The maxon motor **magazine**

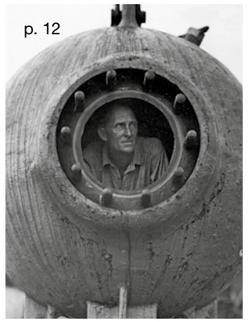
driven

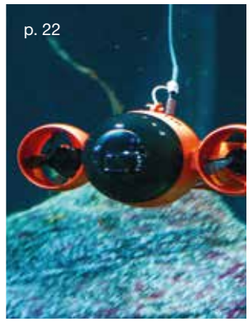
The mysteries of the deep

Vessels dive to find wrecks and investigate the underwater world

eBikes in the snow

DFKI: A mission to Jupiter's moon?





Photos: iStockphoto / Pedrag Vuckovic, Seamor, Wildlife Conservation Society, Aquabotix, maxon motor ag, Philipp Schmidli, Rewalk Robotics, DFKI / Annemarie Hirth

Editorial

The challenges **of the deep**

Eugen Elmiger, CEO, maxon motor ag

You might think that exploring the depths of the ocean would be a breeze compared with a mission to Mars, but you'd be wrong. The extremely high pressure and aggressive salt water create major problems for mechatronic components. That's probably the reason why so few suppliers have been bold enough to venture into this market, despite the fact that there's so much to discover in the ocean, from historic wrecks and ancient treasure to raw materials and new scientific findings.

We at maxon want to solve these problems. This is why we supply not only DC motors suitable for underwater use, but also complete systems, including actuators and thrusters. We also bring together experts from all over the world to identify new solutions.

In this issue of *driven,* you can find out more about the technical challenges involved in working below the surface of the sea. Dive down with us into the darkness, and you will discover that distant planets and the depths of the ocean have a lot in common.

Happy reading!

Bound for Mars

On March 14, 2016, the Trace Gas Orbiter (TGO) of the European Space Agency ESA began its journey to the red planet carrying a Russian proton rocket on board. The Orbiter is scheduled to reach Mars in October 2016. It is transporting a landing module that will be sent to the surface as part of a test. The ExoMars Rover will follow in 2018. It is equipped with dozens of maxon motors. Among them are 18 motor modules designed for the drives and the steering.

Photos: ESA / Boris Bethge, maxon motor ag

South Korea

Relocating to a new manufacturing base

Since December 2015 maxon motor South Korea has produced and developed at a new location. The reason being the need for additional space for storage and logistics caused by the increased demand for EC-i motors and the integration of the EC 60 flat as well as EC 90 flat production lines. Due to this development the previous production site in Sejong had reached its capacity limits.

maxon decided in autumn 2015 to invest in an existing site, which is situated on the outskirts of Cheonan (420,000 inhabitants). The distance between the two sites is 11 kilometers and the new base had been adapted to its new requirements with great speed. maxon carried out the relocation on schedule in mid-December. That way most of the installations and machine acceptances were completed before the end of the year. The Development and Quality Control departments moved to their new quarters in Cheonan during the same period. All members of staff who were trained in Sejong and Switzerland started working in their new environment at the beginning of 2016. The site in Cheonan is an investment in the future due to its buildings and the available space. It also offers sufficient room for further expansion.

Mainly brushless DC motors are manufactured at maxon motor's new production site in Cheonan, South Korea.

Maxon Advanced Robotics & Systems

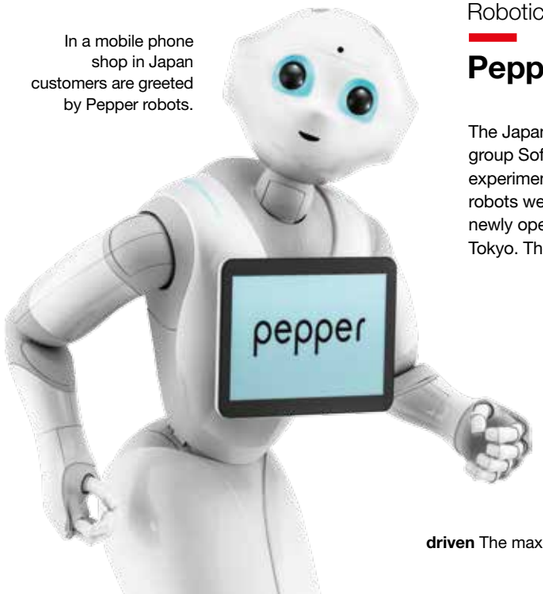
New business unit for mechatronic drive systems in Switzerland

maxon motor is increasingly focusing on robotics and would like to offer its customers mechatronic system solutions. For this reason the new business unit MARS (Maxon Advanced Robotics & Systems) was founded in January 2016. It has the task of combining components such as DC motors, gearheads, controllers and software and integrating them into the respective application. The office is only a few kilometers from maxon headquarters in Switzerland and has around 20 employees. Its first project is the eBike drive Bikedrive, which was launched in 2015. Several thousand units of Bikedrive are to be produced and sold per year.

Added to this are other products for robotics, such as a new drive unit with a dual-clutch gearhead. maxon motor CEO Eugen Elmiger will personally be in charge of MARS until further notice.

600 bar

Deep sea. A pressure of 600 bar prevails at a water depth of 6,000 meters. This equates to 600 kilograms per square centimeter and corresponds to the pressure of a vehicle on an area the size of a postage stamp. An enormous pressure that hardly any living creature can withstand. Fish and other living creatures in the deep sea have adapted to extreme conditions. Diving robots are constantly discovering new animal species. Some of the most bizarre life forms are found at this depth – whether meter-long tube worms, giant isopods, fish or predatory crustaceans. Some of them even live at depths of 6,000 to 8,000 meters, such as a type of snail fish – blind with wing-like fins. But what do maxon drive systems have to do with this dark, freezing cold location? The new underwater actuators from maxon withstand this extreme pressure of 600 bar without any problems. Gearheads, motors and controllers have been adapted in such a way that they function with the usual quality in the deep sea.
(see page 21)



In a mobile phone shop in Japan customers are greeted by Pepper robots.

Robotics

Pepper is running a mobile phone shop

The Japanese telecommunications group Softbank conducted an exciting experiment in March. Mainly Pepper robots were employed for a week in its newly opened shop in the center of Tokyo. They greeted customers, offered entertainment and technical advice. Pepper was developed by Softbank's subsidiary Aldebaran and can not only speak several languages, but also read people's emotions and respond to them. Batches of one thousand robots have been offered every month since last summer. And they always sold out within a minute.

Although Pepper is a humanoid robot, he does not have any legs. Instead, he moves on wheels, which are driven by Swiss maxon motors. Six brushless DC drives are installed in each robot.

Photos: Keystone / dpa, Aldebaran Robotics, maxon motor ag

NEW PRODUCTS

Brushless speed

New products in the X drives family

This spring maxon motor will present the new members of the X drives family. "X" stands for drives which can be configured online and which are produced in 11 days. At the same time it denotes state-of-the-art technology in brushed (DCX) and brushless motors (ECX) and planetary gearheads (GPX). A new addition is, for example, the brushless ECX Speed 22 High Power. It is not only quick (up to 60,000 min-1) but also relatively strong (35 mNm).

There are also several new planetary gearheads, which are designed for high speeds. They can also be sterilized. Their cousins, the GPX High Power, on the other hand, were designed for high-power transmission and are available in diameters from 12 to 32 millimeters.

The entire X drives range can be found at:
xdrives.maxonmotor.com

maxon ECX Speed 22 HP
Ø 22 mm, brushless

maxon GPX 26 HP
Ø 26 mm, 4-stage

maxon EC-i 52 long
Ø 52 mm, brushless

Torque without end

EC-i 52 High Torque

It is amazing what the engineers at maxon have achieved here: a brushless DC motor with an incredible amount of power in a small space. The High Power variant of the EC-i motor with a diameter of 40 millimeters was presented last year. Now comes the bigger and much stronger brother with a diameter of 52 millimeters – ideally suited for applications in robotics, prosthetics, and industrial automation. With torques of up to 520 mNm this motor will delight the drive world.

In search
of a lost veteran

The largest submarine of WWII has been sitting on the bottom of the ocean off the Japanese coast for 70 years. Researchers finally found the lost wreck with the aid of an underwater robot – and Swiss drive technology.

Photos: iStockphoto, maxon motor ag, Seamor, Composing: Peter Kruppa

The I-402 submarine

In the final days of WWII, Japan developed a novel submarine that was larger than all types known at the time. The objective was to create a submarine class capable of reaching any point on the globe and returning to Japan. It also needed to offer space for several planes that could be launched from the deck. In the end, only three of these submarines were completed. They were 122 meters long, with a weight of 6,600 tons. The hull offered space for three specially designed airplanes. Japan was planning to use this super weapon to attack cities on the East Coast of the US. However, these plans never became reality. The three submarines were captured by US forces. The Americans were quite surprised and thoroughly analyzed the technology. I-402 was scuttled right where it was; the two other exemplars were taken to Hawaii, where the US military destroyed them later to prevent the Soviets from inspecting the submarines as well.

The old steel giant rests at a depth of 190 meters, dilapidated and overgrown. Yet the researchers quickly realized that this wreck is the Japanese submarine I-402: the largest submarine built in WWII, 120 meters long, carrying three airplanes that were able to take off via a pair of launching rails. After Japan's capitulation, the US military scuttled the vessel at an unknown location. With the aid of a state-of-the-art dive robot from Canada, scientists discovered the wreck in summer 2015.

LED lamps illuminate wreck parts

The robot is a ROV: a remotely operated vehicle that moves underwater. It was built by Seamor Marine, a manufacturer of compact, easy-to-navigate ROVs that can be fitted with various accessories such as sonar, depth gauge, and scanner. A high-resolution camera and powerful LED lights are among the standard equipment of the ROV. These lights played a central role in the identification of the Japanese wreck, as they illuminated its specific features. Controlled via a cable, the ROVs are able to reach depths of up to 600 meters. The operator pilots the machine with a panel at surface level from a boat, dock or dry land, using a real-time video feed and onboard compass to navigate underwater.

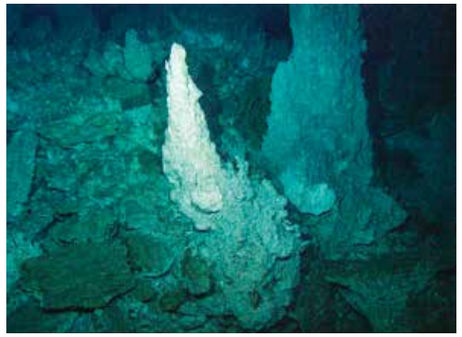
"Underwater archaeology is only one of many applications for our vehicles," says Elaine Parker, who is in charge of marketing at Seamor. The ROVs are commonly used to inspect water tanks, pipelines, or the hulls of ships and boats. "We are also seeing increased applications in tourism, for example at the Shanghai Aquarium, where one of our ROVs is used in an exhibition."

The remote-controlled underwater vehicle from Seamor supports archaeologists in the search for the missing submarine I-402.

maxon RE 40
This 150-watt maxon DC motor is equipped with the proven ironless winding and neodymium magnets. Its efficiency lies at over 90 percent.

maxon GP 32 C
This planetary gearhead with a diameter of 32 millimeters is reinforced with ceramic components. This significantly lengthens the service life.

The ROVs can provide images from a depth of up to 600 meters. The vehicles are controlled via a console – the screen helps with orientation.



Suitable for experts and beginners

Seamor set itself the goal of developing remote-controlled underwater vehicles that are reliable and easy to use. Many customers are not specialists in the field, therefore operation has been made intuitive and easy to learn. "Our ROVs reach places that are inaccessible to humans, or too dangerous," says Robin Li, Seamor Marine Company President. The vehicles also have to be lightweight enough to be handled by one or two people.

The difficulty when developing this kind of ROV is to achieve a compact system that simultaneously has powerful drives. This is why Seamor uses maxon products. The underwater drives of the vehicle consist of a motor-and-gearhead combination: a DC motor (RE 40) and a planetary gearhead (GP 32) with ceramic components. Seamor also uses several maxon drives for the underwater gripper and the camera angle adjustment. The company chose the Swiss drive specialist because, as Seamor Lead Engineer, Dr. Chris Parker, said, "maxon is the leader in high-quality DC motors and is able to deliver a product that fulfills our specific requirements."

The motors of a Seamor ROV need to deliver high power while taking up little space. Low noise is also important. Last but not least, tight tolerances in the drives are critical for preventing vibration that might cause seals to fail underwater.

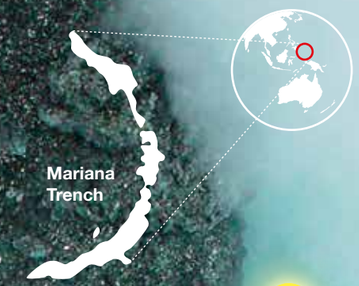
Russian bomber plane in Finnish lake

Seamor ROVs are seeing widespread use these days. The company sells up to 50 units annually. Therefore, it comes as no surprise that, once again, a Seamor vehicle recently caused a stir. On the bottom of a lake in Finland, it illuminated the silhouette of a Soviet aircraft crashed in 1941.

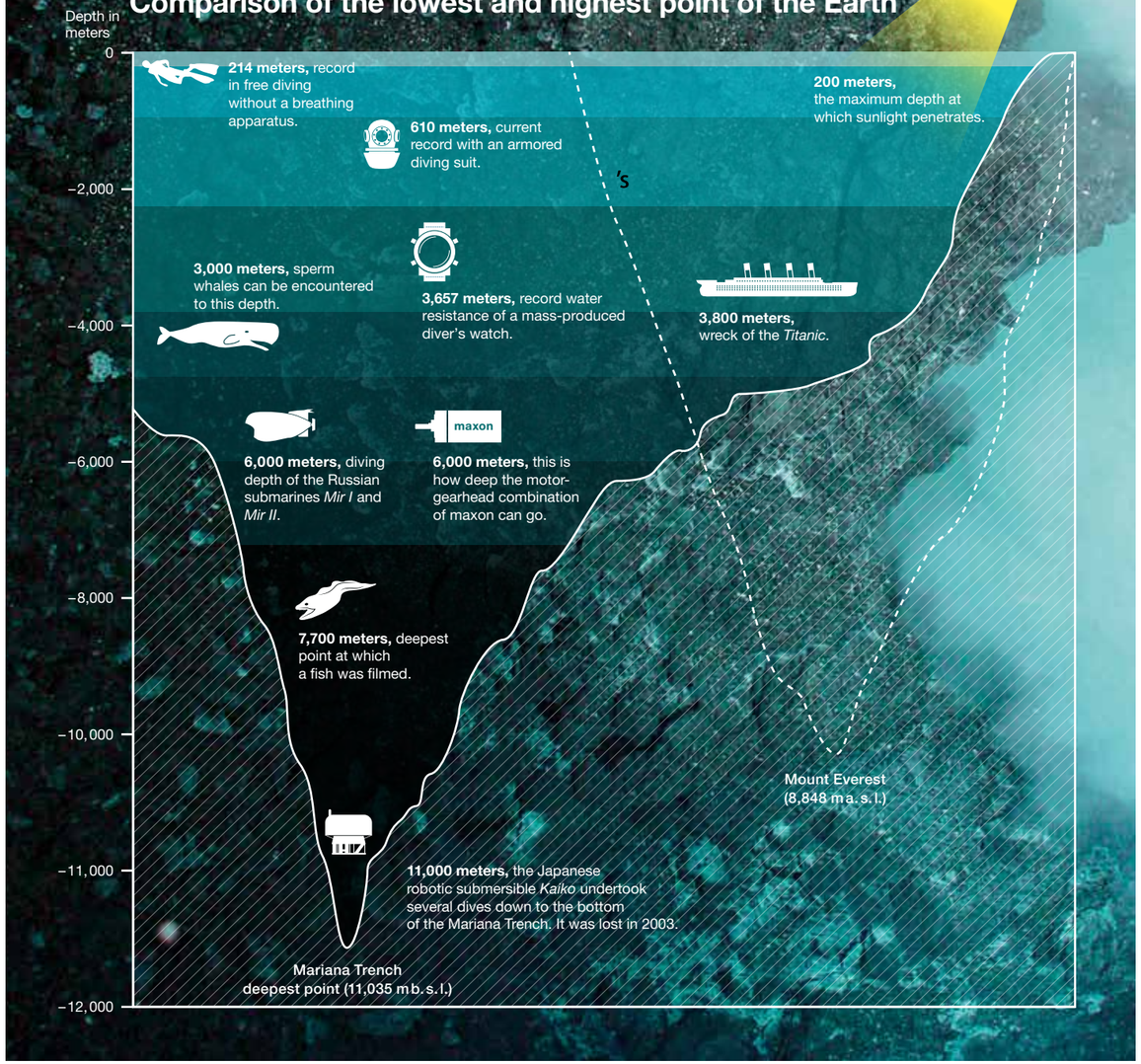
Photos: maxon motor ag, Seamor, NOAA Photo Library

The deep sea: **in eternal darkness**

When we refer to the deep sea, we are talking of a depth of 800 meters and more. It accounts for over 70 percent of the oceans and has still not been investigated very much. This is due to the fact that a murderously high ambient pressure, cold and darkness prevail in the deep sea. On-site research is time-consuming and expensive. New technologies could change this. Autonomous robots which can remain at such low depths for a long time are needed. This can be achieved, among other things, by using better batteries, energy-efficient actuators and intelligent software.



Comparison of the lowest and highest point of the Earth



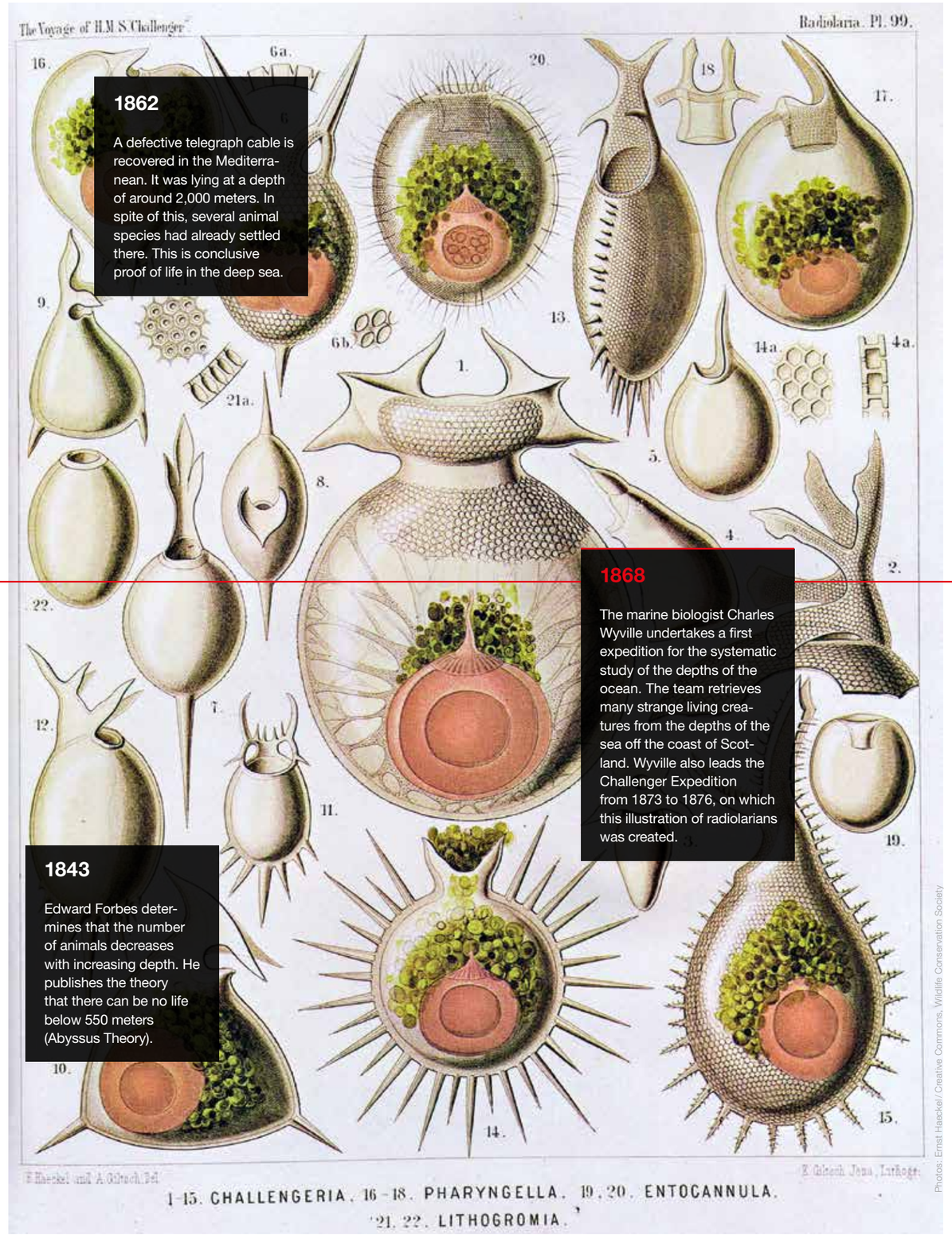
The secret world of the deep

The deep sea is a young field of research. Even as little as 150 years ago scientists believed that there was no life below 550 meters. Today we know better. And yet the deep waters still hold many secrets for us.

1521

The seafarer Ferdinand Magellan drops a rope with a weight at the end into the sea from his ship. The 700-meter rope does not reach the bottom, however, from which Magellan concludes: The sea is of infinite depth.

Photos: iStockphoto / Kuzma, DEA G Dagli Orti Avenueimages



1862

A defective telegraph cable is recovered in the Mediterranean. It was lying at a depth of around 2,000 meters. In spite of this, several animal species had already settled there. This is conclusive proof of life in the deep sea.

1868

The marine biologist Charles Wyville undertakes a first expedition for the systematic study of the depths of the ocean. The team retrieves many strange living creatures from the depths of the sea off the coast of Scotland. Wyville also leads the Challenger Expedition from 1873 to 1876, on which this illustration of radiolarians was created.

1843

Edward Forbes determines that the number of animals decreases with increasing depth. He publishes the theory that there can be no life below 550 meters (Abyssus Theory).

1930

William Beebe (pictured) and Otis Barton dive to a depth of 435 meters in a steel ball with a bulls-eye window, where they are surrounded by jellyfish and shrimp. Four years later they reach a depth of 923 meters with the same ball.

Photos: Ernst Haeckel / Creative Commons, Wildlife Conservation Society

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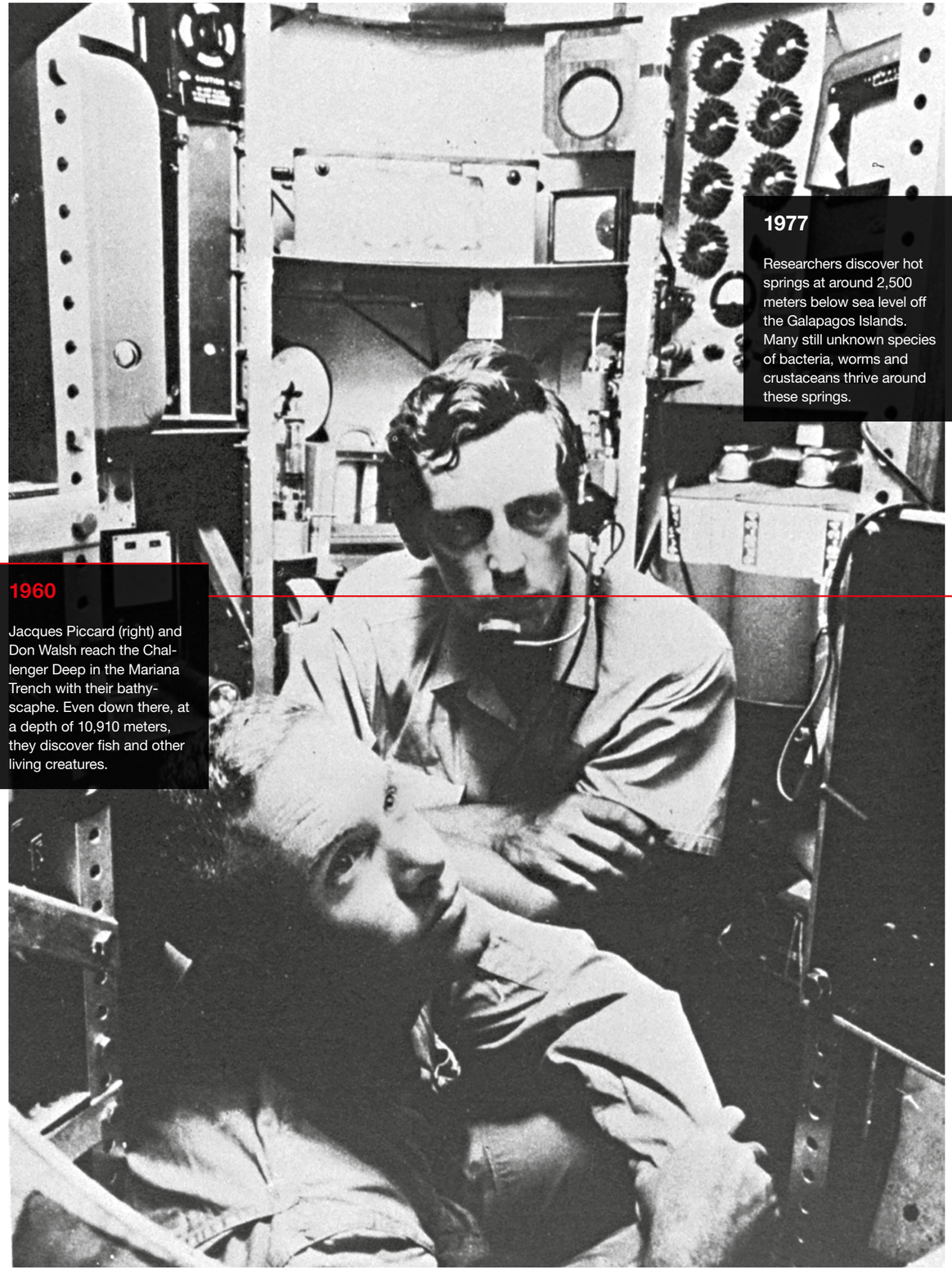

1960

Jacques Piccard (right) and Don Walsh reach the Challenger Deep in the Mariana Trench with their bathyscaphe. Even down there, at a depth of 10,910 meters, they discover fish and other living creatures.

1977

Researchers discover hot springs at around 2,500 meters below sea level off the Galapagos Islands. Many still unknown species of bacteria, worms and crustaceans thrive around these springs.

Photos: Steve Nicklas, NOS, NGS, NOAA, Ship Collection, Keystone / AP, National Geographic, Mark Thiessen

2012

The Canadian director James Cameron dives down to the Mariana Trench to a depth of 10,898 meters. He is the third person to reach this depth. And his submersible *Deepsea Challenger* is only the fourth man-made vessel to reach such low depths.

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Brave new **underwater world**

Engineers at the Robotics Innovation Center in Bremen have been working with underwater robots. They are intended to help us understand the world's oceans. And in the future also the deep waters of other planets.

Robotics Center

The German Research Center for Artificial Intelligence (DFKI) is Germany's leading institute in the field of innovative software technology based on artificial intelligence methods. It has a workforce of 800 spread across various locations. Around 130 employees and 80 students are working on 25 to 30 projects dealing with robots in space or in the deep sea at the Robotics Innovation Center in Bremen.

The passion of the engineers is apparent from the Christmas tree which stands at the bottom of a large water tank throughout December, prominently displayed for all the visitors to the German Research Center for Artificial Intelligence (DFKI) in Bremen. Buoyancy pulls the Christmas baubles upwards. Fairy lights provide suitable lighting – with 230 V. But don't worry. The researchers know what they are doing. Underwater technology is their specialist area. They decorated the Christmas tree for the fun of it in their spare time. "With the excellent conditions here at the institute, the motivation for trying out innovative new approaches is particularly high. Sometimes we enjoy staying here longer," says Peter Kampmann, research associate and specialist in underwater robotics at the DFKI Robotics Innovation Center.

Kampmann takes us through the large maritime exploration hall of the DFKI, which was opened two years ago. This is home to a Europe-wide unique testing system for diving robots: a saltwater basin eight meters deep and with a capacity of 3.4 million liters. Perfectly suited for testing new underwater systems, which inspire ships and pipelines to explore unknown waters or perform measurements in the deep sea.

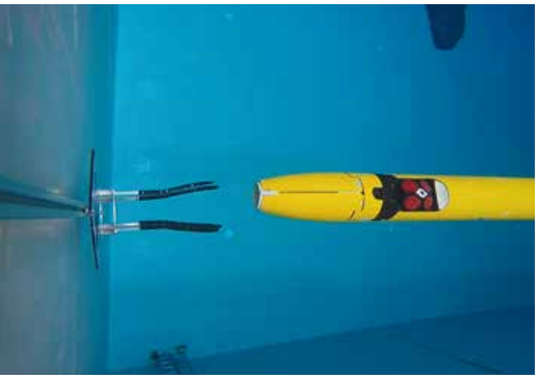
The maritime sector has led a shadowy existence for a long time. Large sections of the deep sea are still uncharted, for example. So we don't know what it looks like exactly down there, at a depth of 3,000 to 6,000 meters. There are more accurate maps of even the surface of Mars. But in the next few years all this is set to change – also due to modern technologies.

The Robotics Innovation Center of the DFKI is working closely together with the engineers at maxon motor on new underwater drives with brushless DC motors. They are pressure-tolerant, compact and energy-efficient and ideally suited for ROVs (remotely operated vehicle) and AUVs (autonomous underwater vehicle). A development which comes in handy for Peter Kampmann and his colleagues. "New components which are lighter and more powerful open up completely new opportunities for us."

The polar bear comparison

The trend in underwater technology is moving towards "small and intelligent."

Photos: DFKI/Annemarie Bartl



The Europa Explorer (left) is to be used to explore Jupiter's moon Europa. Peter Kampmann and his colleagues at the DFKI are testing new approaches to control and navigation with the Micro-AUV.

Engineers are currently building vehicles which are equipped with sensors and electronics. The machines should be able to carry out research, collect data and react autonomously to different scenarios for months without any human intervention. Not an easy task in such tough conditions, for visibility is poor in the sea and wavelengths which are used for GPS or WLAN signals are quickly absorbed in water. This makes navigation difficult. The saltwater also attacks the components, and even corrodes stainless steel after a certain time. Sensitive parts such as motor shafts should therefore be made from titanium. And last but not least, there is the high ambient pressure. The pressure at 6,000 meters is 600 bar. This is roughly comparable to a fully grown polar bear sitting on an area of only one square centimeter. The Robotics Innovation Center can simulate such values in a pressure chamber. maxon motor also had its specially developed underwater drives tested here. Components at a depth of 6,000 meters can be used in over 95 percent of the world's oceans.

Every gram is important

While walking through the Robotics Innovation Center of the DFKI we come across several underwater vehicles. Take, for example, the Micro-AUV. As the name says, it is particularly small and is used by researchers to test new approaches to control and navigation. Everything on this vehicle must be designed to achieve minimum residual buoyancy. Every additional gram of buoyancy plays a role under water. For if a system should fail at any time, it must rise to the surface through positive buoyancy control, otherwise it will be lost for ever. The Micro-AUV is driven by four maxon DC motors. They are particularly energy-efficient drives and enable a long service life in spite of the small battery.

Trip to Jupiter's moon soon?

Another of DFKI's exciting projects is the Europa Explorer, an underwater exploration vehicle, which is long and shaped like a thin cigar. The long-term objective of this project is the exploration of Jupiter's moon Europa. It is covered with a 3- to 15-kilometer-thick layer of ice, under which lies an ocean. The DFKI is researching into the potential of such a mission on behalf of the German Aerospace Center (DLR). This would involve – according to the current theory – the AUV reaching the underground ocean inside a drill, where it then detaches itself, autonomously collects data and then sends it to the Earth. The current test type at the DFKI is equipped with a maxon Escon Module 50/5 motor controller. It is particularly popular on account of its dynamics and assist function. "The controller autonomously detects sources of error, which makes our work much more pleasant," says Peter Kampmann.

And after the visit to the DFKI Robotics Innovation Center it's clear: The field of underwater applications is no longer characterized by large, robust components and improvisations. Sensor technology, automation and robotics are also playing a role in the meantime. A promising starting point for the future.

MT30:
Oil-filled underwater drive comprising a brushless DC motor, planetary gearhead and controller. Pressure-tolerant up to 6,000 meters in depth.

Special deep sea drives

EVENT

Meeting of international underwater experts

Experts in underwater technology will meet up on May 3, 2016 in New Orleans (USA) at the Aquatic Solutions Conference (ASC). The aim of this international non-profit conference is to gain a better technical understanding of underwater applications. The focus is on electric actuators. At the ASC academics and industry experts will discuss new ways of meeting the challenges posed by the deep sea. The event will be organized by maxon motor together with the DFKI.

asc-conference.org

Photos: DFKI / Annemarie Hirth, maxon motor ag

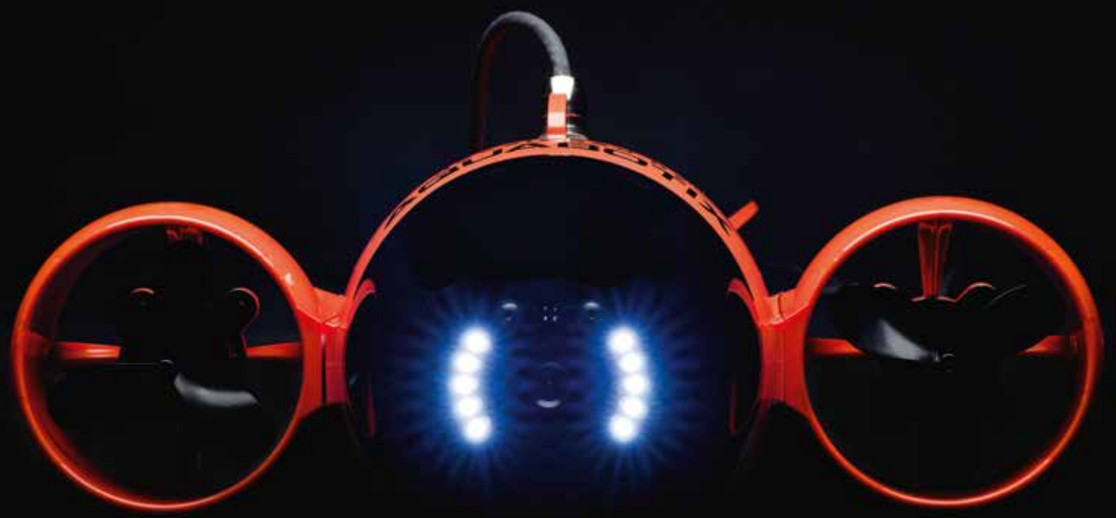
maxon motor is venturing into the dark depths of the ocean. After a two-year development period the Swiss drive specialist is presenting its own underwater drives. These thrusters consist of a brushless DC motor, a gearhead and a controller. Added to this is the housing and a propeller. The unit is designed for use in seawater, withstands pressure at a depth of 6,000 meters (600 bar) and is corrosion-resistant. To ensure this, maxon used mainly titanium and plastic. The engineers cooperated with the German Research Center for Artificial Intelligence (DFKI) to carry out development work. The institute is specialized in underwater vehicles. The first model of the thruster, the MT30, is available this year as a standard product. Other sizes (20-, 40- and 70-millimeter diameters) are planned.

Oil-filled and pressure-tolerant

maxon offers a pressure-tolerant drive system as a standard solution for custom underwater applications. The core element is a motor-gear combination, comprising a brushless DC motor and planetary gearhead. For corrosion protection the drive is encased in a plastic housing and sealed with two titanium flanges. It can be connected to a compensator. The oil-filled drive unit is connected to the compensator via a tube. The water pressure is transferred to the oil by a membrane, which, depending on the depth of the water or water pressure, is compressed by a particular volume. The drive is equipped with connectors to connect the control electronics. The compact underwater drive is available with diameters of 16 to 42 millimeters. And this will be customized depending on the customer's requirements.

aquaticsolutions.maxonmotor.de

Pressure-tolerant underwater drive with motor and gearhead from maxon.



Underwater eye

The dream of every weekend submarine commander: an underwater vessel that can produce high-resolution videos and is easy to control – even with a smartphone.

The engineers at Aquabotix Technology Corporation have been inspired by the sleek design and smooth movements of marine life. They challenged themselves with designing the world's most easily operated ROV (remotely operated vehicle) that is also affordable and fun. The company's Sport Model HydroView produces live video, captures photos, and streams them to a smartphone, tablet or laptop and can be operated by tilting the phone or tablet or via the laptop's touchpad. It brings accessible consumer electronics products smoothly into the complex world of underwater video.

The HydroView weighs less than five kilograms, and comes with a waterproof carrying case and a 22-meter cable. The unit's topside box produces localized Wi-Fi technology so that users don't have to search for a signal while floating on the water. The HydroView communicates from the user's handheld device to the HydroView's topside box, which in turn connects to the submersible vehicle via a cable tether. LED lights and an HD camera provide a direct human-to-machine interface. Intuitive, user-friendly screen displays help make control of the device easy. Operations are designed to imitate video game screens to provide a familiar feel to functionality.

maxon A-max 26
Ø 26 mm, graphite brushes, 7 W

Photos: Aquabotix, maxon motor ag

Three DC motors for the propellers

The ability to accurately control movement is required to make it easier for the user to get the desired information – whether that is to inspect an anchor, view the hull, check propellers, assess the rudder, or take underwater video. Users can study sea life, search for lost objects, or explore shorelines. Commercial uses for the professional series include inspecting tanks and underwater infrastructure, performing search and recovery missions and monitoring aquaculture operations.

The motion system consists of three propellers, one on either side and one rear-oriented, each run by a separate brushed DC motor manufactured and designed by maxon motor. A-max motors provide the required high torque values in a small package. The 26-millimeter motors are also lightweight and efficient, allowing the unit to operate up to three hours on a full charge. More importantly, the maxon motors delivered a smooth, low-vibration operation. This was important, since the HydroView required a longer motor shaft, which would amplify any vibration created inside the motor. Besides corrupting the received video, vibration could cause system leaks, compromising all the electronics and drive functions.

The HydroView remotely operated vehicle operates from 10 volts DC for up to three hours dependent on how it is used. It can be controlled using an iPad or PC laptop.

The photographs and videos can be streamed directly on a smartphone, tablet or notebook.

Tail provides pitch control

Side motors are speed-controlled for vehicle maneuvering. Right and left movements are controlled through coordinated adjustments. The third A-max motor in the tail of the HydroView provides pitch control. Forward motion maxes out at about 3 knots, and depth of the unit is rated to 45 meters. The side propellers are set at two different pitches, so the motors run in opposite directions, which help to stabilize the vehicle in the water.

The unit has full Linux functionality onboard and can be programmed in a variety of languages, including C or C++, while the iPad version uses the COCOA environment. The PC version can be programmed using Java as well. Since the operation of the vehicle acts similar to that of working with a video game, almost anyone can begin using it fairly quickly.

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Only the right controller brings out the best in your motor

Robotics and automation call for increasingly precise control engineering. Daniel Hug, Product Manager for Electronics and Systems Technology at maxon, explains what a good motor controller has to be able to achieve today.

EPOS4
positioning controller

maxon motor control

For over 25 years maxon motor has also been focused on the area of motion control, the dynamic control of brushed and brushless DC motors. The goal is to be able to offer the customer an optimum system solution with all drive components: from the gearhead through the motor with a sensor to the suitable controller. To this end, a team of around 40 employees is dedicated to the full development and support of a wide variety of motion control products and customer-specific solutions. In this area, over half a million products from simple current or speed controllers through to multi-axis, highly dynamic controllers are sold every year.

Daniel Hug, motor controllers have become better and better over the years. What does this look like in practice?
The rapid changes in information technology have also led to the rapid development of opportunities for controllers. To put it bluntly, in the past it was simply about leaving the motor running. Today's requirements are more complex. Topics such as diagnostics, networking or functional safety are becoming increasingly relevant – it is no longer just a matter of controllers in the narrower sense, but rather small complete systems.

What should a good controller be able to do today?
On the one hand, a good controller must offer a lot of functionality and flexibility of use. On the other hand, it must be easy to commission and operate. This is one of the major challenges that manufacturers of controllers currently face. Efficiency and compactness are also often determining factors.

maxon motor has a variety of motor controllers on offer – what are the current top sellers?
Our portfolio covers everything from simple current and speed controllers to highly dynamic motion controllers. And last but not least the motor-integrated controllers. But the EPOS product line remains our backbone.

What's so great about the EPOS product line?
EPOS stands for Easy to use POsitioning System. This is our maxim. The customer should be able to very easily obtain a high-performance positioning system with DC and BLDC motors without an in-depth knowledge of drives. The following three components are particularly important:

- The EPOS Studio: An intuitive graphical user interface (GUI) with many small tools such as the Startup Wizard. This guides you step by step through the whole configuration from A to Z so that nothing is forgotten. Or Auto Tuning. This configured system automatically searches for the ideal control parameters at the touch of a button and after this is ready to use.
- Comprehensive documentation with our strong support.
- Numerous libraries for integrating EPOS into a wide variety of systems and a host of practical examples.

We offer all of this free of charge. Competitors can often only offer parts of this, for which there is usually also a charge.

The new EPOS4 positioning controller is available from April 2016. What has changed?
The new feature of the EPOS4 is the very high power density. By optimizing efficiency and a well-conceived thermal design we achieve maximum output power in an extremely small space. EPOS4 also offers a modular expansion concept for Ethernet-based interfaces such as EtherCAT as well as various absolute encoders. The customer can then put together his own optimum system and only pays for what he actually needs. We are also offering new features.

Photos: maxon motor ag

Daniel Hug is Head of Electronics Product Management at maxon motor. As a graduate electrical engineer with many years of experience, he is responsible for the product design and for the implementation of development projects – from the idea to the finished drive solution.

Where should EPOS4 be used?
EPOS4 will form a complete product line. We cover the whole range of motors available at maxon – and all areas of application too. EPOS4 is suitable for applications where a cost-effective, high-performance torque, speed or positioning controller is required. A controller which is easily integrated into a variety of master systems, whether as a single-axis system or for complex multi-axis applications.

What are the advantages for the customer when he uses maxon controllers?
The major advantage is the optimum coordination of the individual components. In practice, controlling our highly dynamic low-inductance motors in particular requires a suitable controller in order to be able to really take advantage of the benefits of our drives. This is where many products fail, at the latest during manual fine-tuning of the controller.

A good controller must offer a lot of functionality and be easy to commission.

Our algorithms for automatic tuning developed over a number of years, on the other hand, make this step very easy.

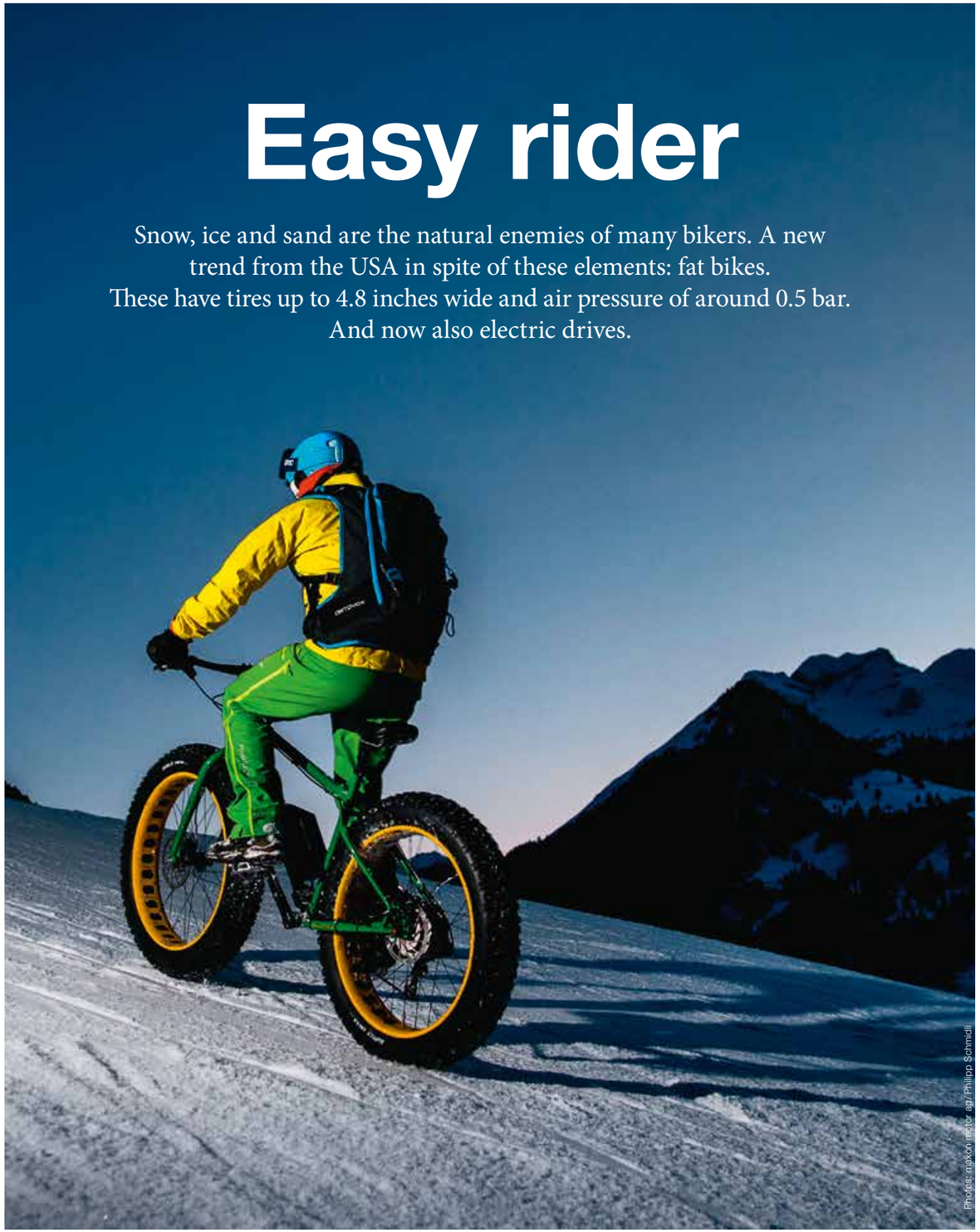
Do you also offer customer-specific solutions?
Of course! In fact the majority of our controllers sold are customer-specific solutions. The range is enormous: from a small firmware adjustment which makes sense for small quantities, through to tailor-made, complete application solutions – also in the high-volume range. A specific solution may make sense wherever a catalog product does not fully meet customer requirements. Here at maxon we can call on a strong engineering team and many years of experience.

What are the challenges when customers come with specific wishes?
The biggest challenge is defining the requirement together with the customer to find as ideal a system solution as possible. Often the customers is not aware of all the options. We can then lay the foundations for added value in the discussion.

How do you ensure local and good customer service?
We have our own team of application and support engineers for this. They look after our Service & Support Desk, an online-based tool which is available to customers for enquiries at all times (support.maxonmotor.com). Together with our application specialists on site, we create a global and competitive network which can quickly respond to customers' wishes.

Easy rider

Snow, ice and sand are the natural enemies of many bikers. A new trend from the USA in spite of these elements: fat bikes. These have tires up to 4.8 inches wide and air pressure of around 0.5 bar. And now also electric drives.



Photos: maxon motor ag / Philipp Schmidli

Like so many trend and extreme sports, fat bikes and snow bikes come from North America. Alaska, Minnesota and New Mexico are typical fat bike regions. Snow, ice, sand or slush are elements which an average cyclist happily avoids. But not the fat bikers. The extremely wide tires and rims make air pressures of around 0.5 bar possible. The large support surface enables the driver to ride on even very soft surfaces without sinking. There is also a lot of traction and low rolling resistance on terrain. There is one drawback, however: Riding uphill with the fat bike is tiring – on account of the difficult ground conditions and the wide tires. And this is where a new solution comes in: high-torque electric drives.

The Bikedrive provides more thrust

It's fun to ride in the snow with the right motor support. This can be seen in the motocross and snowmobile videos on YouTube. The same applies to fat bikes.

Motor support enables you to speed along the winter trails, negotiate every hump and even sometimes create a snow cloud with the back wheel.

This raises the following question: Who needs this anyway? Finally, you could compare the fat bikes to SUVs – oversized for normal use. The answer: Fat bikes are for cyclists who simply want to stay independent in all weathers. As they say: Come what may.

And a real offroader also needs a strong motor. The maxon Bikedrive, for example. The Swiss rear motor with a robust planetary gearhead provides a lot of thrust on every surface. Thanks to the instantaneous acceleration, in boost mode with a torque of 50 Nm, you are equipped for every situation.

The maxon Bikedrive can currently be installed in any fat bike with a 135-millimeter rear axle. These type of models are offered by the well-known fat bike manufacturer Surely, for example.

For the latest information, go to:
maxonbikedrive.com

Photos: maxon motor ag / Philipp Schmidli

maxon Bikedrive – Technical details

Motor
Weight: 3.5 kg
Continuous torque: 25 to 30 Nm
Max. torque: 50 Nm
Efficiency: 85 percent

Battery
48-V lithium-ion battery with 360 Wh
Weight: 2.8 kg
Full power after two hours of charging (70 percent after 60 minutes)
Range: 1,000 to 1,400 meters of elevation gain (depending on the weight of the cyclist)

Power grip
3 stages + Turbo Boost
Temperature monitoring with status LED

The main question: **DC or BLDC motors?**

Brushed and brushless DC motors have both advantages and disadvantages. But what type is better suited for the application in question? We provide advice.

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, both for the employees at the maxon headquarters in Sachseln and for the international sales network, as well as for customers. He has 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.

Anyone requiring compact DC motors from drive technology must first make a choice: between brushed DC motors and brushless DC motors (BLDC). The latter are also referred to as EC motors at maxon (electronically commutated). In the following we will show you different criteria for selecting the right motor type for a particular application.

Service life

The commutation system with brushes limits the service life of a DC motor. The service life is usually several thousand, in the best case as much as up to 10,000 hours, it may, however, also be limited to a few hundred hours. It is hardly possible to make a concrete statement as there are no reliable calculations. The service life depends heavily on the load: High current, high speed, reverse operation and high vibrations reduce the service life. For an estimate, it therefore makes sense to make a comparison with a similar application.

With brushless DC motors, the ball bearings limit the motor's service life, which can be estimated quite precisely. The bearings are typically designed for several 10,000 hours.

The following still applies: A service life of several thousand hours is sufficient for many applications.

What are the differences between speed and torque?

As a starting point, let us consider a brushed DC motor of a given size. It enables speeds up to max. 20,000 rpm. In most cases the maximum permissible speed is under 10,000 rpm, however. Higher speeds have an impact on the motor's service life – it is reduced significantly with increasing electrical and mechanical wear.

A comparable brushless DC motor in terms of size and magnetic structure can be operated at considerably higher speeds, in individual cases of over 100,000 rpm. These types of drives are therefore perfectly suited for use in applications which require high speed, such as for industrial cutting and milling tools or certain fans.

It is an interesting fact that brushless motors are often designed with multiple poles. This increases the torque, but at the cost of the speed, however. For many applications don't require extremely high speeds, but a little extra torque is very welcome. And yet: One of the main advantages of brushless motors are the higher speeds.

So please note: These versions are only trends. Which speeds and torques are possible must be clarified for each specific type of motor.

Photos: maxon motor ag

	DC motors with brushes	EC, DC motors, brushless
		
Service life	The service life of a DC motor of typically several thousand hours is completely sufficient for many applications. How long the brushes last, however, is very difficult to predict. Factors such as current, speed or vibrations have a major impact.	The service life of brushless DC motors is determined by the ball bearings. Their wear can be estimated quite precisely. They usually last for several ten thousand hours.
Speed	**< 10,000 min^{-1}** Brushed DC motors usually reach speeds of 10,000 min^{-1}, which is completely sufficient for many applications. Higher speeds are possible, but reduce the motor's service life.	**< 120,000 min^{-1}** Speeds of up to 120,000 min^{-1} are possible with electrical commuted motors. They are therefore perfectly suited for industrial milling machines or fans.
Special environment	**Special environment** **Brush sparking** – Electromagnetic interference in explosive environment **Abrasion of graphite brushes** – In cleanroom applications – In optical systems – In high and ultra-high vacuum **Lubrication of precious metal brushes** – In high and ultra-high vacuum	**More easily adaptable for** – High and low temperatures – Operation in vacuum – Operation in oil – Sterilization in autoclave – Vibrations and shocks
Operation	DC motors with brushes are very easy to operate. All you need is voltage at both connections and the motor runs.	BLDC motors require additional commutation electronics simply to have the motor running.

Special ambient conditions

The brush system of DC motors may result in complications in some specific applications:

- Brush sparking causes electromagnetic interference, which may have to be damped. These type of motors can therefore not be used in explosive gases. However, a brushless motor also requires modifications to be explosion-proof.
- Graphite brushes generate graphite dust, which can contaminate cleanrooms, vacuum or optical applications.
- Graphite brushes need a certain amount of moisture and some oxygen in the atmosphere to be able to function well.

Precious metal brushes must be lubricated. Both brush systems are therefore not suitable for high-vacuum applications.

For these reasons most motors for use in special ambient conditions are brushless. This applies, for example, to ultra-high vacuum applications, deep-drilling applications or to sterile devices for medical technology.

The Dragon capsule developed by Space X, which supplies the ISS with material, uses maxon brushless motors to set the solar sails.

For the world's first cordless tattoo machine, Swisstattoomachine relies on maxon's RE 13 motor. The drive offers excellent energy efficiency and dynamics.

Control and operation

No motor is as easy to operate as the DC motor with brushes. Voltage at both connections is sufficient and the motor runs. A brushless motor, on the other hand, requires additional commutation electronics. Cabling is more extensive as there are up to eight connections.

The situation changes, however, with controlled drives: The controllers can mostly be used for speed, position or torque for both types of motors (DC and BLDC). In these cases the costs for electronics and the feedback sensor and cabling work are very similar.

Conclusion

Brushed or brushless motors? Various criteria play a role in this decision. Whether you use a brushed or brushless DC motor depends on various criteria:

- The required speed: Brushless motors are an advantage at high speeds.
- The service life: Brushless motors are also an advantage with a long service life.
- Ambient conditions: Adjustments are easier in most cases with brushless motors.
- Cabling and operating costs: Brushed motors are an advantage with simple drives.

Whether you decide on DC or BLDC motors ultimately depends on technical considerations. Ambient conditions, aspects relating to service life and economic considerations also play a role, however. If you require support in selecting a drive, the experts at maxon motor will assist you.

1977

For nostalgics: the home tape recorder

Analog home tape recorders were the dream of every music lover in the 1960s and 1970s – maxon motors ensured smooth drive operation. A look back in history.

In 1977 Uher-Werke in Munich launched the SG 630 hifi stereo tape recorders. "A tape recorder offering a touch of class, for every taste, with almost all possibilities that an audio amateur could wish for" (taken from an advertising brochure). At that time Uher had designed a completely new deck, with new control technology and a tape drive system (4-motor drive).

maxon DC motors were already in use in the high-tech giants of the '70s. And exactly four. One of them was a "commutatorless" DC motor (today it would be called a brushless motor). As a so-called capstan motor, it had the task of driving the shaft next to the tape head and controlling the synchronization of the tape.

Two further maxon DC motors which were produced at that time under the designation 2060.800 had to be developed especially for the application. The extraordinary thing is that the large 27-centimeter spools of the tape recorder were driven directly by the two maxon motors. This means that in the "Recording" position one motor constantly pulled the tape and the second motor slowed the tape down to avoid tangled-up tape. The manufacturer praised the "new" ironless DC motors and had decided to use them "as they had a much lower moment of inertia compared to conventional motors." A further conventional servo-gearhead motor was used for the "Omega loop" of the tape, a special geometrical structure of the gearhead used to transport the audio tape as error-free as possible.

At that time this type of tape recorder was considered to be cutting-edge technology. This technology proved itself for only a few years, however, and in the end disappeared completely from the market due to the triumphant success of digital technology. Admittedly the devices developed by Uher had many flaws – most tape recorders had to be repaired again after a few days, which was not due to the motors, however. There are still nostalgics today who are trying to bring these tape recorders back to life. Some enthusiasts believe the sound from an audio device of this type to be much warmer and pleasant than that of a CD.

Record players with maxon motors

High-precision maxon DCX motors are currently used in the audio sector mainly for expensive luxury equipment, such as in record players from Kronos. In terms of its unique construction and technology, this audio device offers precision like hardly any other player. This is also down to the fact that its turntables are driven by two maxon DC motors.

Photos: Space Exploration Technologies Corp., Philipp Schmidli/maxon motor ag, Uher, Kronos Audio

“I just want to **walk, walk, walk”**

Every year 130,000 people throughout the world end up in a wheelchair on account of paraplegia. Including Andre van Rüschen. Since a car accident he can no longer feel his legs. In spite of this, he still walks every day.

In the meantime he even manages to climb steps on his own. Andre van Rüschen stands with one hand on the handrail and with the other hand supports himself on his walking stick. His legs negotiate one step at a time and when he reaches the top he smiles. Walking gives him a feeling of pure happiness. For Andre is a paraplegic.

His spinal cord was severed in a car accident in 2003 and since then he has not been able to feel his lower body. Despite this, he currently walks upright every day. An exoskeleton assumes the function of his legs. This is a mechatronic support and movement system where motors perform the movement of the hips and knees. The Israeli company ReWalk Robotic develops these systems and is already considered to be well established although the market for exoskeleton is still young. Their products are approved for private use in the US, Europe and other countries. More than 80 people currently have a ReWalk system at home. More than 120 training centers worldwide are equipped with these devices.

Photos: ReWalk Robotics, maxon motor ag

“Such a great feeling”

In 2012 Andre van Rüschen applied to ReWalk to be a test person and was then invited to London to a training camp. There he learned to stand, run and turn round with the exoskeleton. The controller works using a wristwatch-like control device and via shifting of weight. A carer provided him with assistance. Later the family man from Germany was able to move on his own. “It is such a great feeling, almost like floating. As soon as I strap on the exoskeleton, I just want to run, run, run.”

When paraplegics can suddenly walk independently again, this has a positive psychological effect. “A different perspective again.” “Meeting people at eye level.” But not just that.

Andre van Rüschen on the move with his ReWalk exoskeleton.

maxon GP 42 C
Ø 42 mm,
ceramic-reinforced

maxon RE 40
Ø 40 mm,
graphite brushes,
150 W

Clinical studies have shown that walking and standing more is also good for your health. Exoskeleton users have an improved bladder and bowel function, more restful sleep and generally less pain, with the result that they need medication less often. Andre's frequent back pain and chronic bladder infection have also almost completely disappeared since he can walk again.

Quicker and therefore safer

The current model he uses is ReWalk 6.0. With previous systems, the battery had to be carried as a backpack. It is now built into the structure and provides power for one day. This means that the exoskeleton is completely self-supporting. It can be individually adjusted and is suitable for people up to 1.90 meters in height and weighing up to 100 kilograms. ReWalk has also developed a natural gait and increased walking speed to 2.6 kilometers per hour. Users are safer when walking among other pedestrians.

ReWalk uses four maxon brushed DC motors for the knee and hip movements. The RE 40 units are used in combination with a planetary gearhead GP 42 C, which is equipped with ceramic components. This significantly extends the service life of the drives, which is crucial when used in the 6.0 model. For according to ReWalk product manager Andreas Reinauer, the exoskeletons are designed for five years or one million steps. "For this reason the motors must be very reliable, low-maintenance and powerful yet small." We found the right partner in maxon motor: "Projects are executed professionally, deadlines, specifications and budgets are always adhered to."

Andre van Rüschen sets his exoskeleton in motion with his wrist-watch-like control device.

With the ReWalk to the Cybathlon

Exoskeletons have already reached a significant level of technology. But development continues and according to Andreas Reinauer its momentum will surprise a lot of people. "Systems will most probably become smaller, lighter and more intelligent through the use of high-tech materials and synergies from research." An equally important aspect is the financing of these exoskeletons (around 70,000 Euro) through health insurance schemes. This has already happened in individual cases but is still not a matter of course. For this reason ReWalk wants to campaign for more acceptance – amongst other things by taking part in the Cybathlon competition, which is held in Zurich in the fall (see box). "We want to show that in addition to everyday obstacles, an experienced ReWalk user is able to cope with a difficult course."

Andre van Rüschen is entering the race. He has to overcome six obstacles, which isn't easy at all. He managed three in the test run in 2015. But he was still using the older model then. And so the members of the ReWalk team are confident that they will be first across the finish line ahead of all the other participants.

CYBATHLON

Competition for bionic athletes

Parathletes compete against each other with state-of-the-art technology at the Cybathlon. There are six disciplines for motorized wheelchairs, arm and leg prostheses and exoskeletons, among others. The aim is to complete an obstacle course as correctly as possible. The time required is secondary. The Cybathlon will premiere in Switzerland on October 8, 2016. 58 teams from all over the world will take part. The idea behind it comes from the ETH Zurich, which by holding this event wants to break down barriers between people with disabilities, science and the public.

cybathlon.ethz.ch

Photos: ReWalk Robotics, Fotolia / Jag cz, maxon motor ag, Sea-Doo

CONTEST

How many maxon products are hidden under water?

Count how many maxon motors, gearheads and controllers are hidden in our underwater picture puzzle. Send your answer by e-mail to driven@maxonmotor.com and dive down into the underwater world with a diving scooter.

The deadline for participation is July 31, 2016.

Employees of maxon motor are not eligible to participate. There will not be any correspondence in regard to the contest. Legal recourse is excluded.

The Sea-Doo Seascooter GTS offers the ultimate in fun both under water and at the surface of the water. 1-gear operation and ease of use with acceleration of up to 4.7 km/h.

Outlook 2 // 2016
Medical technology

Discover exciting new applications and interesting stories from the world of drive technology in the coming issue of *driven* – the maxon motor magazine, which will appear on November 7, 2016.

What aspect of this topic do you find particularly interesting?
Let us know on our Twitter channel @maxonmotor
or contact driven@maxonmotor.com

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