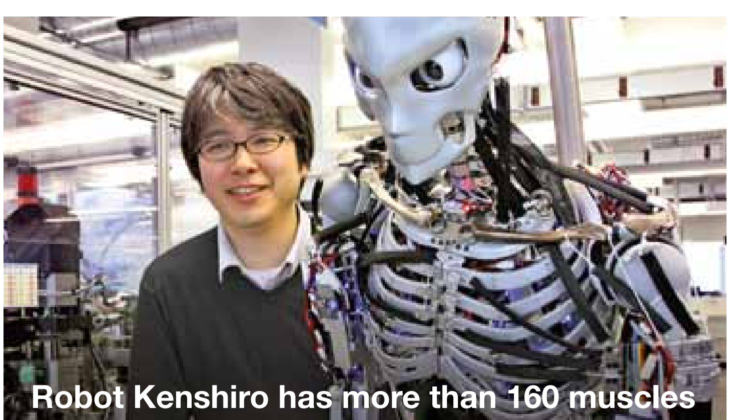
The maxon motor **magazine**

driven

1 // 2014

Revved up

Innovation for road and racetrack



Robot Kenshiro has more than 160 muscles

Long a source of fascination: flying cars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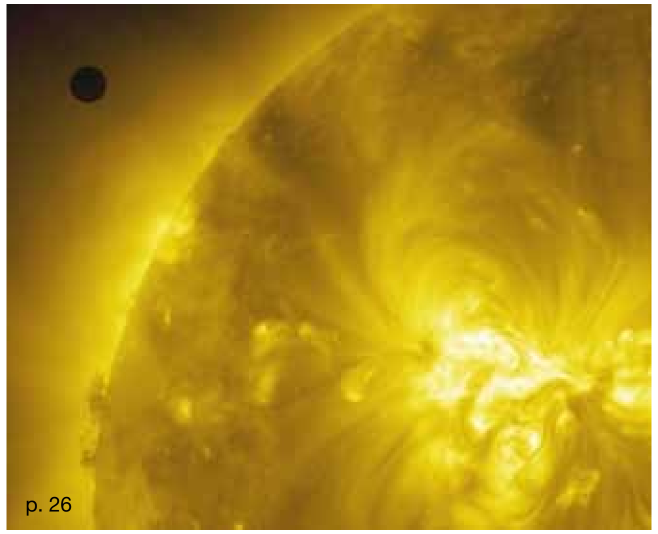
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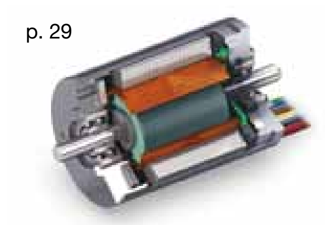
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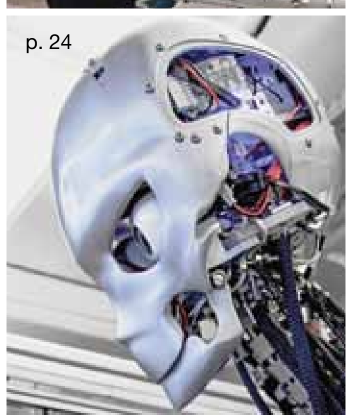
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Photos: Cover: Frame Eleven, maxon motor ag.
San Diego Air & Space Museum
Page 3: maxon motor ag

Editorial

When the small motor is as important as the big one


Eugen Elmiger, CEO, maxon motor ag

On the racetrack, every turn counts. The same is true for the road. This is one reason why engineers are developing smarter and smarter assistance systems for us drivers. Be it for efficient engine performance, better aerodynamics, or improved safety. This usually requires small, reliable drives that generate a lot of power without taking too much space. In this issue of driven you can read where maxon motors are used in racing and in passenger cars.
We've also prepared some exciting contributions from the field of robotics: Kenshiro, a 1.58 m tall humanoid robot, is an attempt to understand human movement through the robot's tendon-controlled movements. And youBot, the research robot from KUKA Robotics, is likely to revolutionize industrial research.

Happy reading!

The current tablet edition with interactive and multimedia features can be found in the Apple App Store and on Google Play.

Dr. Rainer Bischoff, the director of technology development for KUKA, about the youBot:

"We've developed youBot for research and teaching. youBot is delivered without proprietary control software. Instead, it comes with a rich pool of open source software, a PC board and an EtherCAT interface to connect to the drive electronics. This gives researchers and students a lot of leeway for the development of new algorithms for robot control."

EC 45 flat motors drive the youBot
Ø 22 mm, brushless, 100 W, with Hall sensors

Get The **Big Picture!**

Highly focused: Nirmal Giftsun (left) and Alexander Moriarty of Hochschule Bonn-Rhein-Sieg are participating in the Robocup 2013, a robotics competition attended by 2000 researchers and students from all over the world. They are hoping for a win in the discipline "Robocup@work". Their youBot has to find certain objects in an obstacle course and bring them to the proper place - fully autonomously, using only sensors and algorithms. The joints of the youBot contain flat motors by maxon motor. They are responsible for the precise and powerful movements of the robotic arm.

Learn more:
bigpicture.maxonmotor.com

Photos: Flickr / Robocup2013, maxon motor ag

Partnership

Redefining the kilogram

The kilogram is the last unit left today that is still based on a material artifact from 1889 located in Paris, France, and not on a natural constant. The so-called original kilogram consists of a 39 mm x 39 mm cylinder made from a platinum-iridium alloy. As a material object, this artifact changes over the years, for example through deposits of dirt or through wear. Forty prototype kilograms were distributed around the whole world at that time – there is also one in the vaults at METAS. When the prototypes were compared with one another, differences in the microgram range were found.

This uncertainty in the kilogram unit of mass has led to the decision to also define the kilogram by means of a natural constant. This project is to be realized using electrical units, e.g. with the help of a watt balance. In cooperation with maxon motor, METAS is currently developing such a watt balance, by means of which mechanical and electrical power are compared with one another.

An important function of the watt balance is performed by motors from maxon motor. The experiments for redefining the kilogram take place under conditions of high vacuum, which means that high demands are placed on the drives. Therefore vacuum-compatible maxon EC22 motors (100 W) with encoder and the maxon EPOS2 24/5 positioning controller are used for this application. To prevent the formation of particles, only brushless maxon motors are used. The system used is a 3-axis robot which performs various movements in order to carry out exact measurements during the experiment. The maxon drives are responsible among other things for the precise movement of a turntable and for the horizontal and vertical movements of various components of the measuring system.

Brushless EC22 motors with encoders from maxon motor are used in the watt balance of the Institute of Metrology.

13.63 seconds

2.7 seconds from 0 to 60 mph (97 kph). 5.6 seconds from 0 to 100 mph (160 kph). And even higher speeds are possible: The Hennessey Venom GT which, according to the Guinness Book, is the fastest production car in the world, accelerates from 0 to 300 kph in 13.63 seconds. The current record holder when it comes to top speed is still the Bugatti Veyron Super Sport at 431 kph. Thrust SSC, a rocket-propelled vehicle, even achieved 1190 kph. Anyone who drives fast needs not only special tires and a lot of gas, but also a lot of electronic assistance. maxon drives can be found, for example, in the safety and aerodynamics systems of sports cars and passenger cars.

Photos: Paliphot / Ali Eichenberger, Metas.ch, Hennessey Performance, maxon motor ag

NEW PRODUCTS

Sensorless operation

maxon ESCON 50/4 EC-S module

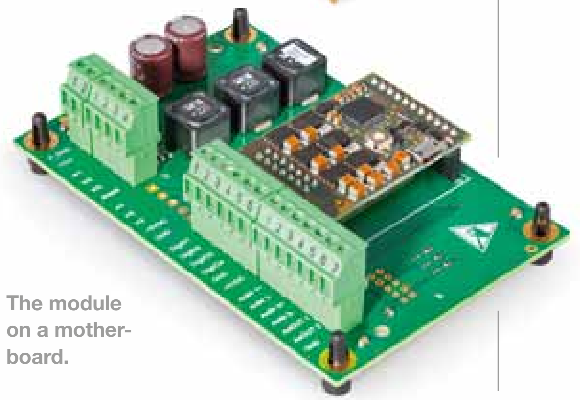
The ESCON 50/4 EC-S module is designed for efficient control of brushless and sensorless permanent magnet EC motors with Hall sensors up to approx. 200 W.

The powerful 4-quadrant PWM servo controller has excellent control characteristics and allows for a wide range of speeds up to 120,000 rpm. Thanks to its rich set of features and with fully configurable digital and analog inputs and outputs, it is the perfect match for dynamic drive solutions with maxon motors. The module is able to operate in closed loop or open loop mode.

All these are ideal prerequisites for use in cost-sensitive applications and applications with high requirements for reliability, e.g. medical devices used in respiratory therapy or handheld surgical or dental tools. The decisive characteristic is lower system complexity through sensorless operation.

The large ranges for input voltage and the operating temperature provide flexibility for many applications.

maxon ESCON 50/4 EC-S module



The module on a motherboard.

New:
DCX motor 16S / 32L GPX gearheads 16 / 22 low backlash / 32

New motors and gearheads

Our family of configurable products is growing

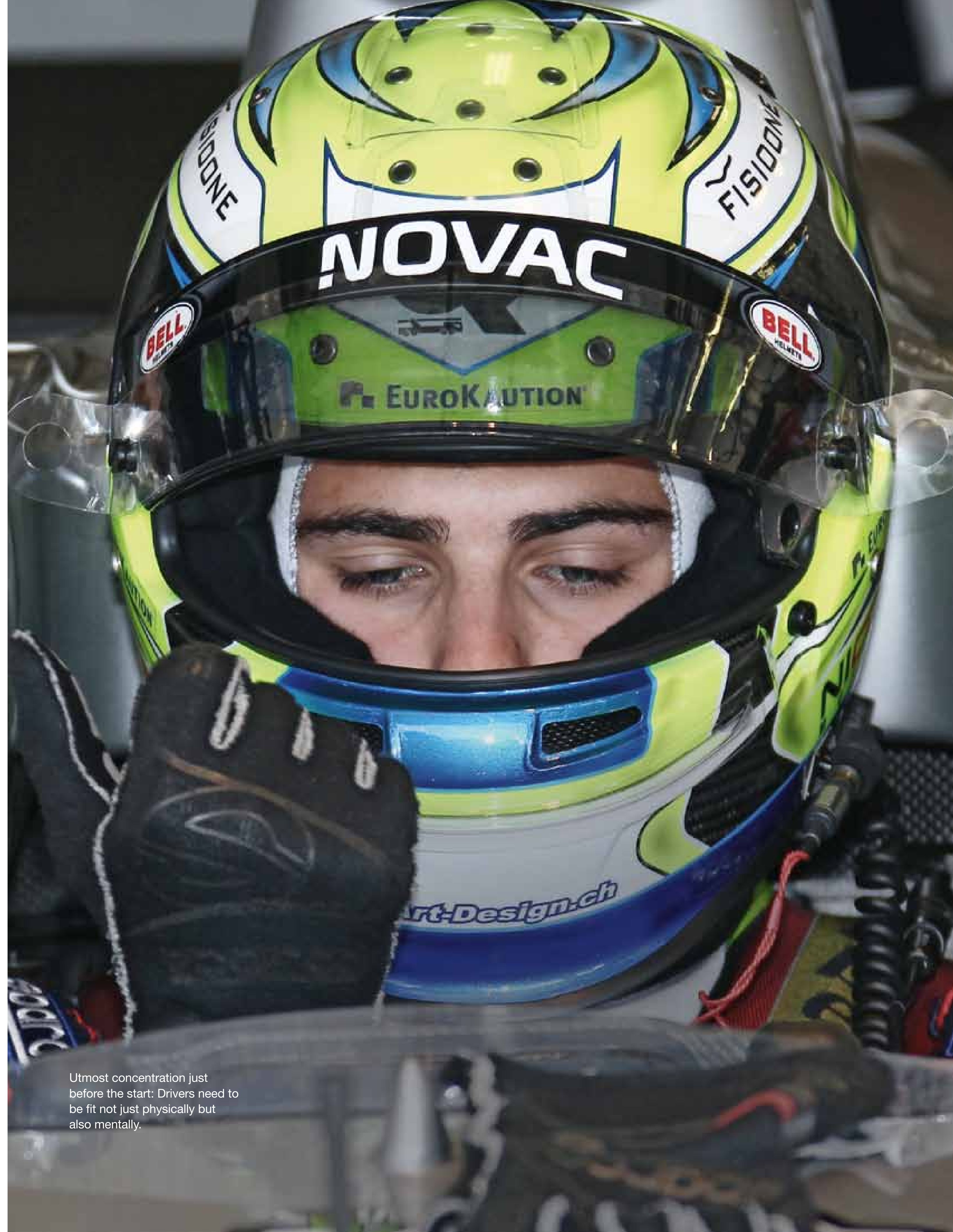
The configurable DCX product family now includes the two brushed DC motors DCX 16 S (up to 9.5 W continuous output power) and DCX 32 L (up to 110 W continuous output power). This expands the DCX portfolio to a total of seven motors with diameters from 10 to 35 millimeters. The GPX series of planetary gearheads has also been expanded with two new sizes: the GPX16 (up to 90 percent efficiency, short build) and the GPX 32 (one or two stages, up to 3.6 Nm short-time torque). There is also a version of the GPX 22 with reduced backlash.

Full throttle

Fast, competitive, spectacular: The Formula Renault 3.5 is seen as a crucial stepping stone on the way into the premier class, the Formula 1. Ambitious racers do not just bring their talent – they also have maxon motors on board to control the throttle of their 530-HP V8 engines.

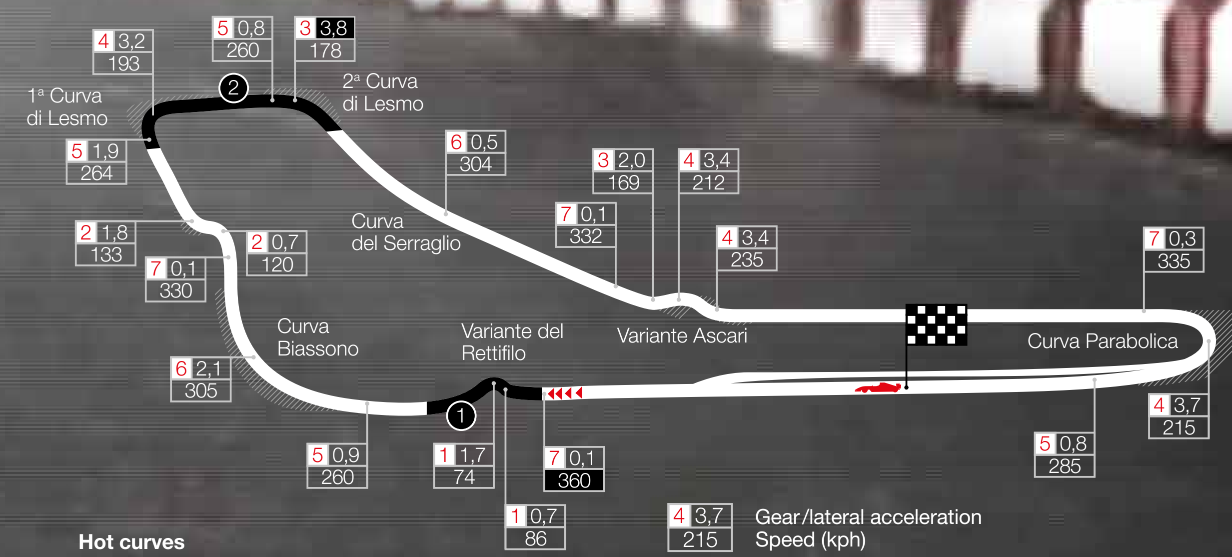
Article: Andreas Turner

Photos: Paolo Pellegrini, Nico Mueller



Utmost concentration just before the start: Drivers need to be fit not just physically but also mentally.

ON-BOARD CAMERA



Hot curves
The racetrack of the Autodromo Nazionale di Monza is technically demanding. Two turns are particularly difficult (see right). They demand extremely precise accelera-tion and braking. This makes reliable control of the motor's air intake through the throttle flaps even more important.

4 3,7 / 215 — Gear/lateral acceleration Speed (kph)

Run-out areas

Maximum braking force

1. Risky: Here, the cars in front are braking while cars in the back are still accelerating.
2. Demanding: Staying on the road can be difficult here.

driven

Download the tablet issue 1 // 2014 and experience a race from the driver's point of view.
magazine.maxonmotor.com

On a high-speed racetrack like Monza, the car is at full throttle about 70 percent of the time.

Top gear. 260 kph … 270 … 280 … 285 … 290 … speed pours into the cockpit like hot bathwater. The back of Nico Müller's neck is pushed against the edge of his bucket seat under the heavy, even pressure almost like a mud pack. Strangely it does not relent even after reaching the top speed of 310 kph. The 21-year-old executes the required steps as if in an oxygen intubation: Inhale, exhale, raise shoulders, drop shoulders, all with exaggerated slowness to ride out the adrenaline rushes.

Exploding fuel vapors

The tachometer shows 9000 rpm as the hammering pistons of the V8 rip a torrent of fresh air through the fully open throttle flaps in a rasping howl. In the cylinders, fuel vapors detonate in controlled explosions, delivering brutal acceleration.

A sharp bend, initiated with a quick dip of the left foot on the brake pedal, causes a centrifugal pull on tires, suspension, chassis, and neck muscles. And yet, like the rotating blade of an edge trimmer, the car cuts smoothly along the track in the midst of a lush green area interspersed with a few trees.

The one seater clings like a barnacle to the smooth gray band winding its way through the Royal Park in Monza, past the Milano Golf Club. The down pressure from wings and diffusors now exceeds the weight of the Formula Renault 3.5 car – strong enough to activate the natural laws of a compressed world. Under the heat of the load, the steering seems to have merged into a unit reaching all the way up into the driver's shoulders. In the approach to the Parabolica, the carbon brakes are suspended like a guillotine waiting to hurl the young Swiss racer into his harness with a force equal to three times his own weight.

Fine tuning

The pit at Draco International Racing in the Autodromo Nazionale di Monza: "We nailed it this lap, the car felt great on every section of the track", says Nico Müller almost casually. He flashes a relaxed smile. Before the actual lap time was announced, the young man from the Bernese Oberland knew instinctively that he would appear in the upper reaches of the provisional ranking. As he turns to walk off towards the shower, he lets the pit master know where the set-up of the 610 kg Zytek-powered Formula Renault could use some fine tuning.

"We are working on the details of the adjustable rear wing and the pedal mapping, even if we gain less than one tenth of a second per lap in the end", says Draco team manager Simone Giglio. He explains how the characteristic fields of the accelerator pedal, the so-called pedal maps, affect the performance and drivability of the engine. "It is always about the relationship between speed and accelerator position. Thanks to drive-by-wire, the electronic throttle control, this can be defined in almost any way." Even some serially manufactured sports cars today are using this technology to provide a more dynamic characteristic as an option. Drivers can choose a more direct, quicker response from the engine, which then feels more like a racing unit.

Butterfly throttles

The Zytek engines used in the Formula Renault 3.5 are equipped with so-called butterfly flaps that are mounted on a rotating axle. At full throttle, the flap is vertical, offering no resistance to the air flowing into the cylinder. To close, it rotates into a horizontal position and interrupts the air flow.

The precise control of the Zytek throttle system is handled by a maxon RE-series DC motor and planetary gearhead. All eight flaps are connected with a single mechanism. They open and close in just 10 to 15 milliseconds, comparable with the flash of a camera. On a high-speed racetrack like Monza, the car is at full throttle about 70 percent of the time. The throttle flaps open and close about 100 times per lap. During a fast lap, such as 1:35 minutes, they change position about every 0.9 seconds.

Reliable under extreme conditions

The challenging application conditions – strong vibration and temperatures up to 130 degrees Celsius – made special adaptations on motor and gearbox necessary. John Manchester, Zytek Operations Director: "The support from maxon motor during the test and evaluation phase has ensured that the motor is working flawlessly and reliably even in difficult conditions."

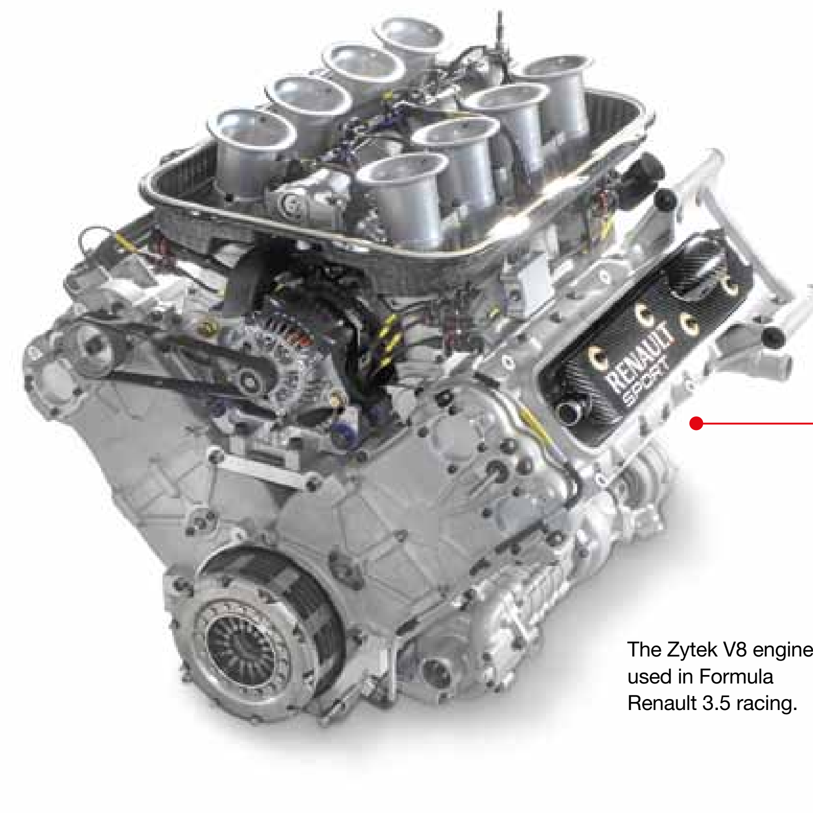
Conditions are extreme in Formula 3.5: high vibration and temperatures up to 130 degrees Celsius.

In the past, Draco Racing had pilots like Felipe Massa, Pastor Maldonado and Rubens Barrichello under contract. In other

Nico Müller trades his Formula racer for a car with a roof

A glorious victory in Monaco, another in Budapest, and fifth place in the Formula Renault 3.5: Nico Müller's resume for the 2013 season has won him much renown in racing circles and helped him to take the next step up on the career ladder. He will spend the 2014 season as a factory driver for the Audi team in the famous Deutsche Tourenwagen Masters (DTM).

Photos: Paolo Pellegrini, Nico Mueller, Zytek Engineering Ltd, maxon motor ag



The Zytek V8 engine used in Formula Renault 3.5 racing.

maxon RE 35
Ø 35 mm, 90 W, graphite brushes

maxon GP 32 HP (High Power)
Ø 32 mm, planetary gearhead 4.0–8.0 Nm

Power for extreme demands

For racing applications, the maxon RE 35 DC was fitted with custom quiver brushes, a special epoxy resin, and a reinforced commutation system. All motors in the maxon RE series have an ironless rotor and high-power permanent magnets (rare earth). They achieve more than 90% efficiency. To provide more torque for controlling the throttle of the Zytek engine, the maxon RE 35 is fitted with a GP 32 HP (High Power) planetary gearhead featuring an optimized output shaft. Depending on the reduction ratio, it can deliver up to 12 Nm.

Nico Müller was highly successful in 2013. This year he is taking part in the Deutsche Tourenwagen Masters (DTM).

teams, the Formula Renault 3.5 has brought forth drivers like Sebastian Vettel, Fernando Alonso, and Robert Kubica. Vettel is a four-time Formula 1 world champion, Alonso has won the title twice.

Time to go home for Nico Müller. In jeans and a polo shirt, he waves good/bye to the team and says, turning to the reporter: "The only times when you really control a race car is at full throttle and when braking." While the reporter is still thinking about what he just heard, Nico opens the trunk of his rental car, drops in his XXL training bag and gets behind the wheel to drive back to the hotel.

His driving is slow, almost conspicuously unobtrusive.

> Every optimization is worth the effort, even if it is only to eke out a few tenths of a second.

Contest

Who is winning?

Win two weekend tickets for the Formula 1 "Großer Preis Santander von Deutschland" from July 18 to 20, 2014 on the Hockenheim Ring. Download the tablet issue 1 // 2014 and join the contest. The deadline for participation is June 30, 2014. magazine.maxonmotor.com

Join now!

Photos: Paolo Pellegrini, iStockphoto/JestersCap, Zytek Engineering Ltd

Made for **extreme environments**

The World Series FR3.5 vehicles developed by Renault Sport use Zytek engines. Zytek is a British company that produces control systems for the automotive industry, drive technology, engines and hybrid technology. John Manchester, Engineering Operations Director at Zytek, explains in the interview why drives by maxon are suited for the electronic throttle adjustment in the V8 engine of the racing cars.

Interview: Anja Schütz

John Manchester
After completing his mechanical engineering qualifications in 1979 John Manchester secured a position at Alan Smith Racing Engines. In 1985 he went to work in the USA for Dick Simon Racing. He was employed as an engineer, being responsible for both the engines and gearboxes on their Indy Car programs. On returning to the UK in 1987 he joined up once again with Alan Smith, who were eventually bought by Zytek. John Manchester has been influential in the development of Zytek's Engineering Technology Facility.

What is Zytek best known for? And what was the most important development in your company?
Zytek are now universally regarded as world leaders in motorsport for both engine and energy recovery powertrains, and have supplied products to all the major racing series in the world. The most significant development we have made over the years has been with our energy recovery systems. This is ground breaking technology and is set to have a big impact on motorsport over the coming years.

What do you think has been the most important development in the automotive industry in the last 20 years?
The development of hybrid and electric vehicles has made a significant change to the type of vehicles we drive today and will drive in the future. In motorsport you have to continually develop and improve products in a very short timeframe and this of course has the added effect of accelerating product development at a greater rate than in main stream production. This has enabled Zytek to make big steps in technology transfer from motorsport applications into main stream automotive products, which of course enables rapid product improvement.

> We were impressed with the service we were getting from maxon.

Does Zytek still have its own racing team? If yes, what are the goals?
Zytek have run their own race team, with the intention of giving us greater control over the development of our many race products. However, this is no longer a requirement.

Zytek is using a maxon drive in the throttle system of their powerful V8 engine (Formula Renault 3.5 Series). What were the requirements for the maxon motors and gearheads, and why did you choose the maxon drive system?
Zytek first began working with maxon products in July 2011 and we were extremely impressed with their technical backup and service. The motors used in our drive by wire throttle systems on the Renault FR3.5 engines need to function in a very extreme environment. maxon really understood this problem and made suggestions on how to improve their product to suit this application. Since we started working together Zytek have built up an excellent relationship with maxon and we now use their products in other applications, such has a new clutch control system which will be introduced next season.

What do you think is the future of automotive? (also in motorsports)
I believe the main changes in both automotive and motorsport vehicles will be the development of full electric and hybrid drivetrains, which is going to help create alternative and more efficient powertrains.

“Velocity and environmentalism are not **mutually exclusive.**”

Battery-powered cars for everybody, cars without drivers, and energy efficiency in motor sports – Dominik Stockmann talks about three visionary theses.

Prediction no. 1

People are slowly coming to realize that petroleum is too precious to burn. In 2025, developed countries will have more electric cars than cars with a combustion engine. They will be powered by on-board batteries or hydrogen fuel cells.

Energy storage remains the critical factor in electric mobility. Lithium-ion batteries are the most advanced batteries currently used in electric cars. However, these batteries are still a long way from reaching the energy density of fuels like diesel or gasoline. Gasoline has an energy density of about 10,000 watt-hours per kilogram (Wh/kg). The modern lithium-ion cells used in top-of-the-range electric vehicles have an energy density of about 120 watt-hours per kilogram, about 80 percent less. Researchers have some hope for the potential of zinc-air batteries, which are expected to deliver 10 times the energy density of today’s lithium-ion batteries. Because electrical drives are very efficient compared with combustion engines – about 90% vs. only 30% – electric vehicles would not look so bad.

To achieve a range of 500 kilometers, an electric car with the current technology would need an 800-kilogram battery. This is why electric car developers try to compensate for the added weight of batteries by saving weight elsewhere. A possibility here is to adapt various technologies and materials from racing or aerospace, for example by using extremely lightweight and rigid carbon fibers for car bodies.

If we are to become independent of fossil fuels, new battery technologies need to be researched and developed until they are ready for serial production. These technologies also need to be affordable in order to become applicable in mass-produced vehicles. It is likely that the battery will prevail as an energy storage device compared with the fuel cell. Fuel cells would need far greater technological breakthroughs to become competitive.

It remains to be seen whether the majority of people in industrialized countries will be driving electric cars by 2025. One thing however is certain: Sooner or later, electromobility will become the rule.

The “Audi urban concept” technological study: Super-lightweight body meets powerful lithium-ion batteries.

Dominik Stockmann has been the director of motor engineering at maxon since 2010. In the past he held various leadership positions in the Swiss Sauber Motorsport Formula 1 team. Stockmann was in charge of gearbox and chassis construction before taking charge of all mechanical systems as Head of Mechanical Design. Other professional stations: project manager for semiconductor mounting machines at ESEC AG, commissioning engineer for hydroelectric power plants at Sulzer Hydro AG and designer at the electrical appliances manufacturer Leister. Dominik Stockmann is a mechanical engineer with an Executive MBA.

Photos: maxon motor ag, 2014 Audia AG

Prediction no. 2

By 2030, the automobile will finally live up to its name: It will accelerate, brake, and find its way all by itself. We will take the steering wheel only for fun.

Autonomous vehicles are being tested even today. Google’s autonomous car has already traveled 600,000 kilometers on public roads in California. Many leading carmakers are also developing such vehicles. The biggest challenge is the cost. According to expert estimates, a typical test vehicle is equipped with CHF 80,000 worth of sensors, software, and hardware. This is of course far too much for a normal car.

Many of these systems however are already installed in luxury cars today, for example to recognize lane demarcation lines. If the vehicle unintentionally approaches the demarcation line, the system assists the driver to stay on track with discreet steering support, or warns him by gently vibrating the steering wheel. Some cars are already capable of keeping a constant distance from the vehicle ahead, initiating emergency brake maneuvers, or parking automatically.

As early as 2010, Audi sent an unmanned vehicle to the legendary Pikes Peak mountain race in the US. The car completed the just under 20 km long, fenced off racetrack up a 4301 meter high peak in the Rocky Mountains in 27 minutes without any human intervention. This was an acceptable time, even though it was far from the winning time of about 10 minutes.

One day, autonomous vehicles will revolutionize road traffic. The majority of traffic accidents are caused by human error. Computer-controlled cars will significantly reduce the number of accidents. Communication between cars will help to avoid congestion, yielding economic benefits as well.

The autonomous car has already been invented. It just needs to be completed and made affordable. In 2030 it will be a matter of course for cars, at least on highways, to operate in full automatic mode.

Autonomous cars by Google are equipped with laser, radar, GPS, and cameras.

Prediction no. 3

On one hand there are sports cars with combustion engines that accelerate to 300 kph in 13.63 seconds, breaking all records. On the other hand, the automotive industry is putting an emphasis on electric cars and energy efficiency. This contradiction will not go away any time soon.

People have always wanted to set new records, to be the first to reach the summit or break the sound barrier. In automotive engineering, new accomplishments were always proven with records or in competitions. Take for example the record set by Frenchman Camille Jenatzy, who was the first person to go faster than 100 kph with an electric vehicle in 1899. This shows that world records and environmentalism were compatible even a century ago!

The latest super sports cars like the LaFerrari by Ferrari, the LcLaren P1, and the Porsche 918 Spyder, are all hybrid cars that utilize the power of electric motors to reach their full potential. The electric motor has the advantage of delivering its full torque from the outset. This makes it an ideal complement for a combustion engine that needs higher speeds to deliver maximum torque.

The same efforts being invested in making passenger cars more energy efficient are also being invested in sports cars. Energy efficiency is becoming more important even in racing, especially in Formula 1. Hybrid technologies made their entry with the KERS (Kinetic Energy Recovery System) in 2009. Even though this was ten years after the first mass-produced hybrid vehicle was introduced, the trend is at least going in the right direction.

The F1 rules for the 2014 season limit the hybrid system power to about 600 HP from the combustion engine and 160 HP from electric motors. For a stronger emphasis on energy efficiency and electrification, the ratio would need to be the reverse – 600 HP electric and 160 HP from combustion. The trend however is confirmed by the Formula E championship for 100% electric vehicles, held in 2014 for the first time.

Camille Jenatzy in his electric car that was the first to reach a speed of 100 kilometers per hour.

The contrast between high-performance sports cars or race cars and energy-efficient vehicles is no longer as pronounced as it may seem sometimes. However, as long as people are competing in speed contests and have the desire to set world records, it will probably endure.

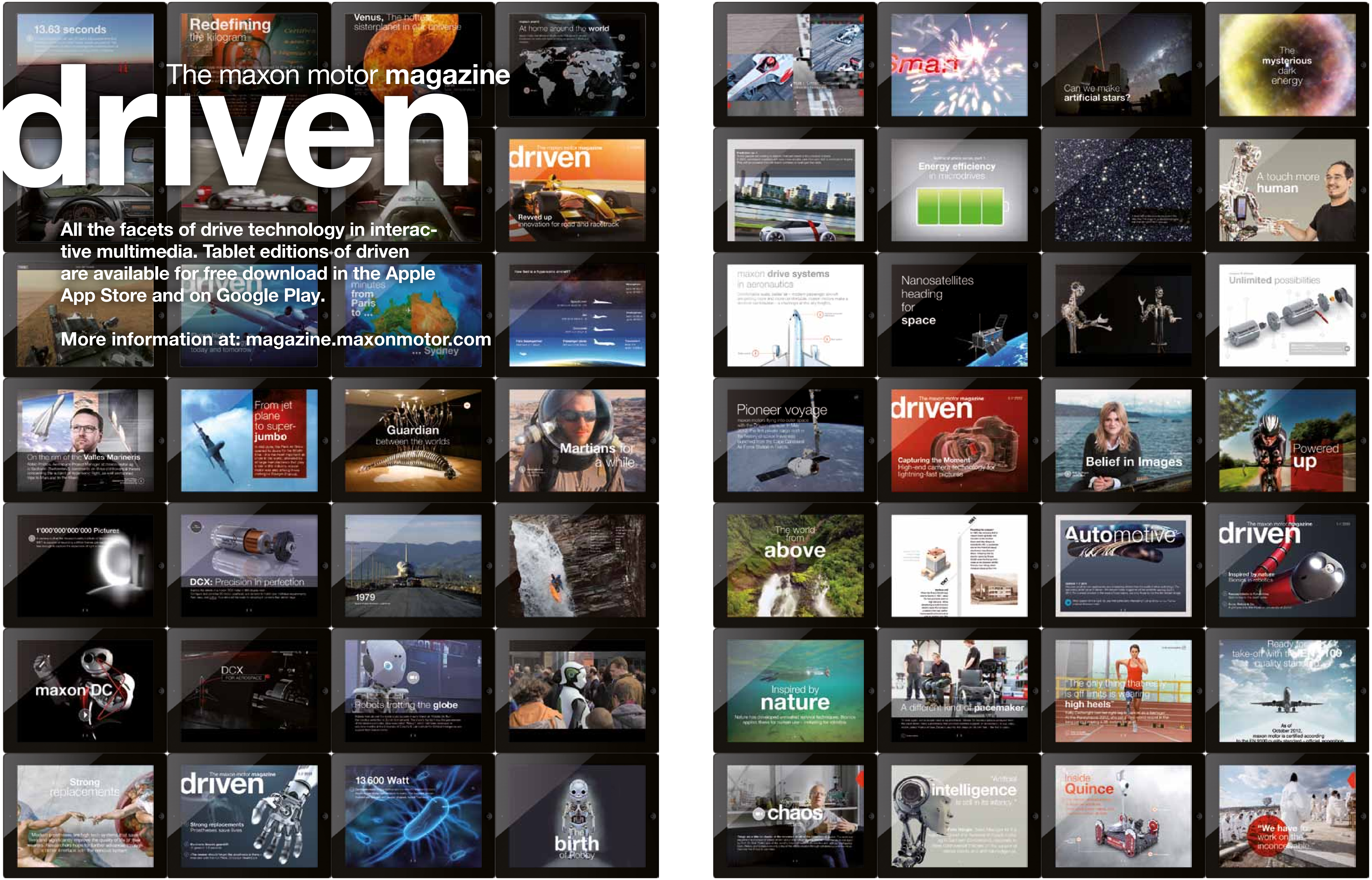
Photos: Wikipedia/Mariaordo, Wikipedia/teethdozen, maxon motor ag, iStockphoto Igor Alecsander

Staying **on track**

Driver assist systems can save lives, for example by waking a driver from microsleep.

Driver assist systems in cars are instruments that can save lives. Examples include adaptive cruise control (ACC), brake assist systems, or lane departure warning systems (LDW). The latter warn the driver when he is about to leave the lane unintentionally. This is accomplished with various systems and computers that determine the vehicle's position in the lane. When the car is in danger of leaving the road, the system activates an electric motor in the steering wheel that causes the wheel to vibrate, warning the driver. maxon motor is supplying a luxury car manufacturer with motors for this application. The base motor is the brushed A-max 16 (precious metal brushes, 2 W), modified for the application with an eccentric weight and a specified bearing. In order to prevent the other vehicle systems from being affected by the electromagnetic fields of the motor, it is equipped with special EMI suppression for automotive applications. The requirements for the small drive system are high: It needs to be low-noise, dynamic, compact, and feature high power density. The small A-max 16 was able to fulfill these requirements without any problem.

maxon A-max 16
Ø 16 mm, CLL precious metal brushes, 2 W, with terminals



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driven
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13.63 seconds
Redefining the kilogram
Venus, The hottest sisterplanet in our universe
At home around the world
Revved up
innovation for road and racetrack
How fast is a hypersonic aircraft?
On the rim of the Valles Marineris
From jet plane to super-jumbo
Guardian between the worlds
Martians for a while
1'000'000'000'000 Pictures
DCX: Precision in perfection
1979
maxon DC
DCX
Robots trotting the globe
Strong replacements
13 600 Watt
The birth of Roboy
Can we make artificial stars?
The mysterious dark energy
Energy efficiency in microdrives
A touch more human
maxon drive systems in aeronautics
Nanosatellites heading for space
Unlimited possibilities
Pioneer voyage
Capturing the Moment
High-end camera technology for lightning-fast pictures
Belief in Images
Powered up
The world from above
Automotive
Inspired by nature
A different kind of pacemaker
The only thing that really is off limits is wearing high heels
chaos
intelligence
Inside Quince
"We have to work on the inconceivable"

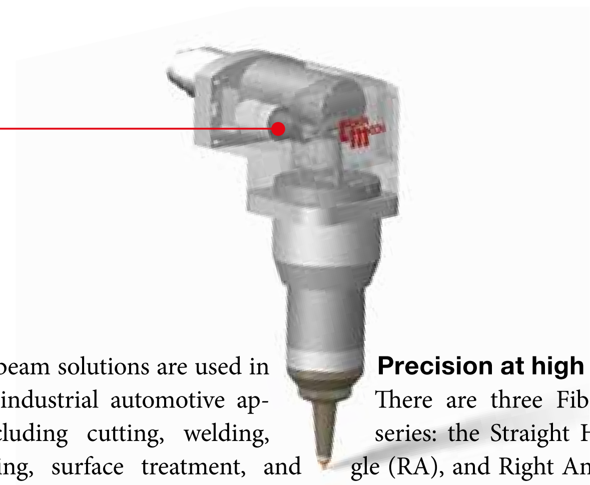
Smart head

The FiberCut laser cutting head by Laser Mechanisms cuts metal like butter, accurately and fast. The gap between laser head and workpiece is controlled by maxon DC motors and planetary gearheads.

Article: Deb Setters

maxon RE-max 29
Ø 29 mm,
brushed

maxon GP22
Planetary gearhead
Ø 22 mm



Millimeter precision
Laser cutting heads of the FiberCut series use RE-max 29 brushed maxon motors as the key components for controlling the gap. Each system also uses a GP22 planetary gearhead manufactured by maxon. The brushed RE-max 29 motor by maxon is very high-powered for its size. Other advantages include durability and a long service life. The ironless core of the maxon design reduces electrical erosion between the brushes and the commutation segments, increasing motor lifespan. Thanks to maxon drives, the laser cutting heads excel through low-noise operation, extremely fast response, long life, and consistently high quality.

Advanced laser beam solutions are used in all aspects of industrial automotive applications, including cutting, welding, drilling, scribing, surface treatment, and other processes. Plus, these solutions can be used with every type of laser, such as CO_2, Nd:YAG, and fiber lasers.

Laser Mechanisms (Novi, Michigan) is a regular innovator in this industry, producing components that enhance performance, increase safety, and provide flexible capabilities while maintaining ease of use, reasonable costs, and greater overall effectiveness. One of the company's recent innovations is the FiberCut™ series of laser cutting heads.

The FiberCut laser cutting head collimates and focuses a laser beam to provide a clean cut along metal surfaces. This three-dimensional cutter is light weight to minimize the inertia seen by the supporting robotic arm. The FiberCut nozzle also senses the required tip standoff distance from the workpiece (using Laser Mechanisms' patented sensing technology) and automatically maintains that distance, providing a high accuracy cut as the cutter moves around the 3 dimensional metal part.

Precision at high speeds

There are three FiberCut heads in the series: the Straight Head SH, Right Angle (RA), and Right Angle Compact (RAc). All three use a maxon RE-max 29 brushed DC-motor to the tip standoff function, and each system also uses a maxon produced GP22 (19:1) planetary gearhead. According to Gerry Hermann, Senior Electrical Engineer at Laser Mechanisms, "Speed is the most important feature we needed and high speed automation forces the need for accuracy at those speeds."

The heads attach to most robot arms used in the manufacturing lines of the automotive industry. The lasers are used to cut out large body panels for cars and trucks, as well as smaller support components such as undercarriage mounts and structural components designed for overall strength and safety of the final automobile.

To keep up with production lines, the creation of components such as undercarriage mounts needs to be efficient. Furthermore, accuracy is key for assembly purposes.

The maxon RE-max 29 brushed motor offers high performance density for its size,

Photos: Laser Mechanisms, maxon motor ag

The laser cutting head is primarily used in the automotive industry, for example for cutting chassis beams.

which is the main reason Laser Mechanisms selected it. Additional benefits included durability and long life. Due to maxon's ironless core design, which results in low electrical erosion between the brushes and commutation segments, the motor lasts longer.

200 mm per second, 24/7

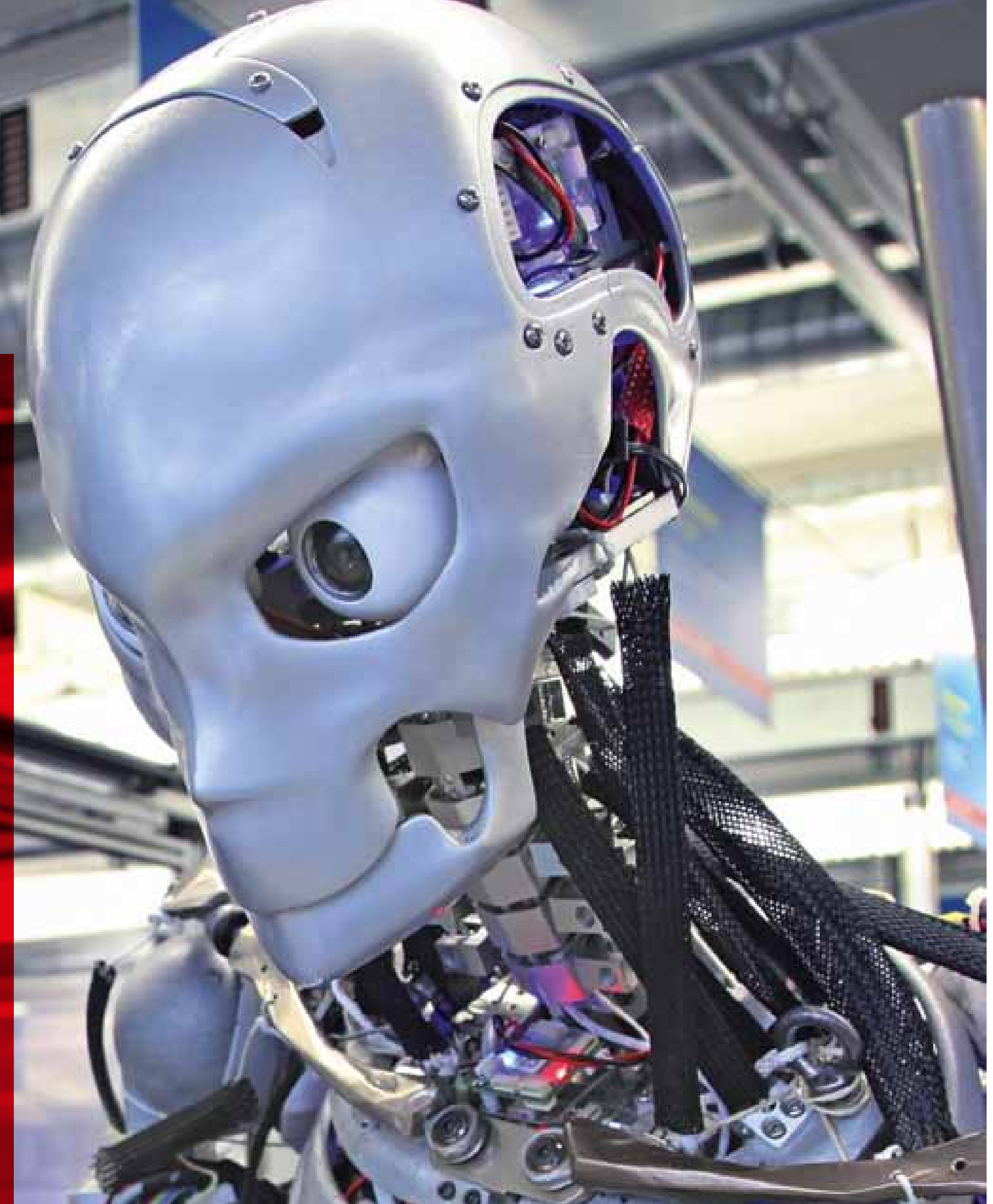
The speed of the FiberCut head can reach 200 mm per second even though the maximum travel of the head – in an up and down motion – is only 25 mm. How this works is that the lower part of the head moves up and down to maintain a constant standoff distance between the laser and the metal being cut. Springs are used to push the head out, while the motor is used to pick the head up.

Some additional features of the FiberCut laser cutting head include an adjustable focus lens for focus-to-tip adjustment and a cam-operated drive system with axial crash protection. The heads work with all leading fiber-delivered laser systems up to 4 kW with wavelengths of 1064/1080 nm. All the wiring and assist gas lines are internally plumbed to avoid snags and breaks when working around structural automotive components.

"High speed was our main consideration."

Gerry Hermann, Laser Mechanisms

Each head in the series includes a sealed beam path and a design that is engineered for the factory floor environment associated with automotive manufacturing, which is essential for the 24/7 operations of the automotive industry. The main enclosure is purged with a dry air source to keep the inside clean. This is important so that debris doesn't get into the optics or into the motor chamber. Along those lines, the maxon motors used in the device produce no particles that could damage the optics or cause a maladjustment to the tip standoff control. Additional motor features include quiet operation.

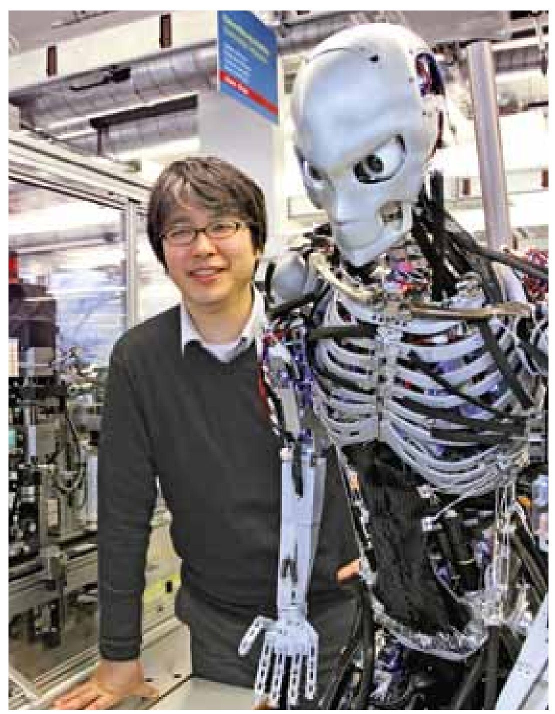


As powerful as a manga hero

The 1.58 meter tall robot answers to the name of Kenshiro. It was brought into being by Tokyo University and has 160 muscles which are controlled via tendons by 93 brushless maxon motors. The humanoid robot is the impressive result of many years of research.

Article: Anja Schütz

The name Kenshiro is known in Japan through a hero in a well-known manga comic series from the 80s. To imitate the human anatomy as closely as possible, the scientists equipped Kenshiro with the most important human muscles: In the legs, 50 drives are used as artificial muscles. There are 76 in the torso, 12 in the shoulder and 22 in the neck. The robot has the largest number of muscles ever installed in a humanoid robot.



"We wanted to understand the movements and appearance of humans and replicate them as closely as possible in Kenshiro," explains Prof. Kei Okada. With a size of 1.58 m and a weight of 50 kg, the robot is modelled on a 12-year old boy.

Photos: maxon motor ag

The picture shows the team at Tokyo University and the responsible maxon employees (from left to right above): Yoshito Ito, Hironori Mizoguchi, Prof. Kei Okada, Kenshiro, Takuma Shirai, Toyotaka Kozuki, Marc Gottenkieny (maxon motor ag). Below: Yotaro Motegi, Oliver Camenzind (maxon motor ag), Yuki Asano.

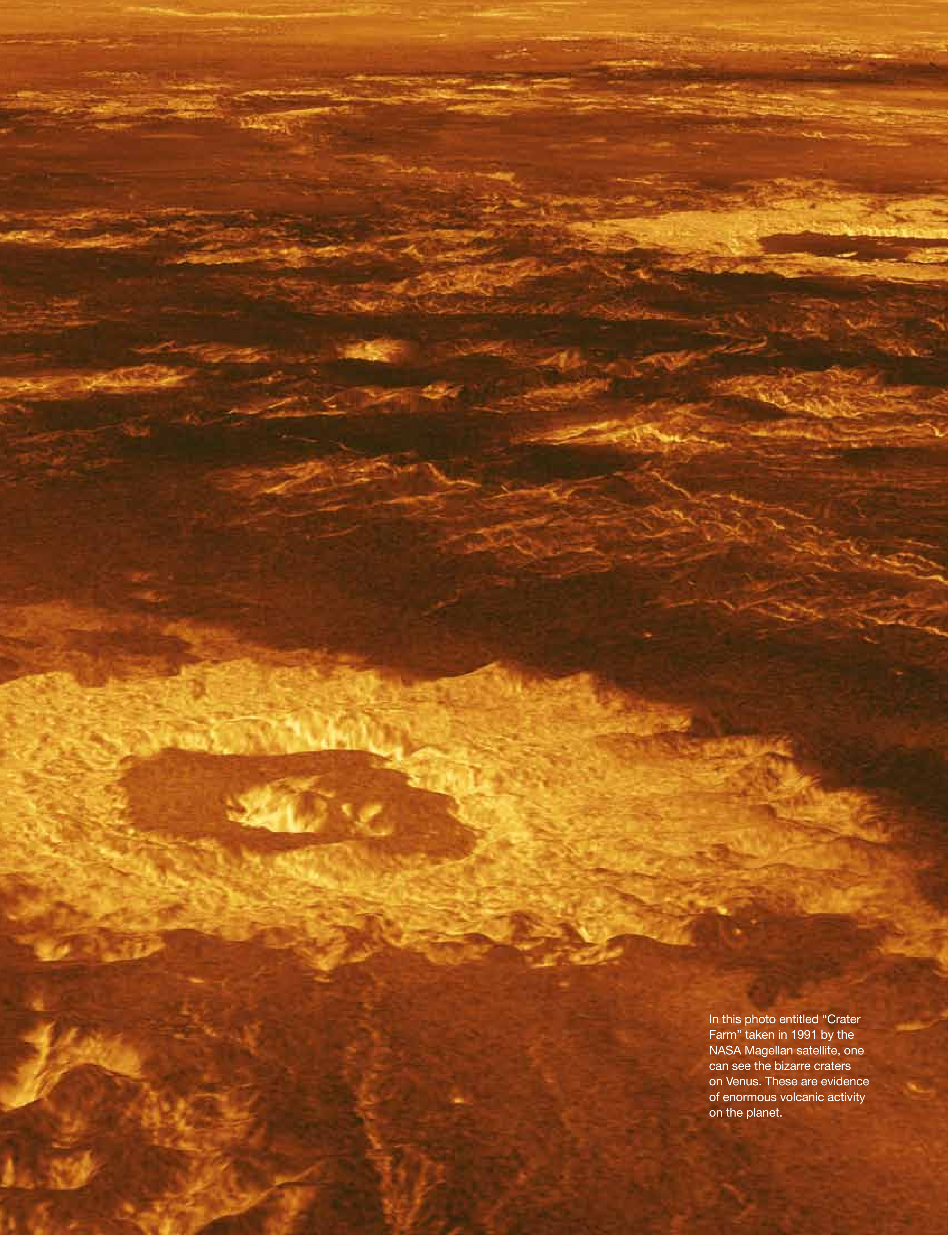
The researchers at the Jouhou System Kougaku Laboratory (JSK) of Tokyo University decided upon maxon motor for the drive system. Kenshiro's 160 artificial muscles are contracted by 93 brushless maxon EC (BLDC) motors.

maxon EC 16
Ø 16 mm, brushless,
60 W

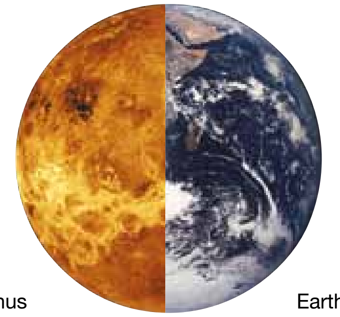
maxon EC 22
Ø 22 mm, brushless,
100 W

High dynamics

Kenshiro's 160 muscles are contracted by 93 maxon EC (BLDC) motors. For the contraction of special muscles, for example the abdominal muscle and thoracic muscles, a single motor provides the necessary drive. Here the brushless EC 16 and EC 22 motors of maxon motor are used. The electronically commutated servo motors stand out with excellent torque characteristics, high dynamics, an extremely wide speed range, and their very long service life. Powerful BLDC motors are required for the muscle contractions, therefore 60 W to 100 W maxon motors are used. Another important criterion for the motor selection was the heat generated by the motor. It is not possible to install a cooling system in the robot. Low heat generation is therefore of critical importance.



In this photo entitled "Crater Farm" taken in 1991 by the NASA Magellan satellite, one can see the bizarre craters on Venus. These are evidence of enormous volcanic activity on the planet.



Venus
Max. temperature **470 °C**

Earth
Max. temperature **60 °C**

Earth's hot sister planet

Venus is called Earth's sister planet, but although the two have a similar diameter and mass, there are very large differences in their history and atmosphere. At temperatures up to 470 °C, Venus is a true hell. maxon motor has developed motors to withstand this extreme heat.

Article: Anja Schütz

Photos: NASA/JPL

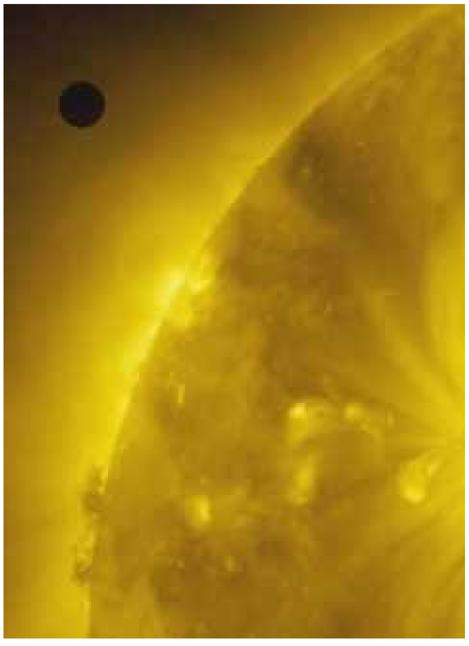
Venus has almost the same size, mass, density, consistency and gravity as the earth. But this scorched world has temperatures hot enough to melt lead. Venus is surrounded by a thick, toxic atmosphere which covers a burned surface with temperatures around 470 °C and has a pressure that is ninety times higher than on Earth's surface – the same kind of pressure that exists a kilometer underneath the surface of our oceans. The atmosphere consists mainly of carbon dioxide, with clouds of sulphuric acid. Glimpses below the clouds reveal volcanoes and deformed mountains. Venus spins slowly in the opposite direction of the other planets. This means that on Venus, the sun rises in the west and sets in the east.

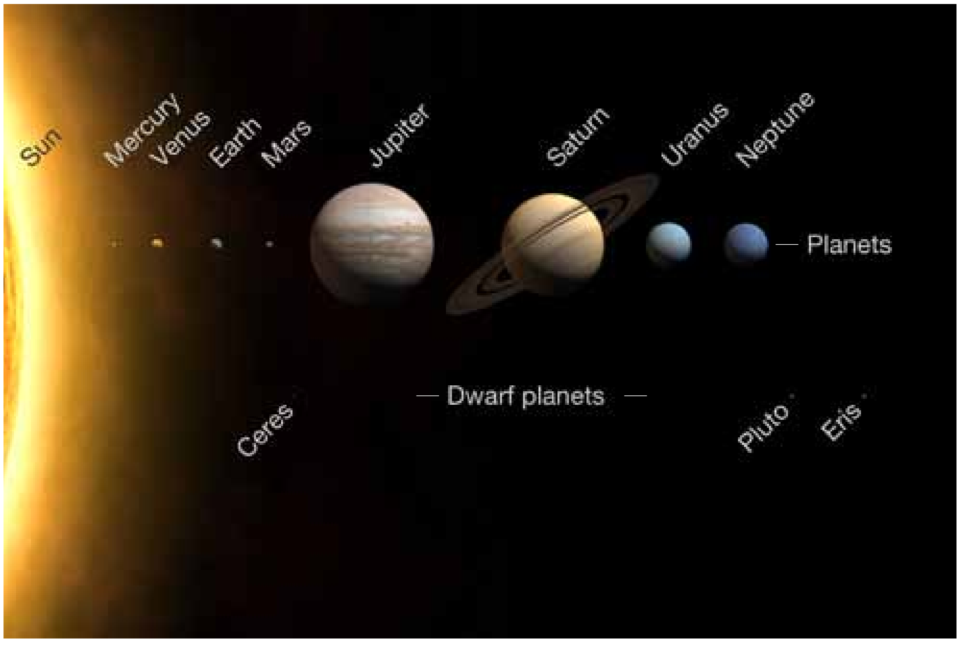
We might think a planet this hot with such extreme temperature and pressure would be impossible to explore. But it is not: More than 40 spacecraft have already explored Venus. The Magellan mission in the early 1990s for example mapped 98 percent of the planet's surface. So why not build a motor for Venus? The request came from Jet Propulsion Laboratory (JPL), which builds satellites and space probes for NASA.

maxon motor and Venus

To be able to go to Venus one day, maxon motor came up with the following solution: The UHT, an ultra-high temperature motor made of special materials that are resistant to 500 °C and higher. maxon used only stainless steel and ceramic components; the maxon winding for example was stabilized with a ceramic part. The first benchmark was operation above 400 °C. In September 2012, we successfully reached 420 °C. In further tests, our motor ran at 450 °C for one hour. This type of motor can be used in any application with particularly high temperature requirements, such as extinguishing robots, deep drilling, or in space.

Tough guys for all occasions: the maxon HD Series motors.





Left: This picture shows Venus on June 5th, 2012, as it slowly advances in front of the sun. Venus appears as a small black dot. Right: All lined up in a row: the planets of our solar system, including three of the five dwarf planets.

In the ultra-high temperature motor from maxon motor only materials are used that can withstand temperatures above 500 °C without damage.

The brushless EC 4-pole 32 HD is designed for operation in air or in oil.

Motors for extreme conditions

The Venus motor is based on maxon's existing Heavy Duty (HD) motor. Some new components were designed, and our engineers were able to draw upon existing knowledge to build a highly heat-resistant version. With the brushless EC 22 HD and the electronically commutated EC-4pole 32 HD, maxon motor launched standard motors for very harsh operating conditions. The electronically commutated version was developed for the exceptionally high requirements in deep drilling technology and stands up to even the most extreme conditions. The different variants of the EC 22 HD are designed for operation in air or submerged in oil. Power ratings depend on the surrounding medium and average to 80 Watt in air (220 Watt EC-4pole 32 HD) and, due to the much better heat dissipation, 240 Watt in oil (480 Watt EC-4pole 32 HD). They are designed to resist ambient temperatures of more than 200 °C (390 °F) and pressures up to 1,700 bar (25,000 psi).

The 22 mm diameter motors are also capable of withstanding vibration up to 25g rms, as well as shocks and impacts up to 100g – that is 100 times the gravitational acceleration. For comparison, a Formula 1 race car encounters about 2g, a fighter jet about 13g. These motors are highly efficient and therefore offer the best prerequisites for battery-operated applications. Thanks to their detent-free running characteristic, they possess outstanding regulation behavior and are especially suitable for high-precision positioning tasks, even at low speeds.

The EC-4pole 32 HD for example is ideal for use in environments where it is exposed to extreme temperatures, high vibration, or ultra-high vacuum. This means the motors can also be used in aerospace applications including gas turbine starters, the generators of jet engines, regulating combustion engines, or exploration robots. To use the motor in conjunction with a gearhead, maxon offers the GP 32 HD, a powerful and robust planetary gearhead.

Technical article series, part 1

Energy efficiency in microdrives

Low energy consumption. Heat. Power density. For microdrives in particular, these factors play an important role when energy-efficient operation is the goal.

Article: Jan Braun

Jan Braun
Jan Braun was born in Aschaffenburg, Germany in 1974, and received his degree in electrical engineering from the University of Applied Sciences (HTL) in Biel, Switzerland. He started his career programming and commissioning roller coasters and large drives on a Kilowatt scale. For more than eleven years now, he has been working with microdrives at maxon motor ag. In the sales department, he worked as technical sales support for Germany and the Northern European countries. He now provides acclaimed technical training for the worldwide sales network, as well as training seminars for customers.

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Energy efficiency is an important factor not only in automotive applications, but also for many smaller sized motors. Typical applications include battery-powered devices as well as aerospace applications. The following are only a few examples: laser leveling devices, motorized golf caddies, medical power tools, insulin pumps, robots, packaging machines, and fuel cell powered vehicles.

With all these applications, it is critical to use available power as efficiently as possible. This also means that only a minimal amount of power should be lost as heat. The rise in temperature should be kept to a minimum.

A drive component's efficiency describes these losses in terms of the ratio of output power (input power minus losses) to input power. Typically, the optimal efficiency is 80 to 90 percent for DC motors, 90 to 98 percent for pulsed power stage controllers, around 90 percent per stage for planetary gearheads, and below 40 percent for worm gears.

Aspects of a motor's energy efficiency

Energy conversion is described by the torque constant k_M and the speed constant k_n. It should be noted that the speed constant k_n is the inverse of the torque constant k_M. Conversion can therefore be expressed completely as k_M.

Not all of the electrical input power is converted into mechanical power. After subtracting the voltage drop due to electrical resistance, we are left with the induced voltage U_i. Similarly, not all of the generated mechanical power is available to the motor shaft.

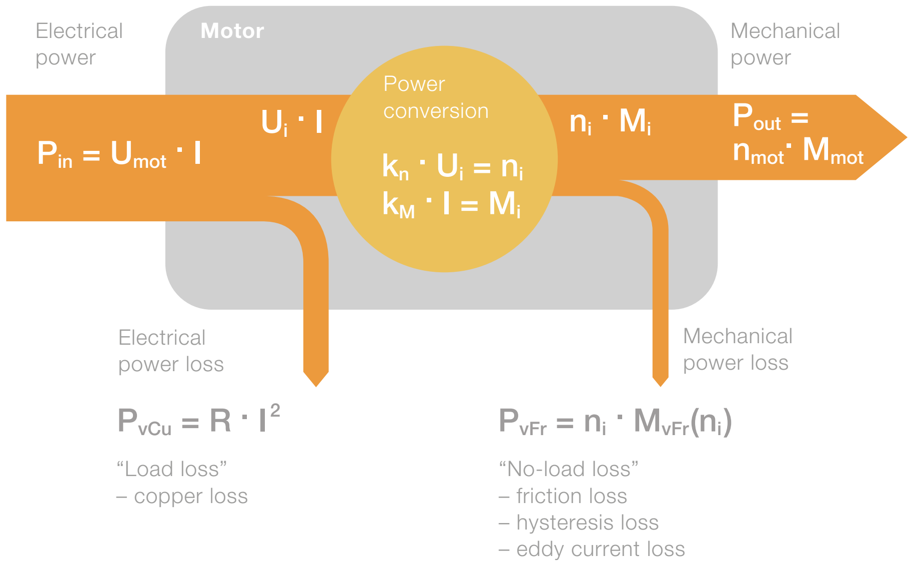
Electrical power loss is the part of the electrical power that is not converted into mechanical power. It is given by the losses due to the load current, or in other words, due to Joule power and copper loss. Electrical power loss is proportional to the square of the current (load). The mechanical power loss after power conversion comprises friction in bearings and brushes as well as iron loss. Mathematically, these can be treated similarly to speed-determined friction. Eddy current losses occur with brushless DC motors, also known as EC motors. The rotating magnet in an EC motor induces eddy currents in the magnetic return of the stator. The advantages

This motorized golf caddy features outstanding power and performance, thanks to its specially developed high performance motors by maxon motor.

Photos: NASA/SDO, AIA, The International Astronomical Union/Martin Kornmesser/DLR, maxon motor ag, Jutec GmbH

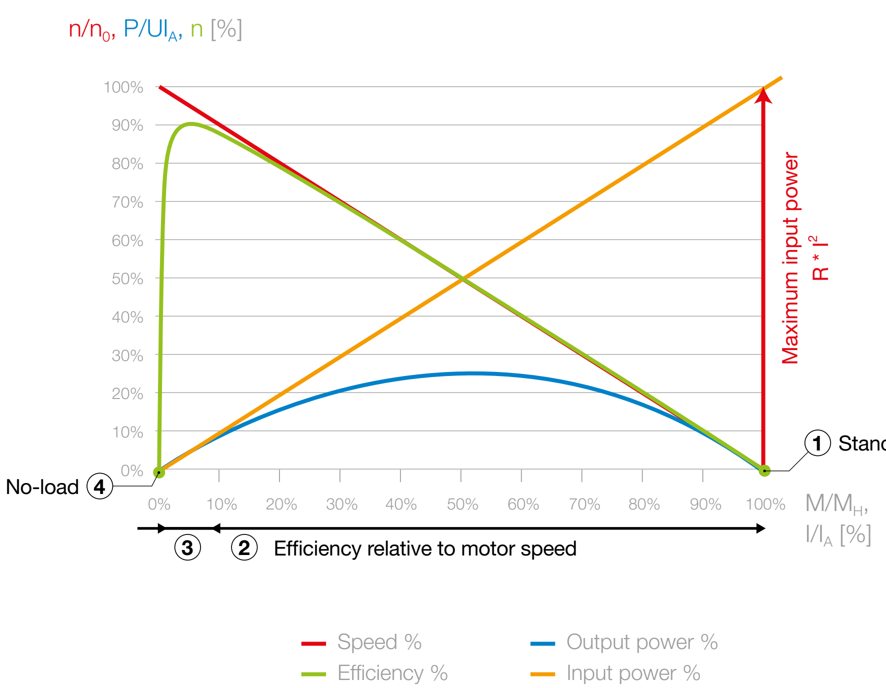
Modeling losses in the motor

The graphic shows how loss occurs in a motor. This assumes that the power conversion itself is loss-free.



Efficiency graph of a motor

For better illustration, all parameters have been normalized and are given as a percentage of the maximum value. It is assumed that the input voltage is held constant for all curves.



①: At a standstill, when the speed is zero, the efficiency and thus also the output power are zero. However, torque is at the maximum level.

②: In the case of high torques compared to friction, efficiency is proportional to the motor speed at a constant voltage – this can be seen by comparing the speed/ torque gradient with the efficiency gradient, which overlap.

③: At lower output torques, friction plays an increasingly important role, until it becomes the dominant factor. As a result, efficiency decreases.

④: When operating at no-load, efficiency is zero since no torque is being delivered. The motor absorbs the entire power in order to overcome friction and iron loss. The no-load current I_0 describes this no-load loss.

Photos: maxon motor ag, NASA/JPL

of brushless maxon EC motors are a long life span and very high speeds, which are required for applications such as manicure and pedicure devices. Unfortunately, eddy currents increase with speed.

Motors operated in the no-load range

For applications where the motor is mainly operated in or near the no-load range – for instance, the mirror drives of laser leveling instruments – it is essential to minimize mechanical friction and iron loss. This reduction can be achieved by selecting smaller bearings, which means the smallest possible motor, and by using precious metal brushes instead of graphite brushes. At low speeds, the use of a controller and sensor instead of a mechanical drive helps to further reduce mechanical friction.

Very low iron losses can be achieved through maxon DC motors with an ironless winding or small 2-pole EC motors, also known as brushless DC motors.

Motors at standstill

If the motor is operated at a standstill – where the motor is at maximum torque – the power loss is given by the electrical losses. This is because when speed is equal to zero, the output power is also equal to zero. By means of copper losses, the entire input power is converted into heat, which turns a motor at standstill into a large heater. This is illustrated by the vertical red line on the far right of the motor diagram. There are neither friction nor iron losses, as the motor does not turn.

Efficiency in practice

High efficiency at nominal voltage is, above all, a persuasive selling point. However, it is important to keep in mind that efficiency depends on the respective supply voltage of the motor. Because the ratio of starting current to no-load current increases sharply with higher voltage, the efficiency is also higher. Furthermore, the efficiency curve for lower supply voltages depends more strongly on the motor torque than for higher voltages. To estimate and take into account losses in the motor, it is better to look at the no-load current rather than the efficiency.

For battery-operated applications like motorized golf carts, it is not just a small power loss that counts. The efficient use of available voltage and minimum current consumption are equally important. The objective is to optimize the winding so that it consumes a minimal amount of current, in order to achieve the longest battery life possible.

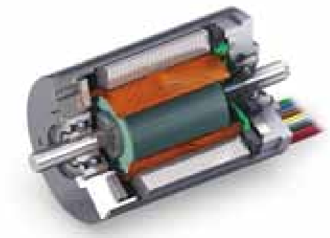
For applications in hand-held devices such as medical power tools, the power loss, namely heating, should be kept as low as possible. To humans, temperatures as low as 50 °C seem very hot. Other applications require accommodating a very limited supply of power – one such example is the Mars rover. Such applications require drives with high power or torque density, low weight, and small dimensions.

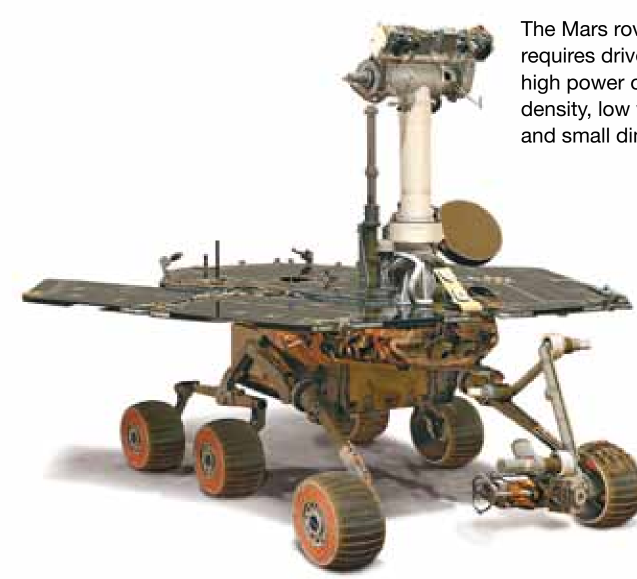
Conclusion

Scaling down a drive doesn't mean the challenges become smaller. They only become different. Even for microdrives, energy efficiency matters. However, the focus is less on saving energy and more on low current consumption, low heating, and high power density.

The next section of the technical article "Energy efficiency in microdrives" provides a detailed explanation of why suitable motor controllers and efficient mechanical drives are important for the energy consumption of a drive.


Ironless maxon DC motor RE 25


The brushless maxon DC motor EC-max 30


The Mars rover requires drives with high power or torque density, low weight, and small dimensions.

Tomorrow's **flying cars** are a thing of the past

Article: Patrick J. Gyger

"The world is as we know it now to be, and always has been: everyone forgets that it could be, or ever was, other than the way it is now." – John Crowley

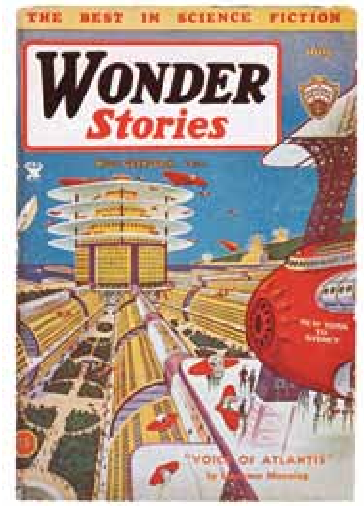
Patrick J. Gyger is a Swiss historian. He is the director of le lieu unique, national center for arts in Nantes, France. From 1999 to 2010, he was the director of Maison d'Ailleurs in Switzerland, a museum for science fiction and utopia, where he curated more than thirty exhibitions (most of which where shown internationally) and published extensively. He is the author of Flying Cars: The Extraordinary History of Cars Designed for Tomorrow's World (Haynes, 2011).

One of the drawbacks of living in a city center is the long journey you might have to endure to reach the nearest airport, which will usually be located in the outskirts. No wonder the City of Tomorrow often tries to solve that inconvenience. Take Aerotropolis, for instance: the author of the concept wants to promote a "new urban form placing airports in the center with cities growing around them".

But the Aerotropolis name rings with a quaint retrofuturistic tone, and brings to mind 1930s pulp imagery (as for instance seen in Frank R. Paul or Arthur C. Radebaugh): massive tower blocks looming over suspended highways. And indeed, having flying machines inside cities is far from a new idea. Few remember today that one could alight in central Manhattan in the mid-1930s: the Downtown Skyport was reserved for an elite, but hinted that aviation would soon be within the reach of everyone.

Throughout the 20th century, inventors filled with industrial-age dreams and nourished by visions of science fiction imagined personal airplanes en masse and how they would shape the city. Before WWII, magazines started promoting the idea of a flying car in each garage. Mr. and Mrs. Smith could expect to conquer airspace just as easily as they had the highway. And so it seemed when the first true flying automobile appeared in 1937: Waldo Waterman's Arrowbile. In the booming post-war economy, several inventors successfully took on the challenge. The most striking examples were Robert Fulton's Airphibian (1946), Theodore Hall's ConvAirCar 118 (1947) and Moulton Taylor's Aerocar (1949). But these projects were seen as simply too risky technically,

Magazine cover by Frank R. Paul (1934).



financially, and legally, to succeed. Their makers wanted to bring into reality machines that society mistook for suburban fantasies.

Today, the use of composite materials and information technologies might allow new projects to take off – several of which will no doubt claim to be the first proper flying car. Paul Moller's Skycar has been in the works for decades, and Terrafugia's Transition is supposed to go into production in 2014, while the vertical take-off and landing TF-X model should be ready around 2020. NASA has also been toying with the idea of Personal Air Vehicles as a solution to the problems of saturation at aerial hubs and highways. Still, financiers and the public will need to be convinced, and the American passion for automobiles never spread to personal airplanes. No matter what happens, the flying car of the future will either have to be piloted by a professional, or be fully automated. You won't just be guided: you'll be overseen or even directed. It will also be horrendously expensive. It is not quite the dream of absolute freedom of movement imagined in the mid-20th century by visionary engineers and science fiction artists.

The flying car as a device of personal liberation, freeing us from timetables and traffic jams, fueled by atomic energy, radically transforming our urban landscapes, will remain a symbol of a future that we were once promised, but that will never be. It will keep filling the skies between powerful skyscrapers, above automated food processors, moving sidewalks and armies of robot servants, landing in the backyards of our imagination.

The flying car "Transition" is to go into production in 2014.

In the 1940s, the ConvAirCar 118 drew some attention.

Photos: Todd B. Kimmell Archives/Arthur C. Radebaugh, Mario Del Curto, Keystone/The Granger Collection/Frank R. Paul, San Diego Air & Space Museum, Terrafugia

Outlook 2 // 2014
The perfect human

Discover exciting new applications and interesting stories from the world of drive technology. The upcoming issue of driven – the maxon motor magazine – will be available starting November 4, 2014.

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

Impressum

Published by: maxon motor ag, Brünigstrasse 220, Postfach 263, CH-6072 Sachseln, Tel. +41 (41) 666 15 00

Management: CEO Eugen Elmiger, Dr. Ulrich Claessen, Norbert Bitzi, Peter Grütter

Project manager: Michel Riedmann
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Realisation: Infel Corporate Media, Militärstrasse 36, CH-8004 Zurich
Editors: Michael Frischkopf, Simona Stalder, Marcel Leibacher
Design: Peter Kruppa (Art Direction), Sebastian Mutti
Photo Editor: Diana Ulrich, Matthias Jurt, Yvonne Schütz

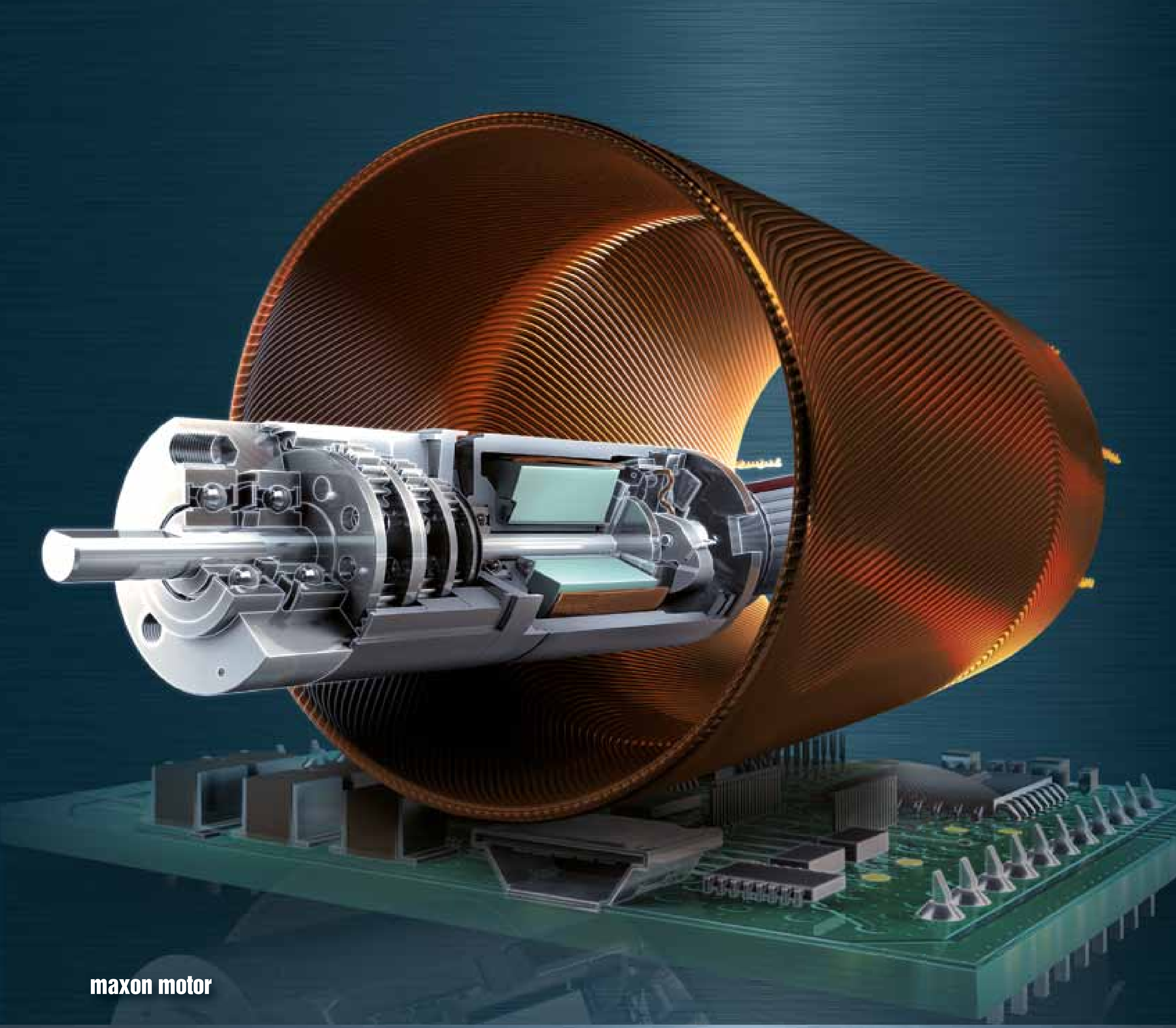
Proofreading: CLS 4-Text GmbH, Spichernstraße 2, D-10777 Berlin

Print: Landenberg-Druck AG, Pilatusstrasse 10, CH-6060 Sarnen

Frequency of publication: Biannual issue as iPad/Android app and as print magazine (April/November)

Languages: German, English
Print run: 11,000 (German), 4000 (English)

Photo: iStockphoto / Malyugin


maxon motor