

The maxon motor magazine

# driven

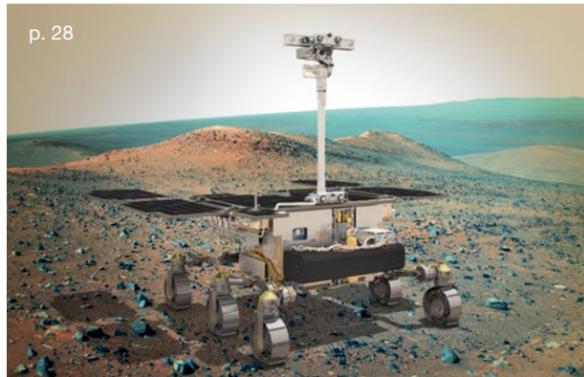
**This is the future!**  
How startups will change the world.



RoboCup 2017: Motors rule the match



Electric power for fresh vegetables



Photos: Hochschule Offenburg, KitePower, ETH Zürich, maxon motor ag, Philipp Schmidli, ESA, Athlas

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# Let us change the world!



Eugen Elmiger, CEO maxon motor ag

**M**any of those who decide to become engineers or technicians want to improve the world through technology. There is no lack of creative ideas and startups are frequently ideal platforms for implementing these ideas. If all fits together, creativity merges with motivation and hard work in these small and flexible companies. Success then becomes only a matter of time.

In this edition of *driven*, we present several startups that make a positive contribution to our society with innovative approaches. There are some surprises waiting for you!

We also take you on a drive through the vineyards around Lausanne with a cargo bike – powered by the maxon Bikedrive. You'll learn more about soccer-playing robots and about designing complex drive systems.

Happy reading!

# 41,329

In 2016, there were 41,329 **new entries** into the Swiss commercial register. That's 0.7 percent more than the previous year – an uptrend is noticeable. According to Startups.ch, low interest rates and a robust economy are among the reasons for the large amount of startups. maxon motor supports startups and young engineers all over the world with the Young Engineers Program (YEP). maxon created the program to promote innovative projects – with discounted drive systems and technical advice. For more information and a registration form, please visit [www.drive.tech](http://www.drive.tech)



Switzerland

## The Cybathlon will return in 2020

The Cybathlon wasn't a one-off event. This summer, the ETH Zurich announced that it is organizing another installment of the contest, which will take place in 2020, in the Swiss Arena in Zurich. Once again, people with physical disabilities will use mechatronic aids to compete against each other on an obstacle course. There will be six disciplines again: prosthetic arms, prosthetic legs, exoskeletons, motorized wheelchairs, bicycle races with electric muscle stimulation, and virtual racing using thought control. This time, the event will take place over two days: On May 2 and 3, 2020. On the first day, there will be qualification runs, the second day will consist of the finals.

The first installment of the Cybathlon, in 2016, was a huge success. Around 4,600 spectators cheered for 56 teams and the event was broadcast live on TV. The idea behind the Cybathlon is to unite affected people, medical experts and technicians, to increase public awareness and to strengthen research in the field.



Lucerne University of Applied Sciences and Arts

## maxon is founding an innovation lab

maxon motor enters a partnership with the Lucerne University of Applied Sciences and Arts. As part of this endeavor, a maxon lab will be set up on the campus. The university contributes its R&D expertise in the fields of mechatronics, robotics and embedded systems, while maxon motor has practical experience and provides new motors and components. On this basis, the maxon lab aims to develop intelligent mechatronic systems.

Ulrich Claessen, head of R&D at maxon motor, is looking forward to the cooperation: "More than half of our graduate engineers studied in Lucerne." And the maxon headquarters in Obwalden will continue to need specialists in future. The maxon lab is to be a first contact point for budding engineers. Simultaneously, Claessen hopes that there will be interesting projects and innovations in the fields of mechatronics, robotics and embedded systems.

Photos: iStock/RichVintage, Philipp Schmidli/maxon motor ag



Formula Student

## Swiss racing team wins with fastest driverless car

In the Formula Student, student teams from all over Europe compete with their electrically driven race cars. The Academic Motorsports Association of Zurich (AMZ) has taken part since 2006 and has already enjoyed several victories. And this summer, the team had another large success to celebrate: It taught "flüela", the association's race car of the 2015 season, to drive autonomously and won the overall championship in the new Driverless category of the Formula Student Germany.

"Since this was the first time that the race took place in this form, it was hard to estimate at what level of development we were," says Fabio Meier, AMZ project manager. The team worked hard the whole year to prepare for this event. The result was very satisfactory. The team reached the podium in all eight disciplines and won five. That earned them the overall first place in the Driverless category. Yet the race was all but uneventful. Rain and a wet track surface caused problems for the sensors that were responsible for detecting the track. The young AMZ engineers were able to quickly and accurately react to this challenge.

The team continues to work on optimizing automatic driving, with the support of maxon motor. Next year, they want to compete again.

The AMZ team after the victory in the Driverless category of the Formula Student.



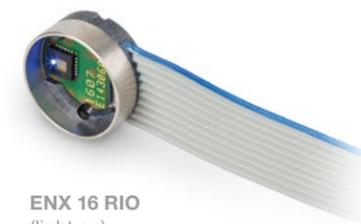
Photos: Formula Student Germany/Elena Schütz, maxon motor ag

## NEW PRODUCTS

Encoder ENX 16 RIO

### For high-precision positioning

With the new ENX 16 RIO optical encoder, maxon motor offers a high-resolution optical encoder that is only 16 mm big. With a resolution of up to 65,500 counts per turn, it is ideal for the precise position and velocity control of DC motors. Additionally, maxon equipped the ENX 16 RIO with a robust and dust-protected housing. The encoder can be combined with the new, brushless EC-i 30 motors and with the configurable, brushed DCX drives, among others. Its counts per turn and electrical interface can be configured specifically. The customer can simply combine and configure the components online – in the maxon online shop. <http://shop.maxonmotor.com>



ENX 16 RIO  
(light on)



The brushed DC motor DCX 16S  
with ENX 16 RIO encoder.



EPOS4 EtherCAT card

EPOS4

### Compact motion controller now also with EtherCAT

The modular concept makes it possible to now also integrate EPOS4 positioning controllers by maxon motor into EtherCAT networks. The EtherCAT card developed for this purpose can be combined with the EPOS4 controllers in a housing, as well as with all EPOS4 modules. EPOS4 Compact designs with EtherCAT versions will follow at a later stage. This expansion for the world of Ethernet-based communication protocols further expands the area of application for the positioning controller – for example to applications where short cycle times are important in synchronized multi-axis systems. 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 that facilitate easy installation is provided to the customers free of charge: for example an intuitive user interface, libraries, and many application examples.



# We create a better world

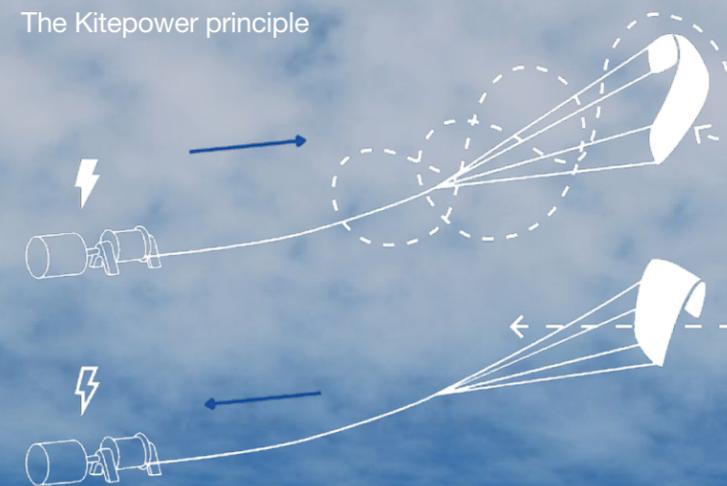
Our society needs new ideas and technologies to solve the various problems we face in everyday life. Here small startups play an important role – and show what it means to think outside the box.

Composing: Peter Kruppa/Intel AG; Photo: Kitepower



# Clean energy from an altitude of 500 m

The Kitepower principle



The kite drives the generator by repeatedly pulling the cable upward.

Globally the number of wind turbines producing sustainable energy keeps growing. But there is also another, newer method to harvest wind energy. A Dutch team is currently changing an entire industry.

**J**ohannes Peschel loves kites. The passionate kitesurfer also sails the skies in his work, and has big plans: As co-founder and CEO of the startup Kitepower, he wants to turn the wind energy sector upside down – by producing electrical energy with kites.

The principle seems simple: The system for generating power consists of a generator on the ground that is connected directly to a cable winch. The kite keeps pulling the cable upward by flying a figure eight repeatedly and thus creating a strong tractive force. This continues up to a height of 500 m. Thereafter, the cable is retracted – a step that requires only little energy – and the entire procedure is repeated.

### Cooperation with the TU Delft

The idea is not new. The Delft University of Technology (TU Delft) in the Netherlands set up a team to research kite energy as early as 2004. The concept kept evolving over the years

and the group grew. But it took until 2016 for the startup Kitepower to be born from it. The company continues to have close relations with the TU Delft. In addition to the core team of ten people, there are always several students working on the project. “That helps us to tackle problems with an open mind and means we are always getting new viewpoints,” says Johannes Peschel.

### More green energy

The long history behind Kitepower helped the company to make a lot of progress in a short time. This summer, the team started up the first prototypes and tested them thoroughly. The first commercial version is scheduled for the end of 2018. It is an attractive alternative to diesel generators and even to wind turbines. The new system, including a 100 kW generator, is mobile and needs less construction material than wind turbines. Additionally, the Kitepower system can flexibly use

winds up to an altitude of 500 m. According to the developers, this makes the system twice as efficient as existing technologies.

Johannes Peschel wants to use his product to contribute to a better world: “The world population is now finally taking climate change seriously. And our solution aims at generating more green energy, by replacing coal and diesel generators. For example on islands, in secluded communities or in military camps.”

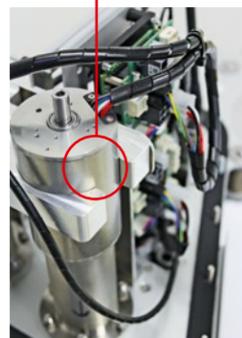
### Both sides profit from each other

Kitepower is developing its system in cooperation with several industrial companies, among them maxon motor. The company is co-developer and supplier of the important control unit for the steered kite, once more proving its skill as system specialist. The unit, which consists of 1000 unique parts, requires perfect interaction between the motor, gearhead and electronics. According to Dominik Frey, the responsible project manager at maxon’s Sexau location (Germany), it was quite a challenge to integrate the different sensors, transmitters, receivers and batteries. Additionally, extreme radial forces act on the gearhead. Therefore the bearings of the drives were reinforced. The products used include the new brushless EC-i 52 in combination with the GP 42 UP planetary gearhead and an encoder. The motor is frequently used in robotics, as it has a high torque and compact design.

Kitepower CEO Johannes Peschel says: “We are happy that maxon was able to fulfill all our requirements.” And he is positive about the future of the cooperation. “maxon as a global player and our company as agile startup can significantly profit from each other.”



maxon EC-i 52  
Ø 52 mm, 180 W,  
brushless



The steering system was developed by maxon motor in Germany and has been equipped with several drive components.



Johannes Peschel is CEO and co-founder of Kitepower. He studied computer science in Berlin, China and the Netherlands and is an enthusiastic kitesurfer himself. Johannes Peschel (gray jacket) and his team pose in front of the generator.



Photos: Kitepower, maxon motor ag



# The art of building a robot

Philip Norman used to be an architect and a painter. Then he made an invention that could prove to be a game-changer for the way robots are built in the future.

Philip Norman is originally from Canada. For many years, he worked as architect and landscape designer in France, before he became a robotics specialist and founded Ross Robotics.

Canada-born Philip Norman has always been fascinated by simplicity. As an architect, he preferred a minimalist style, and as a painter, he reduced forms to their essence. One day as he was watching his children play, he began to ponder the question why toys couldn't be made simpler – using modular parts.

Fascinated by the idea, he got hold of a CAD drawing program and sat down in front of his computer. "I was really enthusiastic and forgot everything around me," he recollects. Finally, one year later, Philip Norman concluded the development of a modular component and applied for a patent. At the patent office it became apparent that nothing comparable existed, no one had yet thought in this particular way.

Now all that was left to do, was to find a suitable area of application. "I thought of the toy industry at first, but that didn't work out. A friend then pointed me in the direction of robots. I knew very little about robotics

and had to teach myself a lot of things. But it quickly became apparent that this area offered great potential." Because today's robots are almost always developed and built for one particular purpose, their sensors and tools are permanently installed, with changes requiring a substantial cost and time investment. If anything breaks, the robot needs to be examined by an expert, which costs more time and money.

### Robots of various sizes

Philip Norman's fledgling company Ross Robotics follows a different philosophy. The robots have a modular design, with each element featuring a brushless flat motor from maxon and the EPOS4 positioning controller. "I needed a motor that is very compact and at the same time delivers high amounts of torque," says Philip Norman.

His modular components can be assembled into robots of various sizes. Sensors and

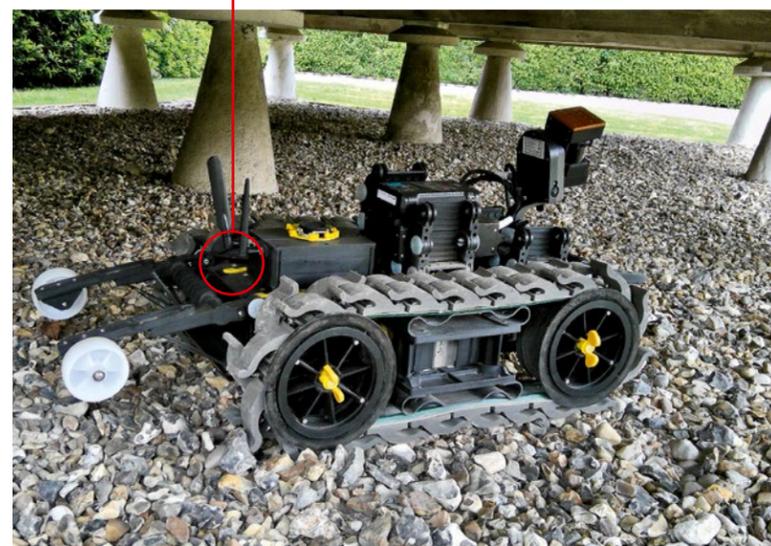
gripper arms can simply be attached and removed as needed. You don't even have to be a specialist to quickly and easily replace a defective part, which makes the robots extremely flexible and economical to operate. If the application changes, the device's modular design can be adapted to the new situation.

### Working at CERN

The startup sees great potential in the field of inspection robots. Several Ross Robotics models are already operating in this sector, including at the European Organization for Nuclear Research (CERN) in Meyrin, Switzerland, where one such robot is used in the particle accelerator. The models will soon be commercially available and are currently undergoing certification. Philip Norman is firmly convinced that his invention will change our understanding of robots. However, he wants his company to remain small enough to be able to continue focusing on research and development – there is much left that he would like to simplify.



maxon EC 45 flat  
Ø 45 mm, 70 W,  
brushless



Photos: Andrea Artz, maxon motor ag

The modular design of this robot from Ross Robotics makes it suitable for many different applications.

### Young Engineers Program

## Drive systems for startups and student projects

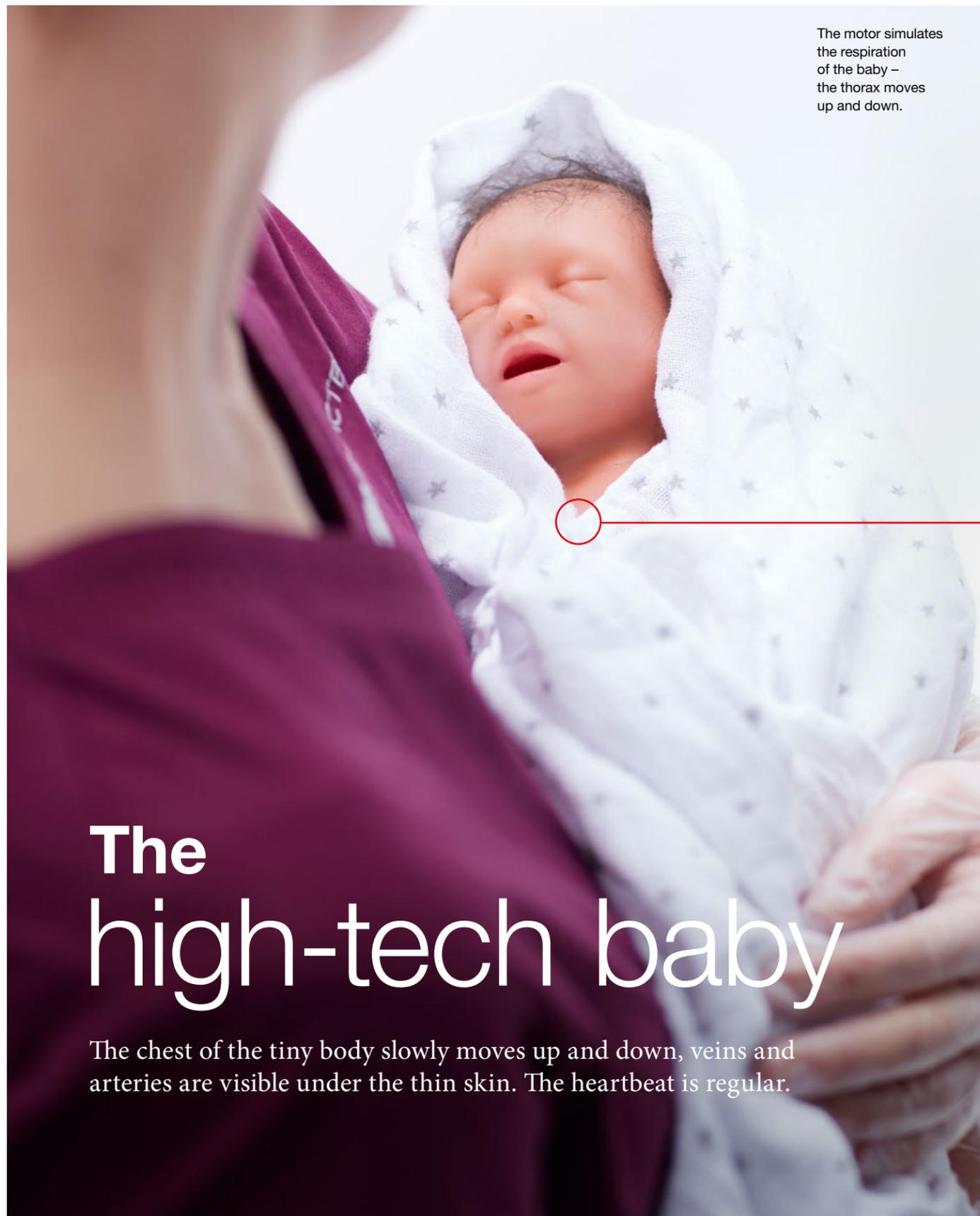
maxon motor has founded the Young Engineers Program (YEP) to support innovative projects with discounted drive systems and technical advice.

Small, innovative projects frequently face the same challenges: A lack of financial support and too little expertise in the relevant technical sectors. Any help is welcome. This motivated maxon motor to create the Young Engineers Program (YEP), with which the drive specialist supports young companies and student projects in the technical sciences. They can register for the program at [www.drive.tech](http://www.drive.tech) and, depending on the degree of support, are provided with motors, gearheads and controllers by maxon motor at reduced prices or even free of charge.

Stair climbing wheelchairs, electric race cars Several projects from all over the world have already been accepted to the program. These include the Swiss startup Scewo, which wants to introduce a stairclimbing wheelchair to the market. But there are also student teams that participate at the Formula Student with electric race cars they developed themselves. Or a team that wants to use drives of maxon motor to improve an open source rehabilitation robot.

**drive.tech**

For more information on YEP and a registration form, please visit [www.drive.tech](http://www.drive.tech)



The motor simulates the respiration of the baby – the thorax moves up and down.



maxon DCX 12 L  
Ø 12 mm, 2.5 W,  
precious metal brushes



**Dr. Jens-Christian Schwindt** is founder and CEO of SIMCharacters. He was born in 1973 in Hanau (Germany). After graduating in medicine in Frankfurt on the Main and Mainz, he went to the Children's Clinic of the University of Vienna to specialize as pediatrician.

Photos: SIMCharacters, maxon motor ag

# The high-tech baby

The chest of the tiny body slowly moves up and down, veins and arteries are visible under the thin skin. The heartbeat is regular.

**P**aul breathes on his own. 35 cm long, 1,000 g light. A preemie, born in the 27th week of the pregnancy. His father is Jens-Christian Schwindt, who worked as a pediatrician in the Division of Neonatology of the Vienna General Hospital for many years. In 2015, he gave up his position as senior physician to look after Paul full-time. Paul needs artificial respiration. Sometimes he even turns blue. But his main need is investors.

Because Paul is not a real baby – he is the smallest and most advanced high-end patient simulator in the world. He can be used to train various emergency situations that occur daily in hospitals that provide preterm care. According to Schwindt, only regular training as a team can ensure a higher likelihood of survival among the babies born prematurely and significantly increase their quality of life later on. He finds the interdisciplinary approach particularly important. “It does not make sense to train only nurses or doctors, because in an emergency, the team has to work as a unit,” says Schwindt, CEO of SIMCharacters.

### Paul evokes emotions

“We couldn't find anything on the market for training with premature babies that met our demands as medical practitioners,” says Schwindt, who has led training courses for many years himself. Everything lacked a realistic look and modern technology. Where that is concerned, Paul is perfect – he evokes emotions, which means that a very realistic scenario arises and the training yields more successful results among the medical personnel.

### Low-noise motors

In addition to the extremely lifelike anatomy on the outside, Paul is full of high-tech on the inside. His skull hosts a Linux system. The preemie training model is charged cordlessly by induction, using a customary charging pad. Paul can be operated for up to two hours. The tiny boy can really whine and cry. And when he has difficulty breathing or the oxygen saturation drops, his head turns blue.

Sophisticated hardware and software fit into a silicone skin. Everything is made locally at SIMCharacters in Vienna. DC motors, gearheads and sensors of maxon motors ensure that the thorax and abdomen move in accordance with the programmed test sce-



Paul can be used to train various emergency situations that occur daily in preterm care. For example, if the baby stops breathing.

narios. “The drive systems had to be small, energy-saving and efficient. And it was very important to us that they run quietly and have a very long service life,” says Michael Haller, Head of Research & Development at SIMCharacters.

Three DCX 12 motors with gearhead and sensors are used – two for Paul's thorax and one for the abdomen. Another DCX 6 maxon motor moves a valve in the lung of the simulator. Haller explains that a total of 40 motors were installed, and they all work perfectly.

### Not a single child

Swindt had the idea to create a baby simulator in 2010 and founded the company SIMCharacters two years later. The startup received extensive support from the Austrian government. Without this funding, it would not have been possible to build a prototype. An investor from Vorarlberg was won over by the product and helped Paul to get ready for series production.

In the mean time, several “Pauls” have been sold. The demand all over the world is very high. A training simulator costs EUR 50,000. “An investment that is worth it,” says Schwindt. “Critical situations in preterm care have to be trained time and time again, under as realistic conditions as possible, to ensure that everything goes equally smoothly in a real crisis.”

Paul will not stay an only child. In the years to come, he will get siblings. ■■■

# The delivery robots are coming!

When people look up at the sky, they see more and more drones. Yet the breakthrough for delivery robots will take place on the ground – if the lawmakers give the green light.

**P**edestrians all over the world have met them on the pavement already: autonomous delivery robots. Boxes on wheels, equipped with sensors, intelligent software and powerful motors. Developed to travel from A to B autonomously and reliably, without obstructing or endangering anyone.

Although the vehicles spotted are prototypes, it is quite possible that autonomous delivery robots will soon be a common sight – as part of the cities of tomorrow. However, the first steps – or turns of the wheel – in this direction are being made far away from the

big cities: In Saas-Fee, a small village at the foot of the highest mountains in Switzerland. Here combustion engines are prohibited. Ideal requirements for testing electrically driven ideas.

### A “mobile trunk” for shopping

The new idea: a delivery robot made by the Swiss startup TeleRetail, which was founded in 2014 by CEO Torsten Scholl. He calls his robot a “mobile trunk.” After all, the robot should transport the shopping or packages just like a car – yet completely autonomously.



Receiving goods by delivery robot – soon a common sight in everyday life, not only in Saas-Fee?



**Torsten Scholl** is a true entrepreneur who tackles everyday problems. In 2014, he founded TeleRetail with the aim of solving the logistical problems of local businesses.

2016, the company has been cooperating with maxon motor as well. “Together with the engineers of maxon, we ran through different approaches to find the optimal solution. The brushless DC flat motor EC 90 has already been used as a drive and provided convincing performance. Soon we want to test more powerful motors by maxon, such as the Bikemotor,” says Scholl. He values the strong support that vastly exceeds mere consulting about the right drive. “I am eager to see what’s next.”

**The optimal drive for delivery robots? Together with maxon, TeleRetail is testing different motors.**

“Even though we will soon have autonomous cars, it does not make sense to have them drive around with only small loads. A small robot is much more economic and does not cause traffic jams.”

Scholl describes himself as an entrepreneur. He tackled a well-known phenomenon accordingly: “Today people mainly order online; the local businesses have to rise to the occasion, else they will soon vanish.” That is how he got the idea for an online sales network for the local trade. People can conveniently order their bread, milk and other goods online and have it delivered to their homes – by bicycle courier or, in future, by robot.

### Support from industrial partners

Now the task is to get the delivery robot fit for use. To this end, TeleRetail works closely with various industrial partners. Since fall

Technical challenges are one thing. Another is changes to laws. Currently autonomous delivery robots can only move around in towns such as Saas-Fee with special permits. Scholl estimates that it will take another five years before the laws are adapted. In some countries, it might go faster. One thing is certain: Sooner or later, delivery robots will be a regular fixture in our normal lives.



“The conditions for startups have never been as good as they are today.”

Do I have the right stuff to be an entrepreneur? How do I recognize a good idea? And how do I become successful? Mike Baur's expert tips for business founders.

Entrepreneur **Mike Baur** from Freiburg is co-founder and member of the board of directors of the startup accelerator Swiss Startup Factory. The 42-year old Swiss supports startups both as mentor and financially. The interview with him first appeared in edition 03/2017 of the Red Bulletin Innovator magazine.

**Behind every successful startup project, there is a good or ingenious idea. Can you give us a tip for getting an ingenious idea?**

*Mike Baur:* I don't have to. It will come to you by itself. Spontaneous ideas are always better than frantically looking for something. And spontaneity is sometimes quite simple. For example, if you need a product and you realize that there is no such thing, and you wonder: "Why doesn't that exist yet?" That's when it gets interesting. You might just have discovered a market niche – and if you then have an idea how you can fill this niche, you should use the chance and found a startup.

**Many people have good ideas, but don't dare to implement them ...**

Because there is something they are not aware of: how easy it is to reach people these days. A website can be set up in no time at all, and getting a test group of 50 people via WhatsApp is just as fast. And it is all free. Low communication costs and ideas that have potential: that has huge power and was not possible twenty years ago. In short: The conditions for startups have never been as good as they are today.

**Which traits do I need to hold my own in the startup world?**

I will give you five tips, if I may: Trust yourself. Do not be afraid to fail. Ignore the naysayers. Work like a horse – and break a rule or two.

**Should one share ideas? Or rather protect them, so that they are not stolen?**

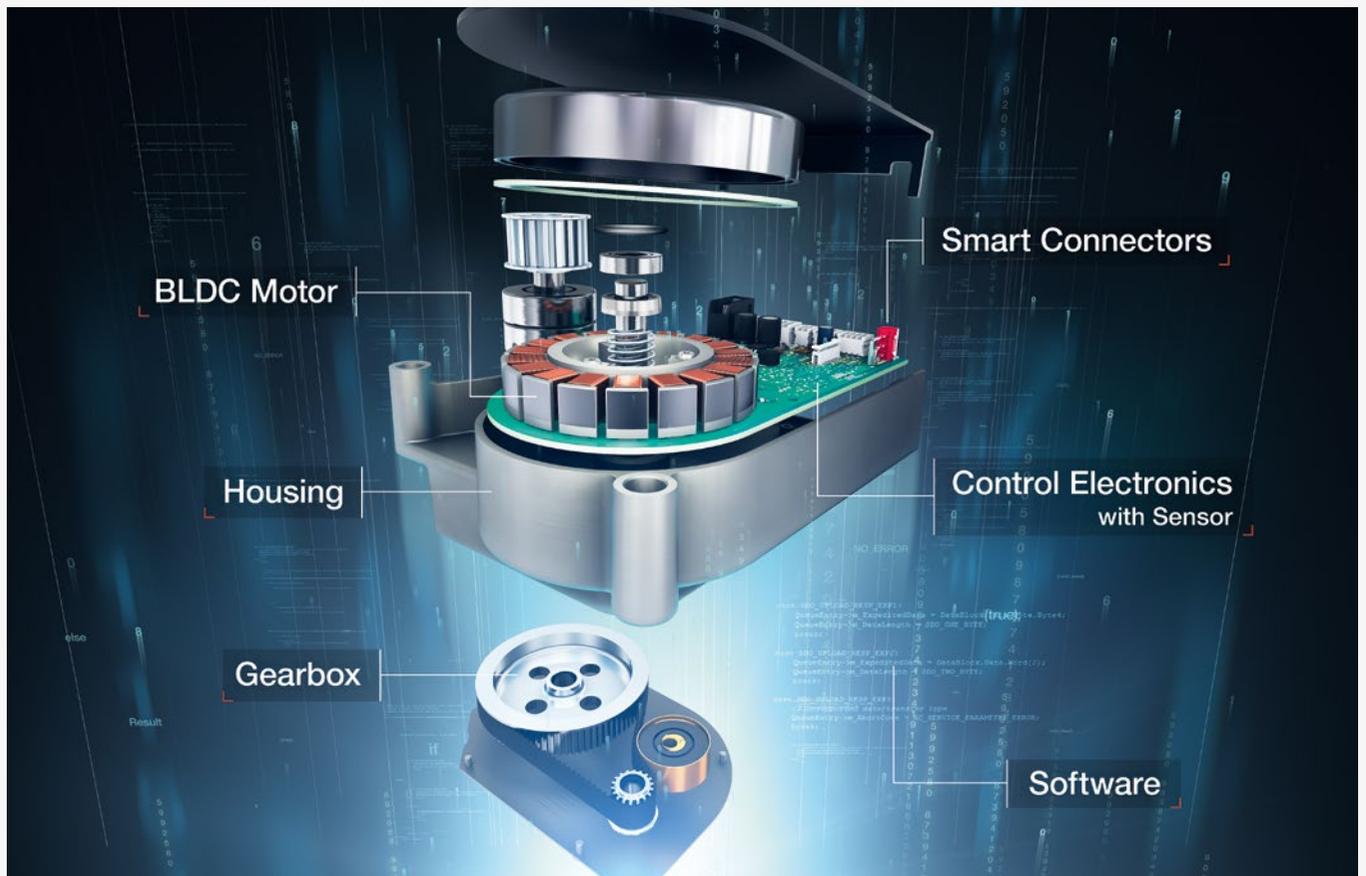
Always share them with others. Always. That has an inspiring effect. It is the only way to get valuable feedback and to see your project from another perspective. And if you talk to people, your passion might catch on – and suddenly you have a team that can achieve a lot more together than a single person could. It is very important to network your thoughts.

**OK, let's say I found a company and fail completely. What now?**

Get up, analyze, and fail again. It is better to fail than to shy away from trying. That's how you learn. Everyone has to go through that process. One day, you get up, analyze and do not fail any more – but are successful instead.

**How can one motivate oneself to keep going?**

There are long dry spells everywhere. And in these phases, the wheat is separated from the chaff. These phases separate the entrepreneurs who really want it, from those who don't. If you get through this dry spell, you come out on the other side stronger – as an entrepreneur and as a person. Knowing that is enough motivation. ■■■



# From motor to drive system

Complete mechatronic drive solutions offer many advantages over individual components. Yet to reach the goal, some important questions first need to be answered.

**m**axon motor evolves more and more from a supplier of components to a provider of system solutions. Components to be understood as motors, gearheads, encoders, as well as speed and position controllers. As a system, we consider complete drive solutions in the sense of mechatronic units and subsystems, which are integrated into a larger context. The focus

shifts from the individual components used towards the main functionality to be fulfilled.

## Example hip joint for a robot

The starting point is a customized component, more precisely a flat motor. For improved heat dissipation, the rotor is perforated and a special cable and connector is required

for the connection to the customer-made motor drive electronics. The precise purpose of the motor and its mechanical and electrical interfaces are unknown at the beginning. Only after a closer look provided by the customer it becomes clear that the motor drives a geared robotic joint. Strongly limited space associated with a correspondingly complex mounting of the existing solution and required additional functionalities are good reasons for an integrated system solution.

### Mechanical requirements

- Low speeds and high torques call for a geared motor
- Motion range at gear output: approx. 120°
- Blocking of the joint in case of power failure (holding brake)
- Possibility to release the blocking. System may not be self-blocking.
- Cables to pass through the joints

### Electrical and electronic requirements

- Driver for the brushless motor (including commutation, current and speed control)
- Communication with higher level master control
- Angular sensor for motor and gear output, position information to be sent to master

All this happens in the context of limited, predefined dimensions and weight. In addition, emissions (temperature, vibrations, and audible noise) must be kept low. Powered by batteries, the system should work energy-efficiently. And of course, costs must be considered as well.

This list of requirements is a showcase for the aspects to think through when pursuing an integrated solution. Only an intense and open communication between customer and system integrator can clarify these aspects.

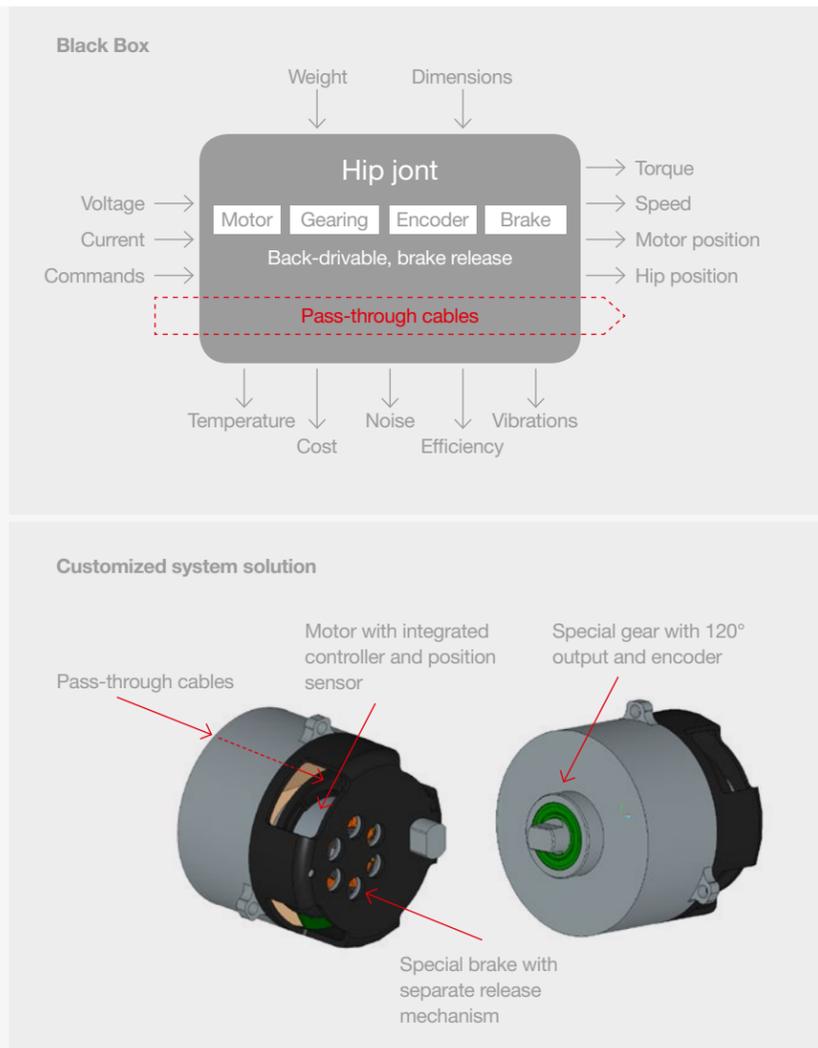
### System delimitation

The first question to answer: What should be part of the system? Where can reasonable system boundaries be set considering the functionality to achieve? How does the system environment, how the mechanical, electrical interfaces look like? How is information ex-

changed and how does the end user communicate with the complete system?

### Different views on systems

When developing complex systems, people with different knowledge background and different points of view are involved. How can communication be set up in an optimum way in order to have all persons understand the same and to strive for the same goals? A black box consideration as sketched above may help. A top-down approach, which does not get lost in details, is also reasonable. Ano-



ther aspect often ignored when dealing with complete systems: How can the needs of the end user be taken into account?

### Specifying systems

The trigger for a system development may contain important hints for the formulation of the objectives. Is it a new development? Is it about improving an existing solution? Why is the existing solution unsatisfactory? The basis for a specification is always a situation analysis: What is it really about? How does the system context look like? It is important to formulate the catalog of objectives neutrally, i.e. not implying a solution. In the example above, the required blocking upon power failure might also be obtained by a self-blocking gear and not only by a holding brake.

### Solutions

The catalog of objectives serves as a basis to develop different solutions, which have to be judged by their suitability. Possible solutions often resort to existing products. In this context, I mention the design of the maxon product platform in recent years. It allows to resort to existing and proven components during system development, which in addition can be customized rapidly. All this minimizes the technological, time, and economic risks.

maxon systems appear most of the time in a mechatronic context combining mechanical and electrical components: drive mechanics, actuators, sensors, controllers. Software becomes more and more important, for instance in the form of controller firmware or of a computer program controlling a complete plant.

When relating different solutions, ascertain that apples are compared with apples. For example for the customer, the costs for an integrated system have to be balanced not only to the costs of individual components but also to the costs for interfaces and mounting.

### Economic boundary conditions

An integral component of the situation analysis is the question, if and when a new design pays off. What quantities can be expected in which time period? Realistic market estimations are necessary. It must be defined if the non-recurring engineering and tooling costs shall

be part of the product price or if they are paid separately. Basically, a net present value calculation (NPV) can serve for the economic decision to start a project. However, additional criteria are strategic fit considerations and a risk analysis.

In summary, besides the aspects presented here, follow the steps and procedures as explained in the textbook "Selection of high-precision microdrives".

### By the way

The proposed solution for the robot hip joint consists of the originally selected motor, however, with integrated electronics based on the maxon ESCON controller platform and combined with a special gear. Motor and gear positions are delivered by integrated encoders. A specially designed holding brake acts directly on the rotor and is located in the compact housing. For the customer, the mounting of this integrated system is much simpler and faster compared to the existing solution made of single components.

**drive.tech**

You can find more technical reports and blog articles by our maxon experts at [www.drive.tech](http://www.drive.tech)

**Urs Kafader** has been supervising the technical training at maxon motor for more than 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.





# Eyes on the ball!

Sweaty, NimbRo and TRUDI have a lot in common. They participated in the international RoboCup 2017 in Japan. They scored goals and practiced disaster relief operations. And all of this was done with motors by maxon.

RoboCup 2017 Humanoid AdultSize Final:  
NimbRo vs. Sweaty (on YouTube)



In Japan, the soccer robot NimbRo from Offenburg (Germany) took first place in the AdultSize class.

A little clumsily, NimbRo positions himself on the green sports field, focuses on the ball and kicks. The ball lands just in front of the goal. Sweaty has his eyes locked on the ball. Slowly he ventures forward, but NimbRo is quicker and maneuvers past him. Sweaty falls. Foul? No, there is no such thing in robot soccer. But there are goals. Two robots compete in the finals of the humanoid league in the AdultSize class. They have to be at least 1.30 m tall.

At the end of July, more than 3000 participants from 42 countries gathered in Nagoya, Japan's fourth-largest industrial hub, to attend the RoboCup 2017. This robot contest started 20 years ago as a robot soccer championship and has since taken place annually at changing locations all across the world. And today robots no longer compete only on the soccer field. For several years now, the machines have also challenged each other in the "Rescue Robot League." In a simulated disaster scenario, the robots carry out rescue operations and are evaluated based on their performance.

**Robots as rescue workers**

The best European robotics team turned out to be the team of the Carinthia University of Applied Sciences, "CUAS\_RRR", who participated with the autonomous rescue robot TRUDI (Third Robot for Urban Disaster Intervention) that they developed themselves. They reached seventh place in the 20-team field of the "Rescue Robot" category. "Our rescue robot TRUDI scored high marks in



"The motors always worked well and had to endure extreme loads," says Martin Sereinig, research engineer at the Carinthia University of Applied Sciences.

particular for its light design and system approach," reveals Martin Sereinig, member of the robotics team.

Several motor-gearbox-encoder combinations of maxon ensure that the robot can move forward with its chain drives. The brushless EC-4pole 30 with its 200 W is a powerhouse with a long service life. The camera arm of the rescue robot is also operated by means of a maxon drive system. Additionally the team uses eight DEC 50/5 modules on self-made circuit boards and four ESCON70/10 motor controllers for the gripper arm of TRUDI.

**A completely German final**

From the rescue robots back to the soccer league. Two German universities led the field. In the final match of the AdultSize class, the University of Bonn with NimbRo competed against Offenburg University with Sweaty. And one robot clearly was a metal-leg step ahead. The title of world champion went to Bonn. NimbRo defeated Sweaty in the final, with a score of 11:1.

"This was the first time we competed in this class and to this end we built a new robot, the NimbRo-OP2," explains computer science graduate Sven Behnke of the University of Bonn. The exoskeleton supporting the 135 cm tall NimbRo was manufactured entirely with a 3D printing method. The 18 kg robot is driven by 34 Dynamixel-MX-106 actuators of the South Korean company Robotis. These all-in-one drive modules with integrated controllers have numerous feedback functions (positioning, speed, input voltage, internal temperature) that are controlled over a network. The maxon DC motors integrated into these modules are very light and have a very high torque. "We have been using the Dynamixel actuators for more than 10 years, and hitherto we haven't found a better solution for our application."

**Balance problems**

Yet vice world champion Sweaty and his team can also be proud of the result. The robot with the bright blue eyes and extra-large feet ran around on the soccer field completely autonomously. Sweaty used only the camera installed in its head to get its bearings. In the "Technical Challenge", the robot took first place in the dis-

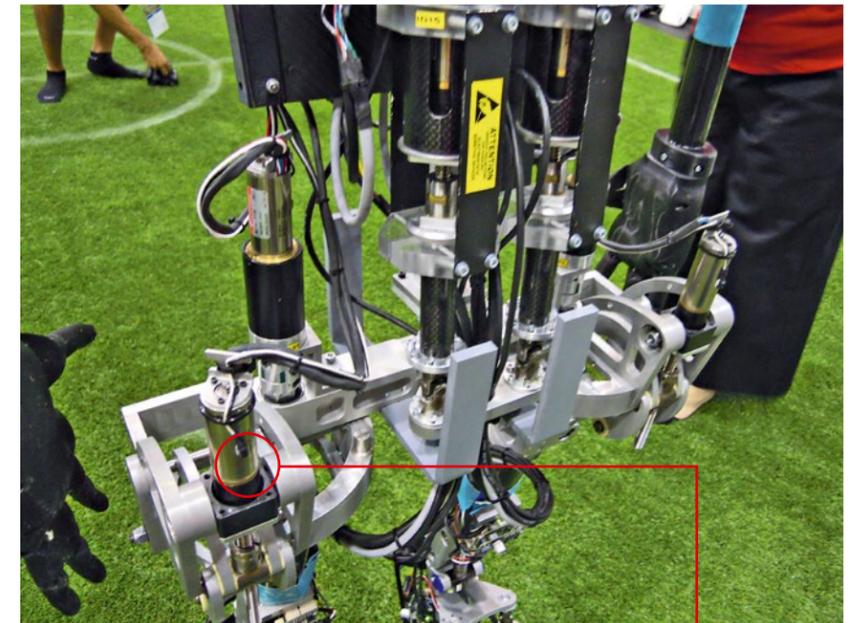


cipline "Goal-Kick from Rolling Ball." No other robot was able to detect the rolling ball with such precision and reliably kick it into the goal.

However, in the final match against NimbRo, there were a few problems. "We had difficulties with the network that was supposed to transmit the commands of the referee to us," says Prof. Ulrich Hochberg, the project leader. Both robots had a team member running along with it, to protect the robot from falling to the ground if it trips and tumbles. Sweaty frequently lost its balance and then had to leave the field for a short penalty period. In that time, the competitor had free rein.

**More power through cooling**

The robot is equipped with 24 maxon DC motors; to 18 of these, an overload is applied with a special motor controller. Two of them are additionally equipped with an evaporative cooling system for motors. This is necessary to prevent the motor from overheating. The evaporative cooling is comparable to sweating in humans. Hochberg reveals that this was the inspiration behind the name of the robot. Sweaty's legs alone contain six motors with planetary gearhead (maxon EC-4pole). The other drives are used in the arms, back, shoulders and hips. The team also uses Dyna-



Sweaty is equipped with 24 maxon DC motors.



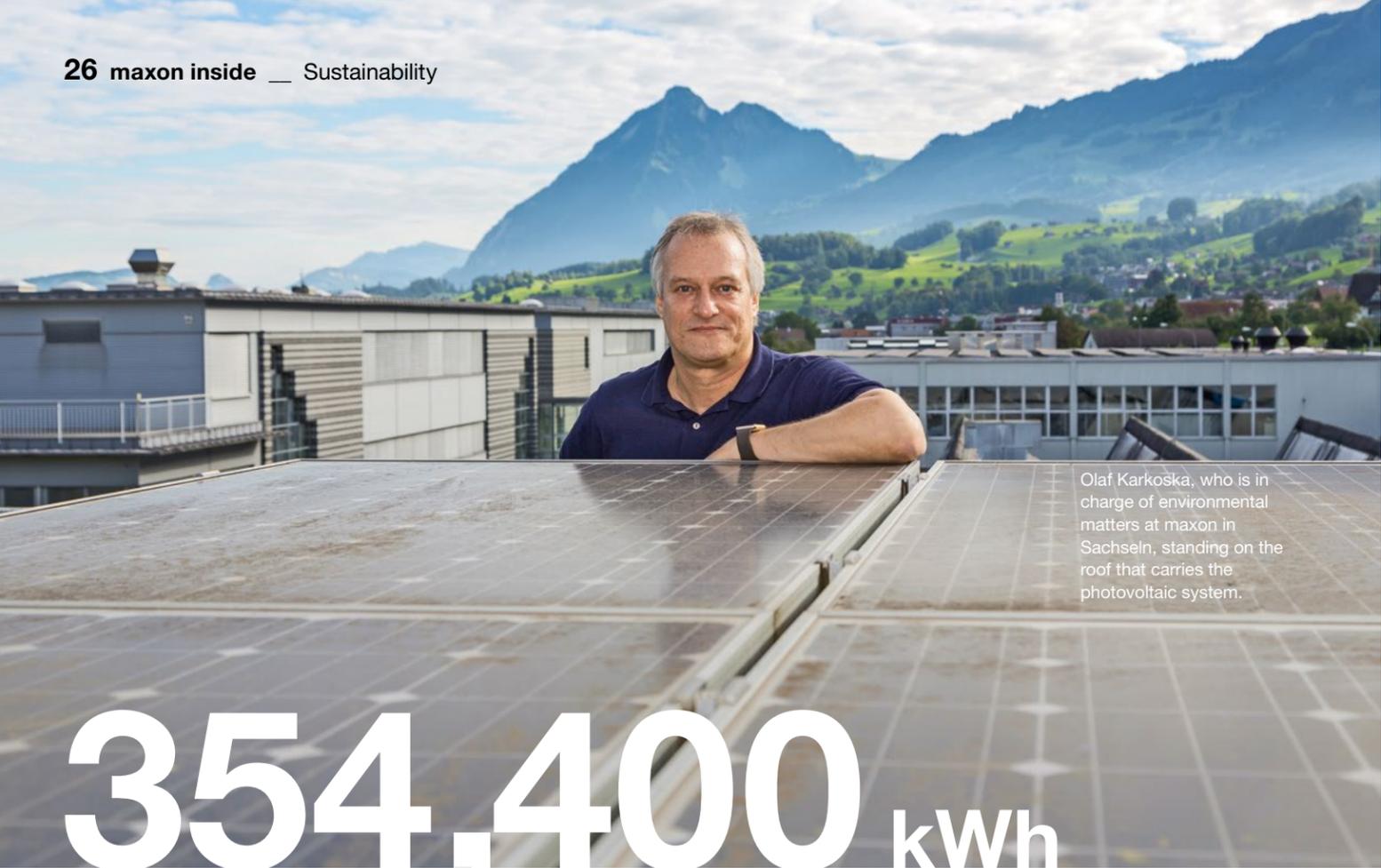
maxon EC-4pole 22  
Ø 22 mm, 90 W,  
brushless

mixel actuators, for example for nodding the head. "We are delighted with the motors," says Hochberg. "We were particularly surprised that the catalog specs of the motors are so conservative and that, in cooperation with maxon, it is possible to get much more out of the motors."

The target of the Robocup is to have a team of two-legged robots beat the incumbent soccer world champion by 2050. At the moment, that still seems utopian. The human-sized robots still come across as rather clumsy on the green grass. And yet: A lot can happen in 30 years!

**drive.tech**  
For more about the RoboCup 2017,  
go to [www.drive.tech](http://www.drive.tech)

Photos: Fachhochschule Kärnten, Universität Bonn, Hochschule Offenburg, maxon motor ag



Olaf Karkoška, who is in charge of environmental matters at maxon in Sachseln, standing on the roof that carries the photovoltaic system.

**354,400 kWh**  
from sunlight



Photos: maxon motor ag

The global climate problem demands that humans have a mindset focused on sustainability. All companies have a duty to implement environmentally friendly measures. And maxon motor is doing its part.

ronment. Another means to this end is using cleaning agents and systems that are more environmentally friendly. At all production sites, chemicals are replaced with environmentally compatible products wherever this is possible.

**Commitment to climate protection**

True to the maxon environment philosophy: “Our environment is the basis of our existence – let’s make sure it stays like that,” maxon thinks of the future and is committed to climate protection. Together with myclimate, a non-profit organization that provides CO<sub>2</sub> compensation, maxon is investing in a climate protection project in Indonesia.

“An important target is to reduce the CO<sub>2</sub> emissions at all maxon sites,” says Olaf Karkoska. Of course that includes training new employees. “Each employee has to contribute to treating our resources with respect. And that starts with the use of paper.”

**27 tons of wood**

In the age of the paperless office, paper consumption should be decreasing. According to Karkoska, the paper consumption at the maxon headquarters and at the German and Hungarian sites only dropped slightly in the past years. In 2016, maxon in Sachseln used 3 million sheets of A4 paper. That corresponds to 12 tons or an area of 24 soccer fields. “Try to picture what is needed to manufacture such a heap of paper. 27 tons of wood, 487,000 liters of water, a total energy consumption of 101,250 kWh. That corresponds to driving 120,000 km with a car.” Therefore maxon has set itself the goal of reducing the consumption of paper and other resources, as well as correctly sorting and recycling more waste.

Karkoska: “Every day, we look for new opportunities to improve, with the goal of reducing the burden on the environment. That is not only important here at the Swiss location, but worldwide!”

**F**rom the bird’s-eye view, the large photovoltaic installations on the roofs of the maxon motor headquarters shine in the light of the sun. Photovoltaic systems generate environmentally friendly energy both at the headquarters in Sachseln (Switzerland) and at the production site in Germany. The energy needs in Sachseln are covered entirely from renewable sources. 92 percent with hydroelectric power and 8 percent with photovoltaics, according to Olaf Karkoska, environmental officer at maxon motor. Every meter of roof space is used to generate sustainable energy. The energy is then used for production purposes, as part of maxon’s environmental management system. In 2016, 354,400 kWh were generated from pure solar energy at the headquarters. For comparison: The annual power consumption of a normal household is approximately 3500 kWh.

**LEDs instead of fluorescent tubes**

The Innovation Center that is currently being built (swissness.maxonmotor.com) is also getting solar panels on its roof – that means another 180,000 kWh annually. Last year, maxon needed 4.5 GWh of power at the headquarters, that equals approx. 5000 lightbulbs that are on nonstop for 365 days. Speaking of lighting – maxon motor is continuously replacing fluorescent tubes with LED technology, to further reduce the energy consumption.

The solar systems are part of a long list of measures that are consistently implemented within the maxon group. This includes the use of two groundwater wells that provide most of the energy required for heating, cooling, and ventilation. Simultaneously, maxon motor makes use of process and exhaust heat. Renewable energy is not the only way to reduce emissions that are harmful to the envi-

At a glance

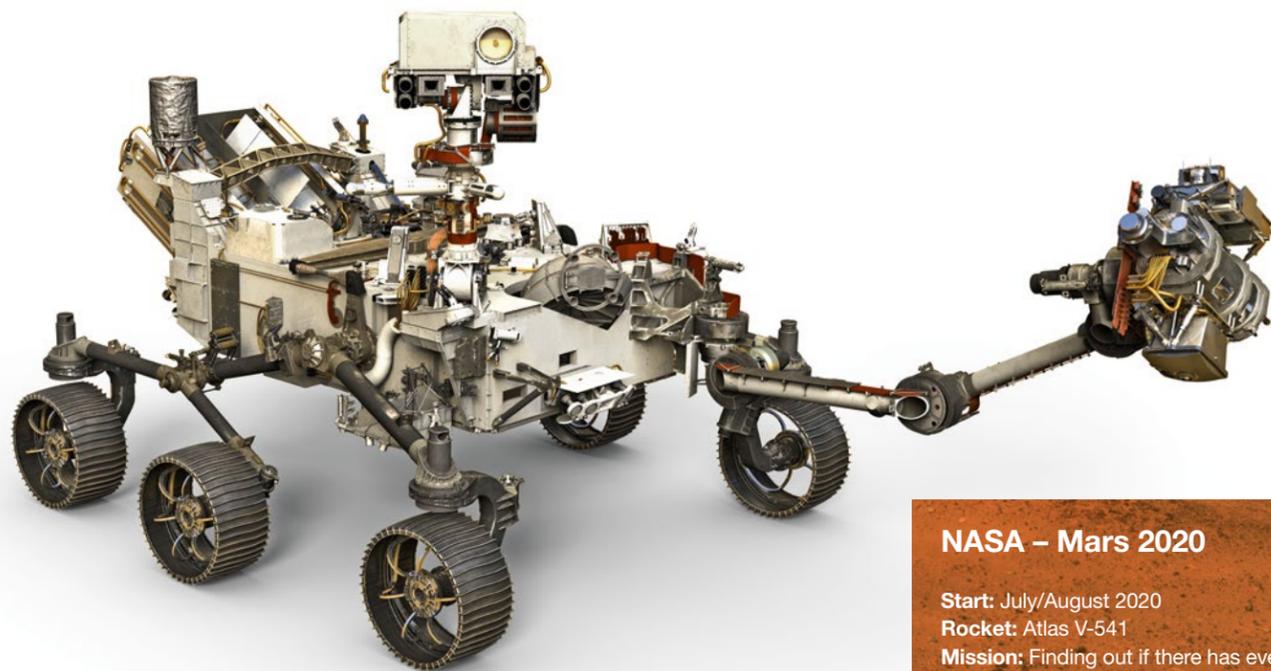
**Consumption of maxon motor in 2016**

- Paper: 3 million sheets (A4)
- Electricity: 4.49 GWh
- Fresh water: 12.59 million liters
- Copper recycling: 3.8 tons

Since 2005, maxon motor has had its own commuter railway station.

# A duo on the way to Mars

NASA wants to send their fifth rover to Mars in 2020. At the same time, the first vehicle of the European Space Agency (ESA) is scheduled to land on the Red Planet. We show the characteristics and differences of the two high-tech rovers.

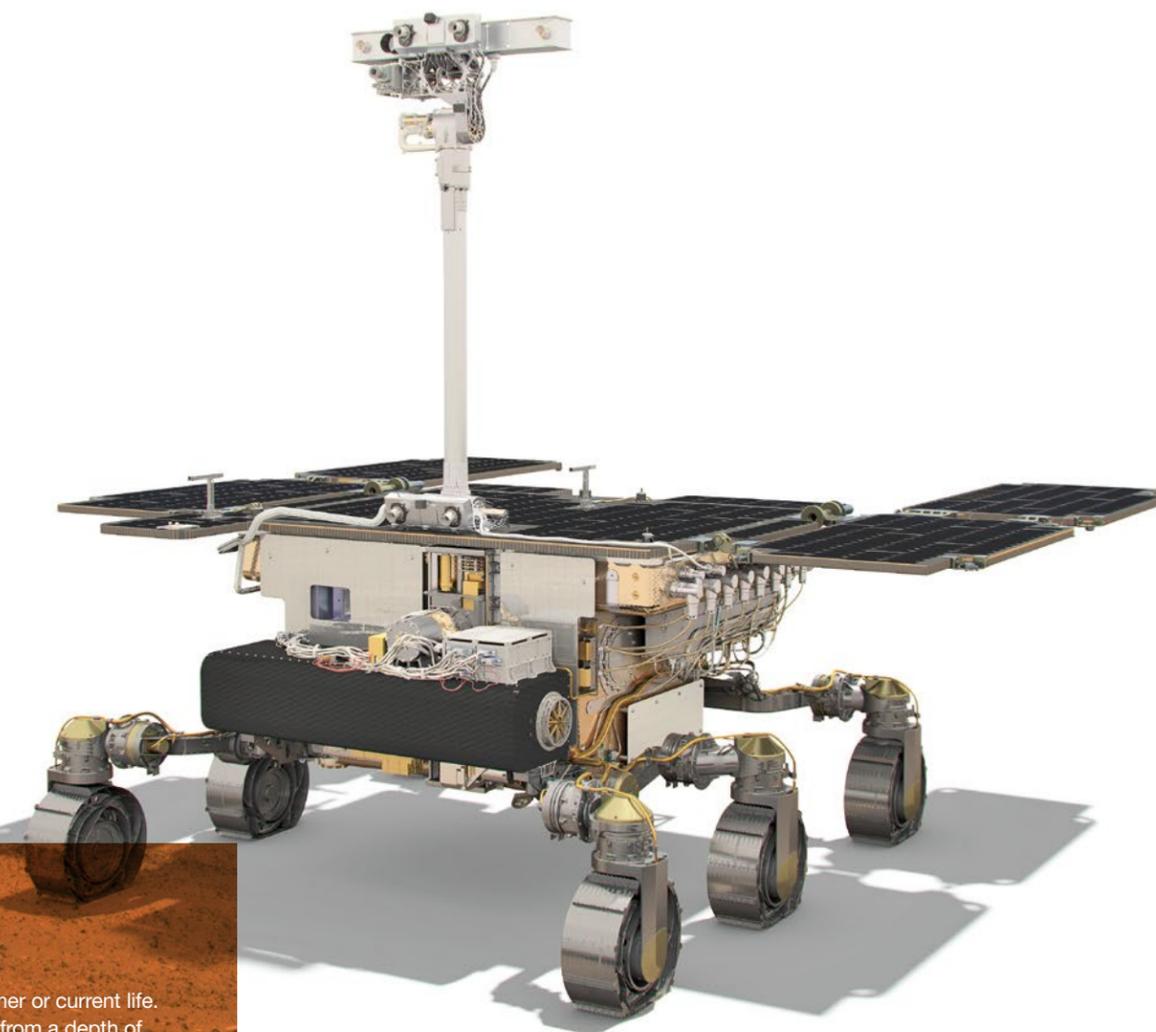


## NASA – Mars 2020

**Start:** July/August 2020  
**Rocket:** Atlas V-541  
**Mission:** Finding out if there has ever been life on Mars. Taking soil samples and sealing them in containers that can later be collected and brought back to Earth.

**Cost:** 2.1 billion US dollar  
**maxon drives:** Nine brushless DC motors (for handling the soil samples), EC 32 flat and EC 20 flat with planetary gearhead, everything specifically optimized for the Mars mission in cooperation with NASA/JPL

Photos: NASA/JPL, ESA

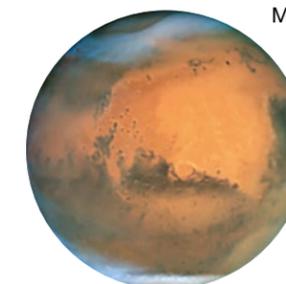


## ESA – ExoMars

**Start:** July/August 2020  
**Rocket:** Proton  
**Mission:** Looking for former or current life. A drill takes soil samples from a depth of two meters. The rover analyzes the samples on-site with measuring instruments.

**Cost:** 1.8 billion dollar (incl. the preliminary mission of 2016)  
**maxon drives:** More than 50 actuators, from the wheel drive to sample distribution to camera movement, with 17 different configurations of brushed or brushless DC motors (such as DCX 10, DCX 22 or EC 40) in combination with gearheads (such as GP 22 HD), brakes and encoders

## Mars



Mars is the fourth planet from the sun and is considered to be an earthlike planet.

- Average temperature:** -55°C
- Diameter:** 6,779 km
- Orbital period:** 687 days
- Length of the day:** 1d 0h 40m
- Gravitation:** 38 percent of the gravity on Earth

# The organic express of Lausanne

The bikers of Plateforme Bio Lokal supply fresh organic vegetables to restaurants and bars – quickly and emission-free. Even 200 kg of potatoes do not faze them.



**M**uscle power is still indispensable. Even when an electric motor provides support. That is immediately apparent when one watches Charles-Louis Mourruau cycling up the steep street that leads through the green vineyards, with Lake Geneva in the background. He exhales deeply and smiles. “That was quite fast, wasn’t it?” For him, such inclines are no problem. He conquers dozens of them daily on his trips with the transport bicycle and frequently cycles 80 kilometers or more. Lausanne is a hilly city. And the bike is carrying a heavy load – usually with regional organic vegetables that are delivered fresh to restaurants, bars and hotels. But Charles-Louis is fit and his bike is equipped with a powerful rear motor. With this combination, he succeeds in delivering the orders to the many customers on time.

Charles-Louis Mourruau of Plateforme Bio Lokal loads fresh vegetables onto his transport bike.



The P’tit Bar, a small café in the center of Lausanne, is also among those who put their faith in organic food produced in the region and delivered emission-free. Owner Murielle and her employee accept the delivery from Charles-Louis with a smile. He immediately jumps back in the saddle and rides back to the premises of his small company Plateforme Bio Lokal, located slightly outside the city. There the next delivery is already waiting. And the day is still long.

**Long working days**

Hansjörg Haas is an idealist. And yes, with Plateforme Bio Lokal, he wants to improve the world a little bit. “I show the people how things could be.” He got the idea for the organic delivery service in 2013. Back then, he was involved in a different project, when a head chef asked him if he is also able to deliver fresh fruit. In the end, his company evolved from that. “Our values are: local, organic, seasonal and emission-free – those are the four leaves of our clover logo,” says Hansjörg Haas. “We deliver fruit, vegetables, but also flour and milk. Almost everything is sourced from a network of local organic farmers and we deliver it right to the doorstep with our electric transport bicycles. From the field to the plate, so to speak.” Frequently the vegetables are delivered raw, but increasingly they are also prepared in the company’s kitchen, so that the customer only has to perform the final cooking steps. And the service is meeting with approval. The customer list is getting longer – and with it the

working days. For the two bosses, Hansjörg and Charles-Louis, 13 to 14 hours are not uncommon. Charles-Louis says: “As long as I spend half of the day on the bike, it does not bother me.” And the spirit in the team of six people is excellent. “We’ve known each other for a long time and are good friends.”

**“The perfect motor for cargo bikes”**

Plateforme Bio Lokal intends to expand their principle. Geneva is already in planning as second location, other cities will be added. Hansjörg Haas would like to provide the entire country with the environmentally friendly delivery service. “The desire for sustainable food is increasing. At the same time, the streets are clogged with cars. Therefore cargo bikes are the means of transportation of the future.” Provided they are equipped with the right electric motors. Charles-Louis says: “Through the years, we have used several bike drives and were never happy until we discovered the maxon Bikedrive. It is powerful, saves energy, is robust and can be installed quickly – with no bells and whistles. Motor, battery and Powergrip, reduced to the basics.” In his opinion, it is the perfect motor for cargo bikes. “We frequently transport boxes that weigh more than 100 kg.” And Hansjörg adds: “Once I even fetched 200 kg of potatoes from a farmer and took it to the depot. Without any problems.” Another plus is the fact that the rear motor is a Swiss product. “It fits excellently with our philosophy of promoting local business.” Five cargo bikes are already equipped with the Bikedrive. And if the vision of Hansjörg Haas becomes reality, hundreds of these bikes will soon hit the streets – packed with fresh vegetables. ■

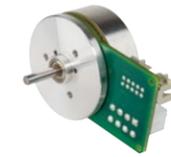
The maxon Bikedrive rear motor weighs only three kilograms. It can be retrofitted into almost any bicycle – even cargo bikes.



More information:  
[plateformebio.ch](http://plateformebio.ch)  
[maxonbikedrive.com](http://maxonbikedrive.com)



Only 20 minutes later, a small café in Lausanne receives the delivery.



maxon EC 45 flat  
Ø 45 mm, 30 W,  
brushless

# Landing like an insect

Helicopters are masters of the skies and can land without a runway, but they hit their limits when faced with steep or uneven terrain. A group of young engineering students aim to make this a thing of the past.

**H**elicopters are amazingly agile and free in the air, but their limits become apparent when they have to land. The ground has to be even, else there is a risk that the helicopter, with its rigid landing structure, will tip.

### Target: A 20-degree slope

A new approach could provide the answer to this problem. A group of 12 engineering students has developed an adaptive landing system for helicopters. The system comprises four individually controlled legs, which independently adjust to the surface below – without intervention from the pilot. The idea behind this is to facilitate safe landing at any time.

The project team is made up of budding mechanical and electrical engineers from

ETH Zurich, with support from systems technology students at the Zurich University of Applied Sciences (ZHAW) in Winterthur. Jointly they constructed a prototype of the landing system over the last year, using a model helicopter with a rotor diameter of 3.2 meters and an unladen weight of 50 kilograms. The engineers mounted the four legs onto the model. Their purpose is to compensate for uneven ground without problems.

The team hopes to facilitate landings on slopes with an incline of up to 20 degrees. Individual obstacles up to 50 centimeters in height should also not be a problem.

### Flat motors as perfect solution

The focus project at ETH Zurich is part of the maxon Young Engineers Program (YEP), and

is receiving support from maxon motor in the form of discounted drive systems. On each landing leg, the engineers are using a brushless EC flat motor to drive a ball screw gear. “Because of their shape, the flat motors are perfect for installation in our power train, as we have a limited length available to us,” says one team member. The young engineers are using positioning controllers from the EPOS2 range to control the drives. Among other things, this will regulate the force that the legs exercise on the ground.

With their landing system, the students want to expand helicopters’ field of application. One example they mention is mountain rescue. Usually this is done with a cable winch when the helicopter is unable to land. This takes more time and is risky. The hope is that the adaptive landing system will make such situations rarer. But when and if it will be used in manned helicopters remains to be seen. The engineers are happy with the result of their development. “We were able to demonstrate the functionality and think that the concept has a lot of potential.” Now the principle is to be presented to some helicopter companies. Independent from this, the ETH Zurich continues to work on the innovative landing system, with term papers and diploma theses being written about it.

More information on the Athlas project:  
[www.athlas.ethz.ch](http://www.athlas.ethz.ch)

The students of the ETH test the helicopter landing system on a meadow.



Photos: Athlas, maxon motor ag

**drive.tech**

You can find more projects from the Young Engineers Program at [www.drive.tech](http://www.drive.tech)



# Nature as prototype

Author: Roland Siegwart

**Roland Siegwart** (1959) has been professor for autonomous mobile robotics at the ETH Zurich since 2006 and is co-director of the Wyss Translational Center Zurich (WTZ). He studied mechanical engineering at the ETH Zurich, founded a spin-off company, was professor at the EPFL in Lausanne, vice president at the ETH Zurich and guest at the Stanford University and at NASA's Ames Research Center.

In the past 30 years, **industrial robots** have increased the productivity and quality in mass production enormously and simultaneously reduced the production costs. Since 2005, the number of industrial robots installed annually has more than doubled, to well above 250,000 in 2015<sup>1</sup>.

However, the next evolution – or perhaps even revolution – in the field of robotics are the service robots that support us outside of the protected shop floors, for example at our workplace or at home. But service robots that work with us in our everyday environment need a lot more abilities. Contrary to industrial robots, the focus is not on abso-

lute precision in the movements, but instead on understanding environments and situations, performing localization tasks within our very complex surroundings, as well as flexible interaction with objects and people. That means: Service robots have to be more “human” than industrial robots, but without necessarily looking like humans. Therefore it makes sense to take a look at nature and use the concepts present in humans and animals as a source of inspiration.

Our **motion apparatus** consists of joints, muscles and tendons. Contrary to the joints customarily used in today's robots, which are rigidly connected via a gearhead, us humans

have an elastic coupling in the form of the tendons. It enables us to store energy and protects our skeleton against hard impacts. Additionally it makes force-regulated interaction with the surroundings possible. Inspired by the natural motion apparatus, “Serial Elastic Actuators (SEA)” can be created that have a spring element downstream of the motor and gearhead. The spring protects the gearhead against impacts, permits very accurate measurement of the forces involved in interactions and enables a highly efficient gait with up to 70 percent energy savings. Such SEA drives can, for example, be found in the ETH robot ANYmal sold by ANYbotics.

Where **perception** is concerned, artificial systems are also increasingly getting closer to nature. The rapid development of cameras, inertial measurement units (IMU) and microprocessors that can be installed in smartphones have made the robots of today capable of navigating in similar ways to humans. To this end, image data is combined with the measurements of the accelerations and rotational speeds of the IMU. Analog to the human equilibrium organ in the ear, the IMU enables a very quick estimate of movement, which, however, slowly drifts off as a result of the lack of reference to the environment. The drift can be compensated through data fusion with the image data; this makes exact localization and 3D reconstruction of the environment possible (see image).

Nature is also frequently used as inspiration for the learning skills of robots. Neural networks, a primitive reproduction of the human brain, was first hyped in the 1980s and 1990s. Today the enormous increase in available computer power makes neural networks capable of providing promising results in the segmentation and classification of data (e.g. images) and in learning motion sequences and characteristics. These approaches, which have gained new popularity under the name “Deep Learning”, help robots to analyze complex situations and learn sequences by themselves. Nevertheless, the research still lags far behind the skills of animals and humans.

All these new technologies in robotics have resulted in much progress in the field of

service robots, but time and time again also show the limits of what is possible. As robotics researcher, one gains large respect for the fascinating abilities of humans and animals, which, from the current vantage point, seem unlikely to ever be equalled by artificial systems. ■

<sup>1</sup> <http://worldrobotics.org>

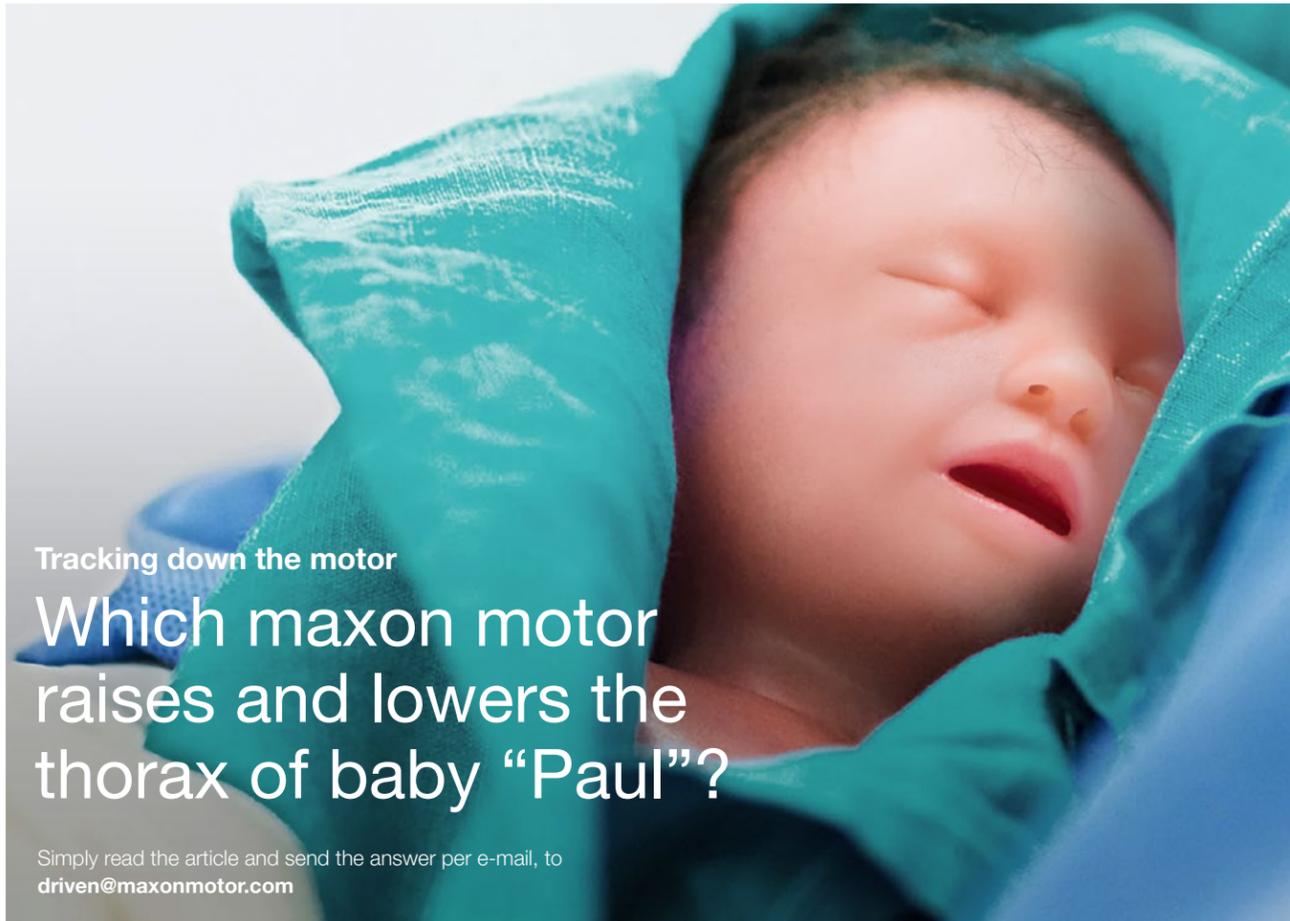


ANYmal, Robotic Systems Lab, ETH Zurich



3D reconstruction of the environment by flying robots in realtime, Autonomous Systems Lab, ETH Zurich

Photos: ETH Zürich



Tracking down the motor

# Which maxon motor raises and lowers the thorax of baby "Paul"?

Simply read the article and send the answer per e-mail, to [driven@maxonmotor.com](mailto:driven@maxonmotor.com)

The prize up for grabs is an iconic Polaroid 600 instant camera from the 1980s – professionally refurbished. Including three films.

The deadline for participation is January 30, 2018. 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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