piece of equipment from a railway depot turned museum? Industrial espionage? In the digital new world maybe, but not here, in this nostalgic Eldorado of railway romantics!

Between rows of railway cars, Bill explains the history of workplace health and safety to a visitor. In the early days, for example with the postal service trains of the 1860s, the massive, rolling cars were hitched manually. If you weren't quick enough, you might be one hand short. Today we have strict rules, artificial joints, and high-tech prostheses. Accidents drive progress. However, who's going to regulate or insure packet delivery drones – before accidents happen?

So many things that we take for granted were once hard fought for. That's why the stories that go a long way back are the ones that keep driving innovation in the future. The digital new world remains a colossus with feet of analog technology. I hope that people will remember this when a robot takes Bill's place one day...

Michael Funk (31) is an academian and PhD candidate, essayist, writer, and musician. He studied philosophy, German, and history at TU Dresden. From 2007 to 2015, he worked as a researcher and lecturer at TU Dresden's faculty of technological philosophy, before accepting an assistant professorship at the University of Vienna in 2016. Among other topics, his research covers the impact on society of social robotics, drones, and synthetic biology.

An inspiration to think, not only for Michael Funk: the reverse steam locomotive "Southern Pacific" built in 1944.

Roboy: Two images, one difference!

Compare the two images and find the one difference!
E-mail your answer to
driven@maxonmotor.com.

And win a Cozmo robot – currently the robot with the most advanced artificial intelligence and a personality that develops independently, according to the manufacturer. The small intelligent robot is controlled via mobile phone (iOS, Android).

The deadline for participation is June 30, 2017. Employees of maxon motor are not eligible to participate. There will not be any correspondence in regard to the contest. All decisions are final.

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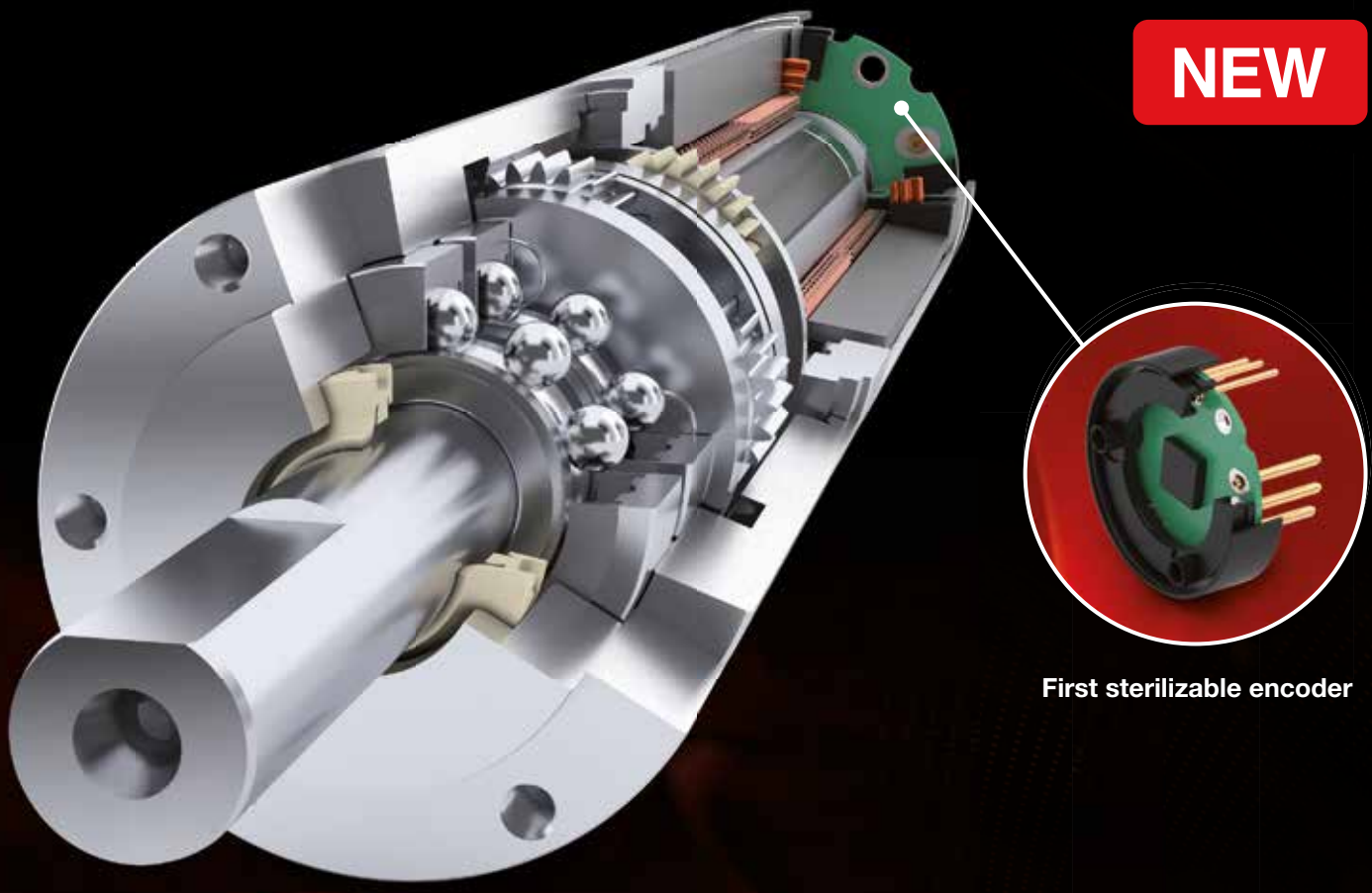

First sterilizable encoder

The first sterilizable drive system.

maxon is launching a sterilizable encoder, offering its customers a complete system with high speed BLDC motor, gearhead and encoder that survives more than 1000 autoclave cycles.

Advantages of a sterilizable drive sytem

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maxon GPX gearhead	Transmission of high torques and speeds. Up to 90% efficiency.
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