1.2016

# drive

THE ZF MAGAZINE

MICHIGAN
**Where cars learn to drive**

DIGITIZATION
**Silent revolution**

INDUSTRIAL TRANSMISSIONS
**Driving giants**

## SWITCHED ON
# E-POWER SPECIAL

THE ZF MAGAZINE 1.2016
drive

Do you drive an electric car? The enormous torque produced by electric motors has always fascinated me – how a mere touch of the gas pedal is enough to deliver instant power, over and over again. When people discuss electromobility, they often forget one thing. Not only does electric propulsion conserve resources – it is also really good fun.

These are just two of the reasons why we believe in electromobility – as delivered by all-electric drives, but also by hybrid and plug-in hybrid drives. These two technologies in particular will hugely accelerate the adoption of electromobility, of that we are convinced. It will be hard for the auto industry to switch over to all-electric mobility in the space of just 10 years – hybrid drives will play a key role in the transition. And we supply all the technologies required.

Back in 2008, ZF was the first company in Europe to start volume production of hybrid modules. Now we are sending out another clear signal confirming our commitment to electromobility, having put the necessary structures in place. Our new E-Mobility division combines all our existing and future electromobility activities under one umbrella – from electric motors and hybrid modules to power electronics. We have brought together all the relevant expertise from across the company, and our customers will also reap the benefits of streamlined communications and fast decision-making through a single point of contact.

Personally, I am delighted that, as Head of Division, we have been able to appoint a proven specialist with over 20 years' experience of vehicle electronics and electromobility: Jörg Grotendorst. Together, we will help develop and drive forward the electrification of our mobile lifestyles. Because one thing is certain: it will not be possible to meet the stringent emission regulations due to come into force across Europe in 2020 without large-scale electrification.

**"Not only does electromobility conserve resources – it's also really good fun."**

*Dr. Stefan Sommer*
*Chief Executive Officer of*
*ZF Friedrichshafen AG*

Photos: shutterstock (2), Getty Images (1), Andreas Pohlmann

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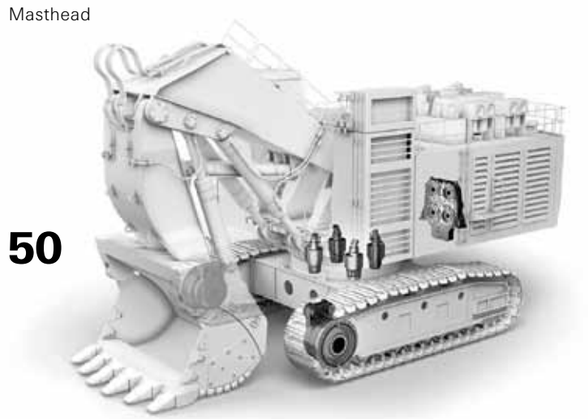



Photos: iStockphoto, Dominik Gigler, Matthias Schmiedel, Zachary James Johnston, Felix Kästle, Illustration: ZF


*ZF at NAIAS*

# A prominent visitor

On his first visit to the North American International Auto Show (NAIAS), U.S. President Barack Obama showed great interest in the pioneering ZF technologies that are helping improve automotive efficiency and safety and paving the way for autonomous driving. "ZF was honored to be able to demonstrate and explain the technologies we're using to shape the future of mobility to President Obama," said Dr. Franz Kleiner, Board member responsible for North America. ZF was the only automotive supplier at whose booth the President spent time in conversation. Bryan Johnson, Head of Communications North America (left), answered the President's questions.

Photo: David Freers

# ON HIGHWAYS AND HIGH SEAS

From sporty sedans through high-performance trucks to luxury yachts, these newly launched vehicles are all equipped with ZF technology.

## Alfa Romeo Giulia

**8-speed automatic transmission with torque converter, or 6-speed manual transmission**
**Rear Axle Drive**
**Vibration dampers**
**Chassis components**
**Seatbelt systems**

The second generation of the 8HP 8-speed automatic transmission delivers even greater responsiveness, comfort and efficiency, reducing fuel consumption by an additional three percent. The optional stop-start function offers further potential for fuel savings.

## BMW 7 Series

**Safety Domain ECU**
**Forward-facing camera**
**8-speed automatic transmission**
**Torque converter**
**Active Kinematics Control (AKC)**
**Electronic parking brake**
**Chassis components**
**Electronic components**
**Seatbelt systems**

The cutting-edge Safety Domain ECU (SDE) is a flexible hub for control functions such as chassis and driver-assist systems. The SDE comprises microcontrollers and an open software architecture into which automakers' own software modules can be integrated.

## Ducati Multistrada 1200 Enduro

**CDC adaptive damping system on front fork and rear wheel**

The CDC adaptive damping fitted to the motorcycle's front fork and suspension struts adjusts damping force to match driving conditions in real time. This enables the system to combine the safety of hard suspension settings with the comfort of soft settings.

## Renault Mégane

**Electric power steering**
**Radar system**
**Electronic parking brake**
**Chassis components**
**Airbags**

Powered by an electric motor with very low rotational inertia, the electric power steering system is highly efficient. The "power-on-demand" principle means the system only uses energy when it is actually steering the vehicle, reducing fuel consumption and $CO_2$ emissions. The steering system is also ideal for use with automated driving functions.

## MAN TGX (D38)

**TraXon automatic transmission system, or Ecosplit 16-speed manual transmission**
**Power take-off (PTO) modules**
**ZF Intarder transmission brake**
**Electronic components**
**Radar and camera system**
**Cabin, chassis and steering components**
**Damping technology for axles and cabin**

The new MAN TGX with D38 engine is fitted with the TraXon automatic transmission system. Thanks to smart electromechanical systems and enhanced functionality, TraXon offers many efficiency and productivity advantages. The modular transmission system can also be adapted to a wide variety of different applications.

Photos: Alfa Romeo, Ducati, Renault, BMW Group, SILVERYACHTS, MAN

## Silver Fast yacht

**ZF 7640 transmission**

Australian boatbuilder SILVERYACHTS has equipped the Silver Fast with two ZF 7640 transmissions. Fitted with a hydraulic clutch, the transmission is designed for engines capable of producing up to 3,915 horsepower (2,880 kilowatts). The lightweight housing is very robust and impervious to seawater.

# RETRACTABLE STEERING WHEEL

**ZF presented a raft of new technologies at CES in Las Vegas.**

CES in Las Vegas is the world's largest consumer electronics trade fair. And in 2015, for the first time ever, ZF was present. Under the slogan "Shaping the Next Decade of Automated Driving", the technology company demonstrated its structured response to the prevailing megatrend: autonomous driving. In a concept car developed by Swiss firm Rinspeed, ZF also introduced an innovative steering wheel with hands on/off detection that simply folds away in automated driving situations to give the driver space for other activities.

# 12,000

people

**around the world took part in ZF Services technical training courses on drivelines, chassis systems and steering systems during 2015. Demand for training courses on high-voltage systems continues to grow, because the number of hybrid vehicles on the roads has almost doubled since 2012. Over the same period, the number of all-electric vehicles has actually tripled.**

*Tech Center in Japan*

## Focusing on e-mobility

In Yokohama, Japan, ZF is currently setting up an engineering center where teams of research engineers will concentrate primarily on electromobility. "Japan is currently ranked as the Number One manufacturing country for electromobility," explained ZF CEO Dr. Stefan Sommer, "consequently we're establishing an engineering center there." Over the next couple of years, the new Japan Tech Center should create around 70 new engineering jobs, building more capacity for customer service and support, as well as the development of new electromobility-related technologies. Further recruitment is planned in the future. ZF has had a presence in Japan since 1980, while ZF TRW has been represented in the country since 1970.

*Integrated Brake Control*

## Major order for brake systems

Starting in 2018, ZF's Integrated Brake Control (IBC) system will go into high-volume production in the factories of a major automaker. The system supports conventional braking safety functions as well as semi-automated driving functions. It is compatible with all types of drivelines and helps manufacturers meet increasingly stringent targets for fuel efficiency and $CO_2$ emissions.

## "An organizational masterstroke."

*That's how renowned German legal publishing house Juve described ZF's acquisitions of TRW Automotive and Bosch Rexroth's industrial transmissions business. The specialist publisher bestowed a Juve Award on the company's Mergers & Acquisitions and Legal departments.*

*New giant transmission for offshore wind turbines*

## Maximizing power output

ZF is vastly expanding its wind power business. The company's Lommel plant in Belgium is now producing transmissions for wind turbines capable of generating 6.15 megawatts (MW). And at the company's new site in Witten, Germany, acquired as part of the takeover of Bosch Rexroth's industrial transmissions business, ZF is already manufacturing what is currently the world's most powerful wind-turbine transmission, suitable for 8 MW turbines.

*North American HQ in Livonia*

## An integration milestone

In the course of integrating ZF TRW, ZF took its first decision concerning locations: in April 2016, the existing ZF TRW headquarters in Livonia, Michigan, will become the ZF head office for North America. This was formally announced at the North American International Auto Show (NAIAS) in Detroit by ZF CEO Dr. Stefan Sommer (photo). All administrative activities will be centralized in Livonia. At the same time, the ZF site in Northville, Michigan, (roughly 20 minutes' drive away) will become a central sales and engineering center. "Combining ZF and ZF TRW's administrative functions for North America is another key milestone in the integration process," said Dr. Sommer.


Photos: ZF (5)

# WHERE CARS LEARN TO DRIVE

Tomorrow's mobility solutions are being developed on the highways of the U.S. State of Michigan and in the simulated streets of Mcity. drive paid a visit to the new world center of automated driving.

*Text: Tim Moran*
*Photos: University of Michigan (2), Zachary James Johnston (5)*

**DOWNTOWN – THE CENTER OF *MCITY IN ANN ARBOR, MICHIGAN.* USING MOVABLE FACADES, STREETS IN THE PROVING GROUND CAN BE RECONFIGURED WITH DIFFERENT WIDTHS AND LAYOUTS.**


**WILL FRED THE DUMMY BE RUN OVER BY *A CAR TRAVELING AT 35 MPH?* NO WORRIES – ACTIVE BRAKING ASSIST STOPS THE SUV WITH INCHES TO SPARE.**


Michigan is one of just four states that allow automated vehicles to drive on public highways. ZF TRW is taking advantage of this to test pioneering technologies.

The big GMC SUV is driving along at a sprightly pace when suddenly a pedestrian walks out into the road, directly in front of the car. If his fate depended on human reactions alone, he wouldn't stand a chance – he's too close to the vehicle. But before the driver can even start to respond, the car performs an emergency stop and comes to a standstill with its radiator grill just inches away from the hapless jaywalker.

The SUV's shaken occupants are delighted and relieved, but the pedestrian himself appears unconcerned. That's no surprise: he is, after all, just a dummy. Even so, Fred the Dummy is making an important contribution to the development of future mobility solutions. When the technicians alongside the test track hit a switch, Fred moves smoothly back to the kerb, ready for the next test.

Welcome to Locke Township in the U.S. State of Michigan, one of the leading centers for the development of self-driving vehicles. What's to see? A grain store, miles of dirt roads, a strong olfactory suggestion of cows in the immediate vicinity... Is this where the technologies for tomorrow's mobility are being created? Surely such high-tech enclaves as Mountain View in California or trendy Austin in Texas would be more suitable venues for automated driving developers? After all, that's where Google is testing the company's self-driving cars.

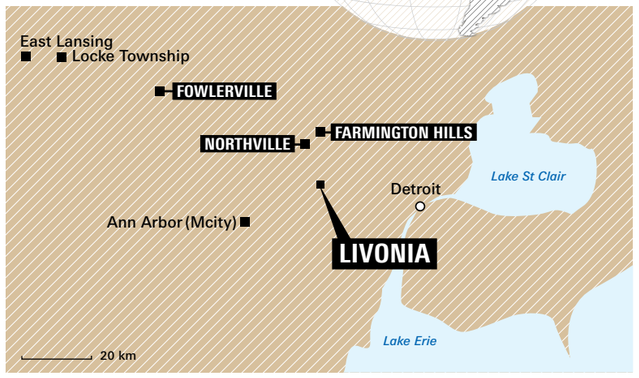
But such preconceptions are misleading. As one of only four federal states where self-driving cars can be tested on public highways, Michigan is the true center of automated vehicle development. ZF TRW has already run many tests on the highways around Detroit, says Andy Whydell, Head of Systems Product Planning.

### New U.S. headquarters

He explains that the other three states – California, Nevada and Florida – are not close enough to the heart of the auto industry, making it difficult for pioneers to test new technologies destined for production vehicles. "We deliberately moved to Michigan and set up our new head office for North America in Livonia," confirms Dr. Franz Kleiner, the ZF Board member responsible for the region.

Autonomous driving will likely evolve through five distinct stages. At present, ZF TRW supplies subsystems and sensors for the first two stages, which focus primarily on safety and driving comfort. Typical examples include adaptive cruise control and lane-keeping assistance. During these two stages, drivers must still keep their hands on the steering wheel. But as automated driving evolves through stages 3-5, the increasingly intelligent interaction of sensors, control units and vehicle systems means that vehicles will gradually take full control, starting with highway driving. Technologies currently under development at ZF's Farmington Hills, Northville and Livonia facilities are an integral part of this process. "In Michigan, we're designing cameras, electronic braking and steering systems and other safety electronics products, such as the Safety Domain ECU," explains Whydell.

While these products are already having a positive impact on vehicle safety, they will play an even more critical role in the vehicles of the future. "It's more practical to start developing the technologies you need for tomorrow's self-driving vehicles as components for today's production cars, because then, once it's time to take the next step, you can combine ▸


**"It's more practical to develop technologies as components for production vehicles than build complete self-driving vehicles from scratch."**

*Andy Whydell,*
*Head of Systems Product Planning at ZF TRW*

By subjecting systems to countless test drives, ZF TRW engineers check and recheck them to ensure they work faultlessly. Here, product engineer Gregory Price is setting up the computer for yet another test drive.

In the test lab, ZF TRW specialists like Mike Babala optimize the cameras used in driver-assist systems.

**NORMAL CITY TRAFFIC SIMULATED ON *THE MCITY PROVING GROUND* INCLUDES CYCLISTS, PEDESTRIANS AND OTHER ROAD USERS.**

subsystems that have already been field-tested," explains Andy Whydell. This is easier than developing a complete self-driving vehicle from scratch and then attempting to market it. "We've focused on things we know we can successfully bring to market," emphasizes Whydell.

The Mcity test facility is less than one hour's drive from Detroit, a major city that is still the pulsing heart of automotive research and development. Along with ZF TRW's research and production facilities, the proving ground is located within the catchment area of several highly respected universities: Michigan State University in East Lansing, the University of Michigan in Ann Arbor and Wayne State University in Detroit. They all top the national league tables for engineering, and all qualify as Research 1 institutions – the highest class of research-driven universities.

### Hotspot for systems development

Each of these universities is carrying out applied research work that is expected to contribute to the development of self-driving vehicles. A project at Wayne State University is currently investigating how much communication is required between vehicles in order for cars to drive safely in urban traffic – the researchers have been using cars belonging to the campus police force as test vehicles. Over a period of years, extensive trials in the area around Northville and Ann Arbor have involved 3,000 cars capable of communicating with the transport infrastructure and with each other – another key aspect of automated driving. "Michigan is developing one of the world's ultimate high-tech products: the car," underlines Michigan's Governor Rick Snyder. "This is a huge opportunity for young talents who want to help change our entire culture and way of life. Michigan certainly sees this as an opportunity – you can feel the resulting energy in the state's industries and throughout Detroit."

> **"Michigan is developing one of the world's ultimate high-tech products: the car."**
>
> *Rick Snyder, Governor of Michigan*

Thomas Wenzel, Head of Technology and Product Communication at ZF, agrees: "The concentration of talent and demand for engineers is turning Michigan into a hotspot for ZF TRW's systems development work. Here, we're just a short distance away from all our stakeholders."

Michigan offers fertile ground for developing systems for the self-driving cars of the future. The rapid pace of innovation of local industry, universities and government means that partially and then fully automated driving will soon become a safe, efficient, enjoyable way to travel. And ZF is right in the middle of it, passionate about bringing this futuristic vision to life.

Recently established by the University of Michigan, the first specialized proving ground for self-driving and connected cars represents a major step toward this goal. Mcity, a 10-million-dollar facility set up at the University of Michigan Mobility Transformation Center (MTC), was opened in Ann Arbor in the summer of 2015. As an affiliate sponsor, ZF is one of the founding members of this public-private consortium. At Mcity, all of the challenges that regularly confront drivers in urban and suburban environments are densely concentrated in a relatively small area of just 32 acres. The facility includes movable downtown facades, a dozen intersections, two railroad crossings, plenty of bends and very few places with an unobstructed view, so every safety-related aspect of automation and connectivity can be tested in depth. The roads also feature a wide variety of surfaces – including a metal bridge.

### Mcity as development accelerator

"For validation purposes, sensors need short distances and consistent driving behavior, which is why we position test features so close together along the test track," explains Dr. Peter Sweatman, Founding Director of Mcity. Because it is possible to drive sensor systems through this dense urban environment hundreds of times over, investors are expecting to halve development times; vehicle designers and developers can look forward to an accelerated learning process.

But Mcity is not just used for testing vehicle technologies. Researchers are also using the facility to explore such crucial issues as insurance liability, cyber security and the legal aspects of autonomous driving. "Safety is an extremely important consideration – first among equals, you might say," adds Sweatman.

When Mcity first opened in July 2015, the proving ground's diary was filled to overflowing in no time as automakers, suppliers and researchers all booked slots for testing components, assemblies, subsystems and driver-assist systems of various degrees of complexity. Numerous companies from the automotive industry are taking full advantage of Mcity. Ford Motor Co. announced that it would be the first company to test fully autonomous vehicles at the facility. ZF TRW is busy testing safety technologies on the simulated city streets. Meanwhile, Fred still has plenty of work to do. Among other things, he's helping to establish just how fast a car can brake to a standstill on its own if a pedestrian decides to cross the road immediately after a bend. ■

To watch a video about vehicle testing in Michigan, scan the QR code above using your smartphone or mobile device.

Photo: Polaris/laif (1), Illustration: ZF

# VISION ZERO

Over the last few decades, the number of traffic accidents has plunged. And experts agree that active safety systems could further reduce the figures.

*Text: Joachim Becker*

No accidents? No worries! In sci-fi stories, accident-free driving is already a tradition. The cities of the future have no need for traffic signals: instead, highly networked, self-driving vehicles hurtle across densely crowded intersections without slowing. Amazingly, even pedestrians emerge unscathed from the turmoil. A wonderful sci-fi trope that bears no resemblance to today's traffic conditions. Because in reality, a world completely free of traffic accidents still appears to be a long way off. The sad truth is that each year, more than 1.2 million people fall victim to accidents on streets around the world. More people die from road accidents than from malaria.

"ACCIDENT, n. An inevitable occurrence due to the action of immutable natural laws." So goes the definition in "The Devil's Dictionary", written in 1911 by U.S. author Ambrose Bierce to describe the car's conquest of America's streets. Only in 1964 were pedestrians finally given priority on crosswalks. Previously, cars automatically had right of way. But even now, even in industrialized countries, the law of the jungle still applies. In urban environments, 75 percent of accident victims are on foot or driving two-wheelers. Without the protection of a tough steel cage, pedestrians, cyclists and bikers always come off worst in collisions. And this will continue unless cars themselves learn to actively protect other road users.

**Objective: zero traffic fatalities**

"Vision Zero" is the name of a project currently being promoted in various industrialized countries, such as Germany and Sweden. Ultimately, it aims to reduce the number of deaths on our roads down to zero. An admirable goal, but there's still a long way to go. Even in the world's safest countries, traffic accidents account for a significant number of deaths. In 2013, there were 2.4 traffic fatalities per 100,000 citizens in Sweden, 3.3 in Switzerland, 3.4 in the Netherlands and 4.3 in Germany. The figure was significantly higher in the U.S., at 10.6 traffic fatalities per 100,000 citizens. Unless vehicles themselves are systematically enhanced, it won't be possible to reduce these figures very much further.

**75%** of accident victims in urban traffic are pedestrians, cyclists or bikers.

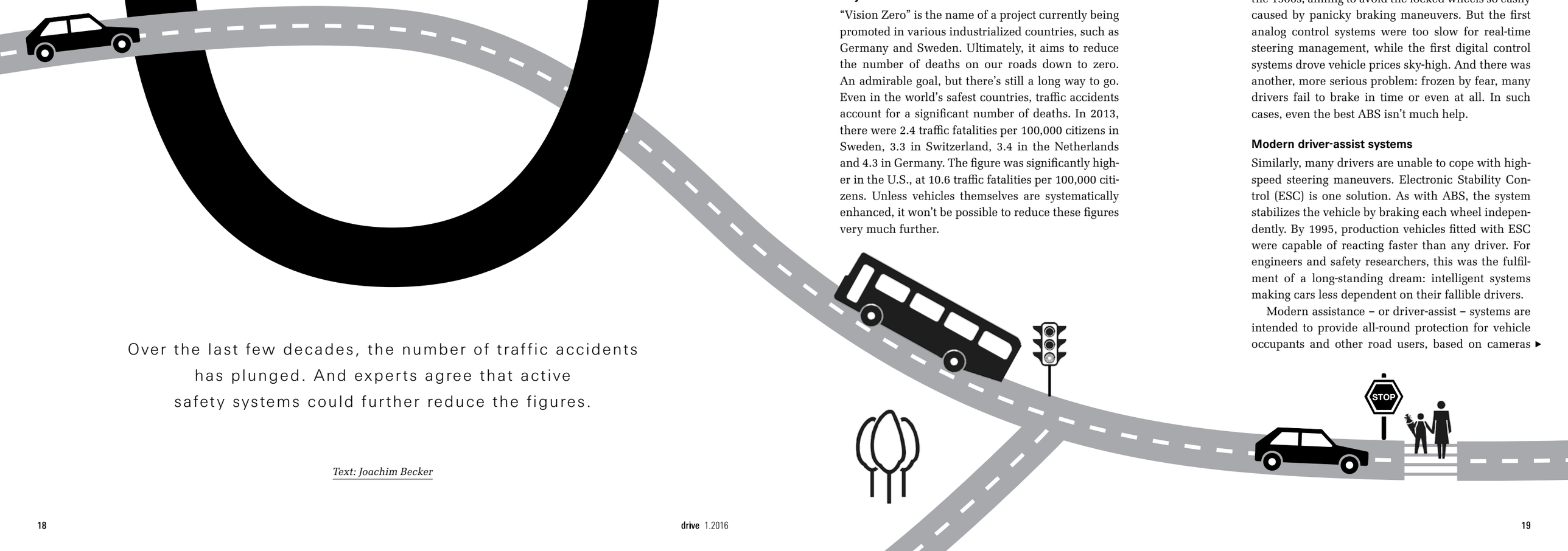
Passive safety features such as seatbelts, airbags and crumple zones have significantly improved survival rates. Over the past 40 years, vehicle occupants at least have benefited from ever more sophisticated safety features. The ongoing refinement of passive safety solutions has cut the number of traffic victims by 84 percent since 1970. And this despite the huge increase in vehicle numbers and traffic levels in countries like Germany over this period. The number of traffic victims around the world as a whole, however, remains as high as ever.

Following the impressive progress made in passive protection for vehicle occupants, attention is now shifting to active safety technologies. Engineers first started to work on a "smart" braking system back in the 1960s, aiming to avoid the locked wheels so easily caused by panicky braking maneuvers. But the first analog control systems were too slow for real-time steering management, while the first digital control systems drove vehicle prices sky-high. And there was another, more serious problem: frozen by fear, many drivers fail to brake in time or even at all. In such cases, even the best ABS isn't much help.

**Modern driver-assist systems**

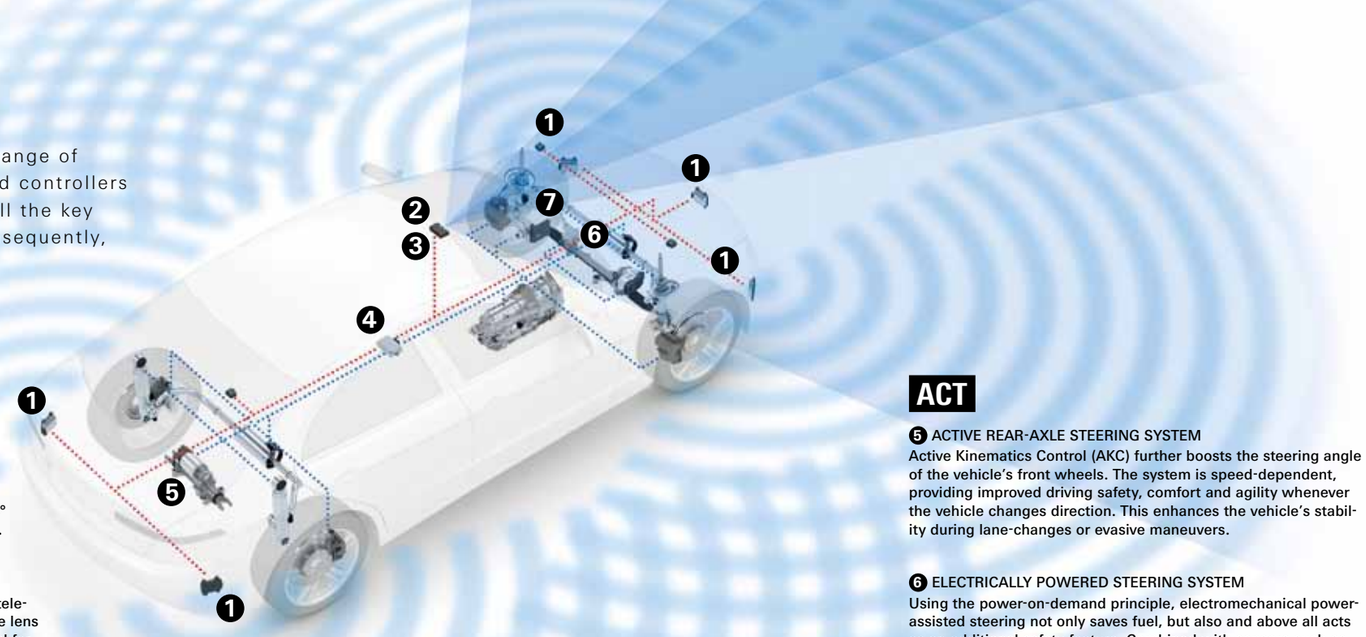
Similarly, many drivers are unable to cope with high-speed steering maneuvers. Electronic Stability Control (ESC) is one solution. As with ABS, the system stabilizes the vehicle by braking each wheel independently. By 1995, production vehicles fitted with ESC were capable of reacting faster than any driver. For engineers and safety researchers, this was the fulfilment of a long-standing dream: intelligent systems making cars less dependent on their fallible drivers.

Modern assistance – or driver-assist – systems are intended to provide all-round protection for vehicle occupants and other road users, based on cameras ▸



## Keeping an eye on safety

**SEE > THINK > ACT:** ZF supplies a full range of high-performance sensors, sophisticated controllers and mechatronic actuators – in short, all the key elements for automated driving and consequently, for enhanced road safety.



### SEE

**1 RADAR SYSTEM**
The new AC1000 EVO radar family has a detection range of up to 250 meters (over 270 yards), a broader field of vision and improved image resolution for reliable environment detection. Versions of the radar system for the front and rear corners of the vehicle deliver the full 360° sensing capability required for automated driving functions.

**2 TRI-CAM MULTI-LENS CAMERA**
In addition to a single-lens camera, the Tri-Cam includes a telephoto lens for improved long-range detection, plus a fisheye lens for improved close-up object recognition. This makes it ideal for automated driving functions such as Highway Assist or Traffic Jam Assist. The extended range of the object recognition capability plus a broader field of vision satisfy the ever more stringent regulatory requirements governing driver-assist systems.

**3 S-CAM4 MONO CAMERA**
The S-Cam4 family of predictive camera systems offer a broader field of vision than previous generations. They are optimized for future market requirements such as the new Euro NCAP test protocols for automatic emergency braking in response to cyclists crossing intersections, or other vulnerable road users.

### THINK

**4 SAFETY DOMAIN ECU (SDE)**
The SDE central electronic control unit processes data captured by sensors so that it can make appropriate safety decisions. It directly manages the actuators that control the vehicle and guide it safely through traffic.

### ACT

**5 ACTIVE REAR-AXLE STEERING SYSTEM**
Active Kinematics Control (AKC) further boosts the steering angle of the vehicle's front wheels. The system is speed-dependent, providing improved driving safety, comfort and agility whenever the vehicle changes direction. This enhances the vehicle's stability during lane-changes or evasive maneuvers.

**6 ELECTRICALLY POWERED STEERING SYSTEM**
Using the power-on-demand principle, electromechanical power-assisted steering not only saves fuel, but also and above all acts as an additional safety feature. Combined with sensors such as camera systems, it can automatically nudge the steering to keep vehicles in lane in critical driving situations.

**7 INTEGRATED BRAKE CONTROL SYSTEM**
ZF's Integrated Brake Control (IBC) system combines electronics, brake actuation and electronic stability control (ESC) in a single package. Superior, high-speed braking performance underpins active safety systems such as automatic Emergency Braking Assist, as well as other automated driving functions. IBC also supports regenerative braking and optimized recuperation of braking energy.

To find out more about ZF's safety systems, scan the QR code above using your smartphone or mobile device.

and intelligent algorithms. Relatively inexpensive optics mounted behind the windshield can identify and distinguish moving objects. A small lens with a range of up to 130 yards films the area in front of the car. Powerful microchips scan the stream of images for street signs, road markings and obstacles. If the vehicle strays too close to the sideline, a Lane Keeping Assist system gently tweaks the steering and guides it back to the center of the lane. The camera's data stream is useful even at night, enabling the system to recognize other vehicles in good time so it can proactively guide high-beam headlamps away from other road users.

### Distractions at the wheel

Modern driver-assist systems can make automatic braking decisions in milliseconds – much faster than any human driver could react. Even careful drivers need more than one second to take action, and then the actual braking distance adds more time. But drivers aren't always careful. Instead, they may be concentrating on their favorite radio shows, fiddling with satnav systems or talking on their cellphones. The Allianz Center for Technology reckons driver distractions are the main cause of one in every ten car accidents. A recent study has shown that 40 percent of drivers make calls without using a hands-free system, and one in five drivers text-message from behind the wheel. "Not paying attention is a factor in around one third of all accidents," confirms Dr. Christoph Lauterwasser, Head of the Allianz Center for Technology.

**40%**
of drivers make phone calls without using a hands-free system; one in five drivers text-message while driving.

A few simple figures underline the dangers of distracted driving: inserting a CD in a car's infotainment system takes around five seconds on average, increasing the risk of accident by 2.3 times. So if a child unexpectedly runs out into the street, the driver has very little chance of stopping his or her vehicle in time. By contrast, driver-assist systems are continuously monitoring the vehicle's immediate surroundings. So they are much more useful for protecting pedestrians than passive safety systems. This is why the Euro NCAP vehicle safety association recently added active safety functions to its widely respected five-star rating system. This makes it much easier for car buyers to judge how well the vehicle they're thinking of buying will perform when it comes to protecting other road users. "These new tests are the first in the world to evaluate highly automated vehicle functions and assistance systems from a pedestrian's perspective," explains Michael van Ratingen, Secretary General of Euro NCAP. "Many new vehicles have automatic emergency braking systems designed to prevent rear-end collisions. But only a few are also capable of detecting pedestrians." The independent testing organization has been evaluating onboard passive and active safety features since 2013. The standard 40 mph crash test shows just how effective a combination of electronic features and mechanical crumple zones can be. When the vehicle's sensors detect that a collision is unavoidable, the computer automatically applies full emergency braking, reducing the impact speed to around 25 mph. This reduces kinetic energy – hence also the risk of injury – by up to 60 percent.

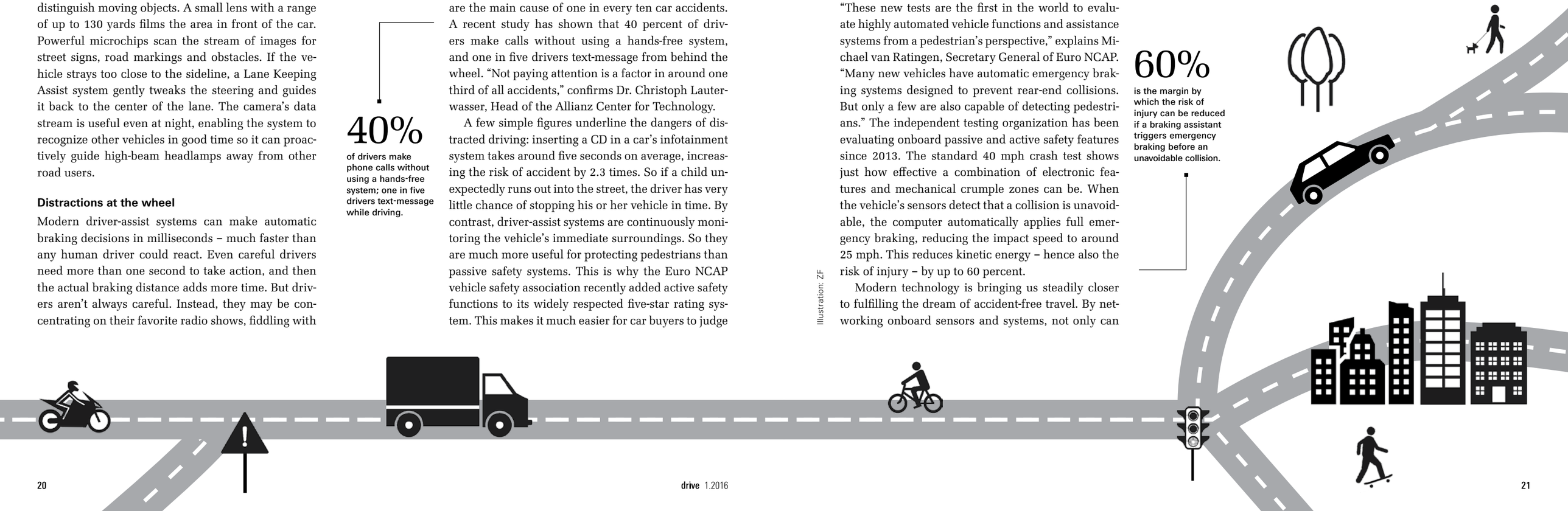
**60%**
is the margin by which the risk of injury can be reduced if a braking assistant triggers emergency braking before an unavoidable collision.

Modern technology is bringing us steadily closer to fulfilling the dream of accident-free travel. By networking onboard sensors and systems, not only can we give cars "eyes" – we can also give them a deeper "understanding" of their surroundings. Connected cars can recognize complex traffic conditions and assist drivers with a broad range of new functions based on their real-time needs. Take radar systems, for example: they can quickly locate vehicles ahead and calculate their relative speeds – but find it more difficult to detect non-metallic objects.

But the new camera systems can close this gap, because they can recognize the human form in all lighting conditions. By merging all of these data sets, the vehicle's computer can rapidly compare and cross-check objects detected by a wide range of onboard systems. The result is an all-embracing electronic safety cocoon.

We have only just started writing the true story of accident-free travel. But the ultimate destination is already in sight: in the future, smart systems will use all possible options to control and manage vehicles. Thanks to environment recognition and steering control, autopilots are taking over more and more of the driver's tasks. This also benefits mixed traffic consisting of cars, cycles and pedestrians. In 2014, the United Nations set themselves the target of halving the number of worldwide traffic victims by 2020 – a much more challenging objective than any previous target. Without the assistance of electronic copilots, it will be very difficult to achieve this laudable goal. ■

Illustration: ZF



# THE FUTURE IS ELECTRIC

Electrification is the key to unlocking personal mobility in the future – and ZF is a key player. In good news for customers, ZF's new **E-Mobility division** will help the technology company serve this dynamic market even faster than before.

*Text: Andreas Neemann*
*Photos: Dominik Gigler*

From the outside, electric vehicles don't look much different from their fossil-fueled stablemates. And when you take your place behind the wheel, it's all very familiar – until you "step on the gas". Instead of the sound of an engine turning over, all you hear is a futuristic hum. But you soon break into a grin when you press that pedal and your electric car performs its party piece. Even low-powered electric motors produce massive torque when accelerating from standstill – a sporty response that has already attracted plenty of gearheads from the world of turbochargers.

### Time for an "e"-breakthrough?

Nowadays, drivers don't even need an all-electric vehicle to enjoy this surge of motoring adrenaline. Modern plug-in hybrid vehicles from BMW, Mercedes, Volvo and many other automakers boast a similarly dynamic getaway. The electric motors in these vehicles are so powerful that you can drive pretty much exclusively on electric power at speeds of up to 80 mph. Their batteries are big enough to support all-electric journeys over distances of 20 to 30 miles (depending on size) before needing to be recharged from a power outlet. And if the destination is further away, their combustion engines can make up the extra range. With this combination of sporty responsiveness, long-distance range and resource-conserving efficiency, plug-in hybrids could deliver fresh momentum to electromobility – gaining further impetus from political and societal demands for greater sustainability and environmental protection.

So the time is just right for ZF to reorganize and consolidate the company's skills and expertise in electrically powered vehicles. "ZF is one of the leading pacemakers in the development of electrically powered drivelines," explains CEO Dr. Stefan Sommer. Parts of the company were already producing pioneering solutions for all-electric buses and cars back in the 1990s. This technological superiority was clearly demonstrated in 2008, when ZF opened the first manufacturer-independent plant for electric car drives. "Since then, we have steadily expanded our electromobility portfolio," adds Sommer, "and today we have an exceptionally broad range of products on the market." In addition to electric motors and hybrid transmissions, ZF also offers an increasingly attractive range of solutions for all-electric drivelines (see overview on pages 28–29).

### Pooling expertise

Nowadays, the company is also perfectly capable of developing and manufacturing its own power electronics systems (see page 27). And ZF's electric driveline solutions also embrace commercial vehicles such as buses and even heavy trucks. Now the company must take the next logical step in order to remain true to its pioneering role. "We've brought together all the inspirations and solutions previously developed and championed by the various divisions in the ZF Group and created a separate, dedicated division," confirms Dr. Sommer. In doing to, the company has pooled its electromobility-related skills and expertise to form a new organizational unit.

Based in Schweinfurt, the new E-Mobility division will coordinate and consolidate all the company's activities in this area, so will be able to take maximum advantage of all the latest opportunities for growth. As a Center of Excellence, the new division is also perfectly placed to drive forward the development of even more attractive customer solutions. These efforts will be coordinated by the E-Mobility Systems House, which will work closely with all divisions – as well as ZF's Corporate Research and Development function – using new methods of interdisciplinary collaboration. The new Head of Division, Jörg Grotendorst, only joined the company a few weeks ago. But he still clearly remembers the launch of ZF's electric motor production facility in Schweinfurt, back in 2008. In those days he was a senior engineer at Continental, ZF's partner in the development of power electronics at the time. The 46-year-old does not believe that the new division's remit is confined to pure electromobility. "Our immediate goal must be to promote electrification, aiming to reduce the combustion engine's workload and optimize fuel consumption." The new division's structure will help ensure that the company can handle the highly volatile, fast-moving e-mobility market and reduce time-to-market development cycles.

**"In China, we'll tap into our existing production facilities."**

*Hans-Jürgen Schneider, Head of Electric Drive Technology*


**"We will leverage our expertise so we can offer even more highly integrated solutions."**

*Jörg Grotendorst, Head of Division*

### The three top priorities

The new division will focus primarily on three areas of activity: low-voltage technology, plug-in hybrid drivelines and electric axle drives. For many automakers, low-voltage applications such as mild hybrids represent an attractive solution, because compatible as they are with the increasingly common 48-volt electrical systems in modern vehicles, they remove the need to install high-voltage electronics while at the same time offering plenty of potential for making significant savings across the average vehicle fleet.

Volume production of plug-in hybrid transmissions has already started. ZF hybrid transmissions are installed in, for example, the BMW X5 xDrive40e and Audi Q7 e-tron. ZF's Car Driveline Technology division developed the hybrid transmission, while the electric motors came from Schweinfurt – a successful collaborative model that will continue under the umbrella of the new division.

The E-Mobility division is also working on an all-electric axle drive, which ZF recently unveiled as an advanced engineering project christened EVD (Electric Vehicle Drive); ZF customers have already responded very positively to the system, which offers automakers a range of options. It can be used as the sole means of propulsion in an all-electric driveline, or as an auxiliary electric drive mounted on the rear axle, assisting the combustion engine that drives the front axle. Almost as an afterthought, vehicles equipped with this "axle hybrid" gain all-wheel drive.

### Space-saving solutions

In view of ZF's broad range of electric products, which covers the entire driveline from motor through to wheels, Head of Division Grotendorst believes there is even greater potential for the future: "We will leverage our product range and our expertise so we can offer even more integrated solutions." In situations where space, for example, is at a premium, upcoming ZF products that package electric motors and power electronics in highly integrated, compact units will save valuable inches. From a manufacturer's perspective, such units represent attractive "plug-and-play" solutions that are both easier to install in vehicles and offer more functionality. So to the company's existing, highly developed integration and connectivity skills, ZF has now added the ability to respond very rapidly to new market demands – at all levels. "ZF's unique competitive advantage in electromobility lies in the fact that no other supplier can offer their customers so many different solutions from a single source: electric motors, plug-in hybrid transmissions, all-electric drives plus power electronics for cars, buses and trucks," underlines Grotendorst.

The key characteristics of an electric driveline are dependent on electronics and software. These both form part of the driveline's power electronics – the technology that regulates the flow of current to electric motors as and when required. "Power electronics represents the brain of an electric driveline. It's also responsible for ensuring energy is used efficiently – hence for the vehicle's range," explains Harald Deiss. He's in charge of development and production in the ▸

Without them, electric motors wouldn't run at all: copper coils awaiting assembly in Schweinfurt.

Electronic Systems business unit. This unit has its origins in Cherry, a company acquired by ZF in 2008, which now also operates as part of the new division. Among other things, this business unit has added its worldwide development and production network, with sites in Eastern Europe, Mexico and China, to the division's resources.

**Electric drives for China?**

Naturally the division will focus on the world's automotive growth markets – such as China, for instance. Head of Division Jörg Grotendorst is not the only one interested in China; so is Hans-Jürgen Schneider, who is responsible for the development and production of electric drive systems in Schweinfurt, and Head of Production Jens Baumeister. Growing demand in China could eventually result in high-volume orders – meaning it makes sense for the division to produce electric motors at local facilities in Asia, as well as at its main German plants.

The market potential – especially for plug-in transmissions – is positively tangible. "We'll leverage our manufacturing network and tap into our existing local production facilities, where we can more or less replicate our stable processes," explains Schneider. Of course it won't be a walk in the park – manufacturing electric motors is very different from building transmissions, clutches or dampers.

Meanwhile, the potential for growth in the European market is already quite challenging enough. Projected figures for the Schweinfurt plant are eye-popping: based on the latest annual production output, which totals around 40,000 units of various electric motors, Baumeister is anticipating that annual output will double year on year – for not just one but several years in a row. As Grotendorst says: "If these current projections remain unchanged, we'll pass the million-unit mark by 2020 at the latest."

This growth isn't just keeping Jens Baumeister and his team of production specialists busy. Alexander Gehring, Head of Electric Drive Development in Schweinfurt, is heavily involved in new volume production operations. ZF customers don't just buy electric motors off the peg. Application engineers prepare very carefully for the launch of each volume production operation, which is precisely optimized to meet the individual customer's specifications. Gehring's work in the new division also involves a great deal of communication with his colleagues. The global development and production network must constantly adapt to meet new market needs and expectations. Which is why the division is currently building an E-Mobility Tech Center in Yokohama, Japan.

Copper coils are vital components in electric motors.

**"Among other things, power electronics is responsible for efficiency, hence also for range."**

*Harald Deiss,*
*Head of Electronic Systems*

Products for electrified commercial vehicles – such as the electric motors in the AVE 130 electric portal axle for city buses, or in the TraXon hybrid transmission for heavy trucks (see pages 32–35) – are not currently manufactured under the auspices of the new division. But even when other ZF divisions act as lead project managers simply because they are closer to their customers, the E-Mobility division – or rather, the E-Mobility Systems House – plays a vital role as coordinator, acting as a platform for exchanging expertise and making important mutual decisions. Such as agreeing a common control systems architecture, for example. This is where engineers from the Advanced Engineering unit in Friedrichshafen leave their mark, as do all of the divisions.

Because one thing is clear. Currently, the main driving force behind electrification is legislative, in the sense that it will be more or less impossible to achieve the stringent and broadly similar $CO_2$ emissions targets set by regulators around the world without electrifying at least part of the global vehicle fleet. But as more electric products go into volume production and people become increasingly fascinated by e-mobility, market demand will also rise. "We're already anticipating this buyers' market for electric drives," says Grotendorst. And the resulting growth. ■

# HIDDEN CHAMPION

On their own, a big battery and a few electric motors won't trigger an automotive driveline revolution. Electric cars are going nowhere without sophisticated power electronics.

Efficiency and precision are everything in power electronics – the technology that controls and regulates the type, voltage and level of just about every electrical current in the vehicle. Power must reach the components that need it efficiently and in exactly the right proportions – as well as flowing back and recharging the battery in an optimized recovery process. So it is hardly surprising that power electronics should be the most important component – the brains and heart, as it were – of any driveline that produces zero local emissions. To ensure enough power reaches the electric motor(s) in current ZF systems, the power electronics must be capable of handling up to 150 kilowatts – equivalent to the power output of 150 vacuum cleaners or around 30 domestic ovens – in a footprint of just 305 cubic inches. The following list outlines the various power electronics functions in more detail. Power electronics is an important part of the new E-Mobility division's portfolio (see overleaf for more details of the division's other products).

## Power electronics must:

- convert the direct current (DC) supplied by high-voltage traction batteries into high-voltage alternating current (AC) for at least one electric drive motor, and into low-voltage direct current for the vehicle's onboard electrical systems (headlamps, heating, aircon, multimedia and so forth)
- convert the high-voltage alternating current produced by the electric motor in generator mode so it can recharge the battery (regenerative braking)
- regulate torque
- ensure smooth transitions between driving modes (e.g. switching from Comfort to Eco mode)
- use battery capacity efficiently
- monitor the driveline's power demands (e.g. coordinating the actuation of electric pumps with the main drive unit)

To find out more about ZF's electric drive solutions for cars and commercial vehicles, scan the QR code above using your smartphone or mobile device.

# TOOLKIT FOR ELECTRIC DRIVES

ZF offers electric components for almost all manufacturer-developed drive concepts. Here we present the company's e-solutions for cars.

ZF launched Europe's first volume production line for hybrid modules back in 2008. Since then, the company has been regarded as one of the leading pioneers of automotive driveline electrification. The new E-Mobility division offers customers everything they need for electromobility: low-voltage hybrid configurations, high-voltage technologies such as plug-in hybrid systems and all-electric drives, plus power electronics and power management systems (see also page 27). We take a closer look. ■

## Electric motor

Drive for various passenger-car concepts, from mild hybrids to plug-in hybrids.

Peak output: 55 kW (75 hp)
Components:
- electric motor
- torsional damper
- rotor position sensor
- housing

## An electrically powered vehicle needs these components

❶ CHARGING CONNECTOR
The electric vehicle's battery is charged through the charging connector.

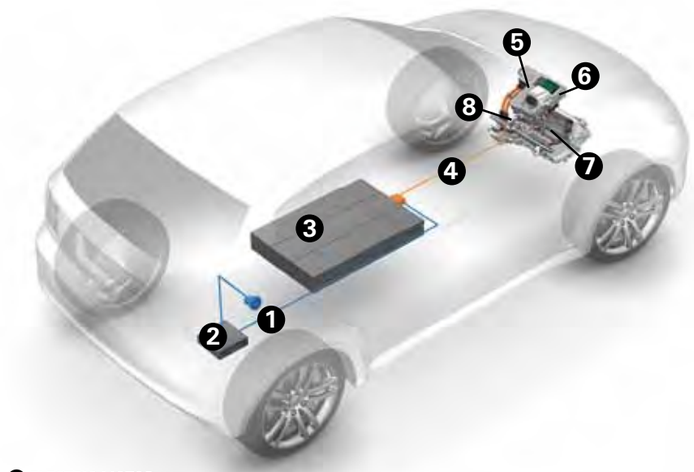
❷ ONBOARD BATTERY CHARGER
The charger converts alternating current (AC) from the grid into the direct current (DC) required by the battery system.

❸ HIGH-VOLTAGE BATTERY SYSTEM
The battery stores electrical energy. The integrated battery management system monitors the state of charge and ensures that the individual cells are operating reliably.

❹ HIGH-VOLTAGE ELECTRICAL SYSTEM
This system connects together the various electrical components in the electric vehicle.

❺ POWER ELECTRONICS
This system converts the direct current from the battery into the three-phase current required by the electric motor. It also regulates the electric motor.

❻ ONBOARD VOLTAGE CONVERTER
Integrated into the power electronics, the converter delivers electric power to consumers in the low-voltage range (e.g. lights, infotainment systems).




❼ ELECTRIC MOTOR
The motor delivers quiet, responsive propulsion with zero local emissions. In generator mode, it recovers kinetic energy produced while braking and stores it in the battery as electrical energy.

❽ TRANSMISSION
In electric vehicles, the motor's drive torque is transferred to the wheels via a single-stage or two-stage transmission.

## Hybrid module

This compact, all-in-one solution for hybrid drives needs very little space for installation.

Peak output: 90 kW (122 hp)
Components:
- electric motor
- torsional damper
- separating clutch
- separating clutch actuator
- housing

The electric motor, a separating clutch and a torsional damper for minimizing rotational irregularities are combined in the smallest of footprints.

## Hybrid transmission

This modular hybrid transmission can also be enhanced to form the plug-in variant.

Peak output: 90 kW (122 hp)
Components:
- electric motor
- torsional damper
- separating clutch
- housing

The electric motor is installed in the transmission housing instead of a torque converter, with almost no space penalty.

## Low-voltage hybrid system

This electric motor and power electronics combination is used in mild hybrids.

Peak output: 15 kW (20 hp)
Components:
- electric motor
- power electronics, incl. rotor position sensor
- housing
- optional torsional damper
- optional isolation element

The electric motor can be used as a generator to convert braking energy back into electrical energy (regenerative braking). Other options include electric starting and stop-start operation.

## Electric axle drive system

This prize-winning concept is ideally suited for compact and subcompact cars.

Peak output: 150 kW (204 hp)
Components:
- electric motor
- two-stage spur-gear drive
- power electronics
- parking lock
- differential
- housing

The motor, transmission (including differential), housing, cooling system and power electronics (including control software) all form a single unit.

## Electrically powered twist-beam axle

This integrated concept features drive and suspension, with independently driven wheels.

Peak output: 80 kW (109 hp)
Components:
- electric motor
- two-stage spur-gear drive
- aluminum housing
- integrated damper/suspension springs assembly
- twist-beam axle

Two electric motors, each capable of 40 kW (54 hp), are integrated into the axle next to the wheels. Torque can be independently distributed to each wheel.

## Modular electric rear axle concept

This system solution from a single source reduces customers' development time.

The electric motor and axle system are supplied as a fully integrated unit, with power electronics pre-installed in the drive itself. This all-in-one system can be used as a full hybrid in vehicles with front-transverse drivelines powered by electric motors, or as an electric all-wheel-drive solution, or as a drive in battery-powered electric vehicles.

Illustrations: ZF

# "E-MOBILITY IS FUN!"

Jörg Grotendorst heads the new E-Mobility division. In this interview, he talks about driving enjoyment, reducing emissions, and the significance of hybrid technology.

*Interview: Andreas Neemann*
*Photos: Dominik Gigler*

***Mr. Grotendorst, is the E-Mobility division a sign that ZF is now really engaging with electromobility?***
Setting up the new division is simply an organizational realignment. ZF is already a well-established supplier of electrified and all-electric drivelines, including electric axle drives, electric motors and the relevant power electronics – and that's not all. We also cover the full range of hybrid technologies, from low-voltage systems to plug-in hybrid systems.

***What role do combustion engines play in this?***
By providing systems that enable cars to use electrical energy really efficiently, we reduce the combustion engine's workload. This effectively means that we're already making a greater contribution to reducing emissions than if we focused on making the combustion engine disappear entirely – which in any case won't happen any time soon.

***But you're not going to try and sell us hybrid technology as a recent innovation...***
We're not interested in innovating at all costs. We want to help cut fuel consumption and reduce emissions as much as we possibly can. And that's why I believe the plug-in hybrid is such an excellent solution. Many car drivers in Germany don't cover more than 30 miles on any given day. Over such short distances, the combustion engine in a plug-in hybrid may not have to do any work at all. Meaning we can cover a large proportion of typical driving profiles with an all-electric solution, without having to worry about consumer acceptance. Because if the same vehicle suddenly has to cover 300 miles in one journey, rather than just 30 – well, that's not a problem for a plug-in hybrid.

***Nowadays, what's still preventing us from running our cars on pure electricity?***
As far as the driveline is concerned, we already have all the technology we need for all-electric vehicles. As a matter of fact, there are already plenty of all-electric cars on the streets, and they've turned out to be very practical in certain environments – think of urban centers, or the short commuter journeys I've just mentioned. More broadly, all-electric vehicles will probably only start to proliferate once we've found optimal solutions for the two key issues: storing and recharging electricity. With respect to battery capacities and prices, the industry will soon break the "sound barrier" of 100 dollars per kilowatt-hour. As for charging, at present, it takes too long, and the infrastructure is too sparse – at least if you're talking about nationwide electromobility. And of course that doesn't solve the perennial problem: that electric vehicles can only have a significant impact on emissions if they recharge from renewable energy sources.

***Would it make sense for governments to offer purchase incentives to boost the electric-car market?***
As I see it, government purchase incentives wouldn't be sustainable. Customers already have other incentives for buying electrically powered vehicles – whether they're plug-in hybrids or all-electric cars. Quite simply, they're fun to drive! Just try pulling away from traffic lights in an electric vehicle. Over the first few yards, you'll leave most conventionally powered sportscars standing. And you can enjoy having fun in the knowledge that it's all being delivered by a highly efficient drive system. As car buyers become aware of this, at some point the market for all kinds of e-vehicles will take off even without government subsidies – reinvigorating the related technologies. In any case, we're already seeing indirect government incentives at work. One of the main factors driving the spread of hybrid technologies is the legislation curbing $CO_2$ emissions. In Europe, the fact that an upper limit of 95 grams per kilometer will become mandatory in 2021 and there's no realistic way for cars to achieve this target without some kind of electric auxiliary drive is really boosting our business.

***Until buyer demand rises significantly, ZF – or more specifically, your division – will have to maintain a highly diversified range of products, from low-voltage hybrids through to all-electric drives. Is this commercially feasible in the long run?***
Well, that's one of the reasons for creating the new division: yes, we need this broad and highly diversified portfolio – at least until the automotive industry starts to focus on specific solutions. But we intend to exploit all the synergies between our various products to the full, so we can respond swiftly to customer needs. Our various products and concepts shouldn't compete with each other for customers' attention. They should build on each other, complement each other. And we intend to use our pooled expertise to systematically push the development of electric motors for hybrid drivelines in the direction of central axle drives.

***Looking forward, what other irons does ZF still have in the fire – especially in terms of technological innovations?***
One of ZF's main advantages with respect to electric drivelines is the fact that we already have all the skills and expertise we need within the company. In the future, we must take full advantage of this broad technological understanding to develop and deliver even more highly integrated systems. For me, one example would be the power electronics integrated into the driveline. Whenever we offer our customers new options with more compact packaging, more functions, streamlined interfaces and enhanced cooling systems, we know we've really done our homework.

***What will be the new division's role within ZF?***
It will make a crucial contribution to the company's future development by focusing its business activities on "efficiency" in particular – one of our key corporate objectives. At the same time, the new division will safeguard the future of ZF's high-tech facility in Schweinfurt following the transfer of our complex CDC damper manufacturing operation to Eitorf.

***What opportunities will this bring for employees and new recruits?***
The new division further enhances ZF's image as a forward-looking, socially responsible technology company that creates environmentally sustainable personal mobility solutions based on a structured and steadily growing commitment to e-mobility. Our employees have the opportunity to play a major role in shaping and evolving tomorrow's mobility.

***So what motivates you personally?***
In my view, it really is important for us to curb emissions by reducing our consumption of resources, and at least attempt to hand over the planet to the next generation with some awareness of our responsibility. In actual fact, this means we shouldn't be satisfied with the threshold values due to come into force in 2021. Do you know how much 95 grams of $CO_2$ per kilometer really is? It weighs about the same as a bar of chocolate. So just imagine this: as you're driving your car along, you open the window every kilometer and throw out a bar of chocolate. As I see it, there simply must be better solutions. ■

Powered by ZF's AVE 130 axle drive, this hybrid fuel-cell bus travels to Stuttgart Airport with zero local emissions – meaning it emits no pollutants whatsoever.

## E-MOBILITY IN LOCAL TRANSIT

# SOFT-SHOE CITY SHUFFLE

Whenever people discuss electromobility, they tend to talk about cars. But electrically powered buses can also solve the noise and pollution issues that plague inner cities, improving the quality of urban life. Buses with ZF technology on board are now running in many cities in Europe and Asia.

*Text: Andreas Neemann and Melanie Stahr*
*Photos: Matthias Schmiedel*

The 79 bus to Stuttgart Airport sets off from Plieningen, Stuttgart's southernmost suburb. As the bus passengers blink sleepily in the slanting spring sunshine, they occasionally glance at an information display inside the vehicle. It shows a kind of X-ray image of the bus lit up by various colored lines.

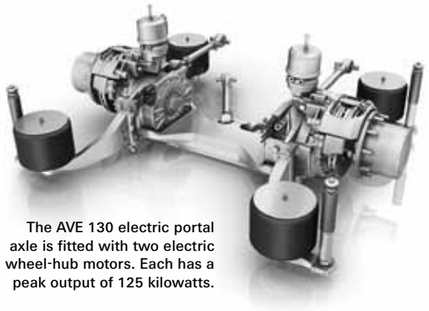
Subsidized by Germany's Federal Ministry of Transport and Digital Infrastructure, the 79 bus is a hybrid fuel-cell vehicle. It runs entirely on electricity and emits no exhaust gases at all, apart from some water vapor. That's because it's a Citaro Fuel Cell Hybrid built by Mercedes-Benz. In this case, the term "hybrid" applies to a combination of fuel cell and high-voltage battery. Both of them are mounted on the roof of the bus, along with seven high-pressure hydrogen tanks and their cooling units. The display inside the bus shows the energy management systems at work, controlling the interaction between fuel cell, lithium-ion batteries and electric motors. The motors, an integral part of ZF's all-in-one AVE 130 low-floor portal axle, are mounted right next to the rear wheels. Pilot projects involving buses fitted with ZF's electric axle drives are currently running on the streets of many European and Asian cities (see box on page 35); these test vehicles have already clocked up millions of miles. Like all electric motors, the AVE 130 can also work as a generator, feeding electric current back into the batteries. The process is known as regenerative braking, and bus drivers are given special training in how and when to use it. "Unlike diesel vehicles, you should deliberately keep on braking for as long as possible, so plenty of current flows back into the batteries," explains Markus Modlmeir, Director of the Bus Driving School run by SSB (Stuttgarter Strassenbahnen AG), Stuttgart's regional transit operator.

This all-electric technology makes no difference to passengers. They do notice that the bus runs more quietly – especially when pulling away from bus stops – and unlike diesel buses, doesn't change gear. As for boarding and alighting, the vehicle has all the usual advantages of a full low-floor bus. It also has just as much space inside for passengers. SSB is field-testing four of the fuel-cell hybrids, at some extra cost. A total ▸

Bus driver Jacqueline Limpio, employed by transit operator Rhein-Neckar-Verkehr, positions her bus over the charging pad.

Bus passengers can watch the entire energy management cycle in real time, on a display inside the bus.


The induction plate (left) is lowered onto the charging pad. A telematics systems supplied by Openmatics monitors its position. A dashboard-mounted display reports the state of charge.



The AVE 130 electric portal axle is fitted with two electric wheel-hub motors. Each has a peak output of 125 kilowatts.

Illustration: ZF

of 200 drivers were given an induction course. And in order to maintain the roof-mounted structures, SSB had to train staff how to handle high-voltage systems. They also had to purchase special stands and mobile scaffolding for accessing the vehicle roofs. “We’ve always been happy to partner with companies who want to test new drive systems for buses,” says Press Officer Birte Schaper. “This gives us useful early insights into technologies that may be suitable for future use once the time comes to replace diesel engines.”

**An all-electric solution based on the AVE 130 axle system needs around 75 percent less drive energy than a comparable diesel vehicle.**

### Charging bus batteries by induction

The city of Mannheim is also testing possible electric bus solutions. Since June 2015, two all-electric prototypes have been operating in the city center, working the bus route 63 between Pfalzplatz, the university and the central railway station. ZF’s electric low-floor axle is not the only stand-out feature: current is passed to the buses by six charging stations buried beneath the road surface at bus stops, using the wireless principle of induction – just like an electric toothbrush.

With practiced precision, driver Jacqueline Limpio (30) positions her electric bus above the charging pad at the Pfalzplatz bus stop and presses a button that lowers the metal plate holding the bus battery down into the induction field. To ensure no foreign objects such as soda cans are sandwiched between charging pad and battery, the underside of the bus is fitted with a camera system.

If she had to, Jacqueline Limpio could reverse the bus and remove any debris from the charging pad. “But that’s never happened yet,” she says. Like 40 other bus drivers employed by transit operator rnv (Rhein-Neckar-Verkehr GmbH), she has been given additional training. The electric buses must fully recharge their batteries at each end of the line, so they can’t make up for delays by shortening the time they spend there. Even so, Project Manager Sebastian Menges is very pleased with the results. “Charging time is included in the total trip time, which means the two electric buses can travel up and down route 63 all day long,” he explains. They can complete two circuits of the bus route, a total of 12 miles, without any recharging at all.

But the aim is to keep the battery charge high by frequent inductive charging – a process known as “opportunity charging”. A conventional diesel bus helps out for a few circuits each day while the resting e-buses fully recharge their batteries. For continuous, detailed information about the buses’ state of charge and charging cycles, rnv relies on Openmatics. Supplied by a ZF subsidiary, the telematics platform stores all relevant data, making it much easier to evaluate the project. “To date, the availability of the electric buses has exceeded 82 percent,” says Sebastian Menges. “That’s significantly higher than we were expecting.” This means that on bus route 63 alone, at least 150 metric tons of $CO_2$ are being saved each year. ■

## In use worldwide

Electromobility in buses is an international market trend

The AVE 130 axle system has already proved just how practical it is in multiple field tests over the last few years. More than 300 electric portal axles have already covered over 8.5 million miles in cities throughout Europe and Asia. Much of that distance was covered in Germany, in serial hybrid configurations coupled with downsized diesel generators. The AVE axle can run on electricity from any source, which is why other European and Asian cities also selected it for use in all-electric applications, including battery-powered low-floor buses and trolleybuses. As well as versatility, the electric portal axle has other advantages – it produces less noise, can be installed in the same space as conventional low-floor axles, and has profoundly impressed users by its ability to climb even very steep or lengthy uphill inclines.

To find out more about electric buses, scan the QR code above using your smartphone or mobile device.

# TWO TO TANGO

Volume production of hybrid cars is still relatively new. Developers hope that by combining combustion engines with electric motors, they can meet ever more stringent regulatory emissions targets. Once again, ZF offers suitable solutions for the effective reduction of emissions.

*Text: Achim Neuwirth*
*Photos: Dominik Gigler*

Up to **15%** fuel savings can be achieved by mild-hybrid systems

By 2021 at the latest, a new EU regulation will come into force. It will impose an average emission limit of just 95 grams per kilometer on manufacturers' car fleets. Similar regulations are also being enacted outside the EU. But experts agree that there is no way all-electric solutions can be implemented fast or comprehensively enough to meet these new targets. Electric cars are still having a hard time matching the costs, range and convenience offered by fossil fuel-powered vehicles and expected by customers. Consequently, they are not going to conquer our streets, vehicle fleets and home garages overnight – not until they become the single most obvious answer to all personal mobility issues. Experts believe all-electric automobiles will only start to establish themselves worldwide starting in 2020 at the very earliest.

So what should we do while powerful engines are still required in certain segments – engines incapable of meeting the new emission limits? "Hybridization is and remains a key technology," confirms Dr. Ralf Kubalczyk, Head of Hybrid Transmission Series at ZF. "That's why, as one of the European pioneers of this technology, we're already carrying everything in our portfolio that can help combustion engines save fuel, from mild-hybrid systems to plug-in hybrid systems, plus all the necessary power electronics. And we're continuing to work on hybrid innovations alongside our all-electric drives and drivelines."

### Cutting consumption with electric power

So hybridization is clearly the right tool for making the transition to pure e-mobility. Cars in which a combustion-powered driveline is supplemented by an electric motor are known as Hybrid Electric Vehicles, or HEVs for short. ZF offers the entire range of products required to build and optimize the many different types of hybrid solutions.

HEVs can be categorized according to how much power the electric motor contributes to the combustion engine. At the bottom of the performance spectrum is the "mild-hybrid" system. This is based on a low-voltage power supply of, for example, 48 volts. More and more cars are being wired to support this standard in any case, because of the growing number of power-hungry electrical devices they now carry; 48 volts simply makes common sense. This is why entry-level hybrid variants based on this standard are considered very inexpensive and yet effective. An electric motor that outputs 10-15 kilowatts supplements the combustion engine by adding features such as coasting, boosting, energy recuperation, electric starting and "creeping", as well as stop-start functionality. So even the "mild" type of hybrid can reduce fuel consumption by 10-15 percent.

> **"Hybridization is and remains a key technology for complying with emission limits."**
>
> *Dr. Ralf Kubalczyk,*
> *Head of Hybrid Transmission Series at ZF*

### Range of up to 30 miles

Driving longer distances powered purely by electricity is only really possible with a high-voltage, full-hybrid system – and in particular, the latest development of this concept, the Plug-in Hybrid Electric Vehicle (PHEV). A PHEV can be recharged either as it is driving along, by the combustion engine, or once it is parked, by plugging it into a power outlet. It is perfectly realistic for commuters driving PHEVs to make their daily journeys to and from work on electric power alone. PHEVs fitted with ZF plug-in hybrid transmissions – the electric motor is installed in the transmission's bell housing to save space – are capable of driving at speeds of 80 mph or more without producing any local emissions. If the potential efficiency of the combustion engine-electric motor combination is exploited to the full, fuel consumption over short distances drops by 100 percent in ideal cases.

### Future evolution of plug-in hybrids

Ultimately, it's not just about augmenting combustion engines with electric drives. It's about integrating both power units as intelligently and efficiently as possible so they form a seamless, all-in-one system. "In any case, integrated electronics plus a smart drive management system embedded in driver-assist functions are important prerequisites for making further progress," explains Harald Deiss, Head of ZF's Electronic Systems business unit. This includes drivelines that are capable of recognizing the route in advance and adjusting the vehicle's speed as it approaches bends – without activating the standard service brakes.

Another example is the interaction between the electric motor – capable of switching over to generator mode to brake the car while simultaneously generating electricity – and the car's service brakes. To ensure that the transition from one to the other is smooth and efficient, you need a smart brake management system. This is known as "brake blending".

> **"What people want is integrated electronics, plus a smart drive management system embedded in driver-assist functions."**
>
> *Harald Deiss,*
> *Head of Electronic Systems at ZF*

Up to **100%** fuel savings can be achieved by plug-in hybrid systems over shorter distances.

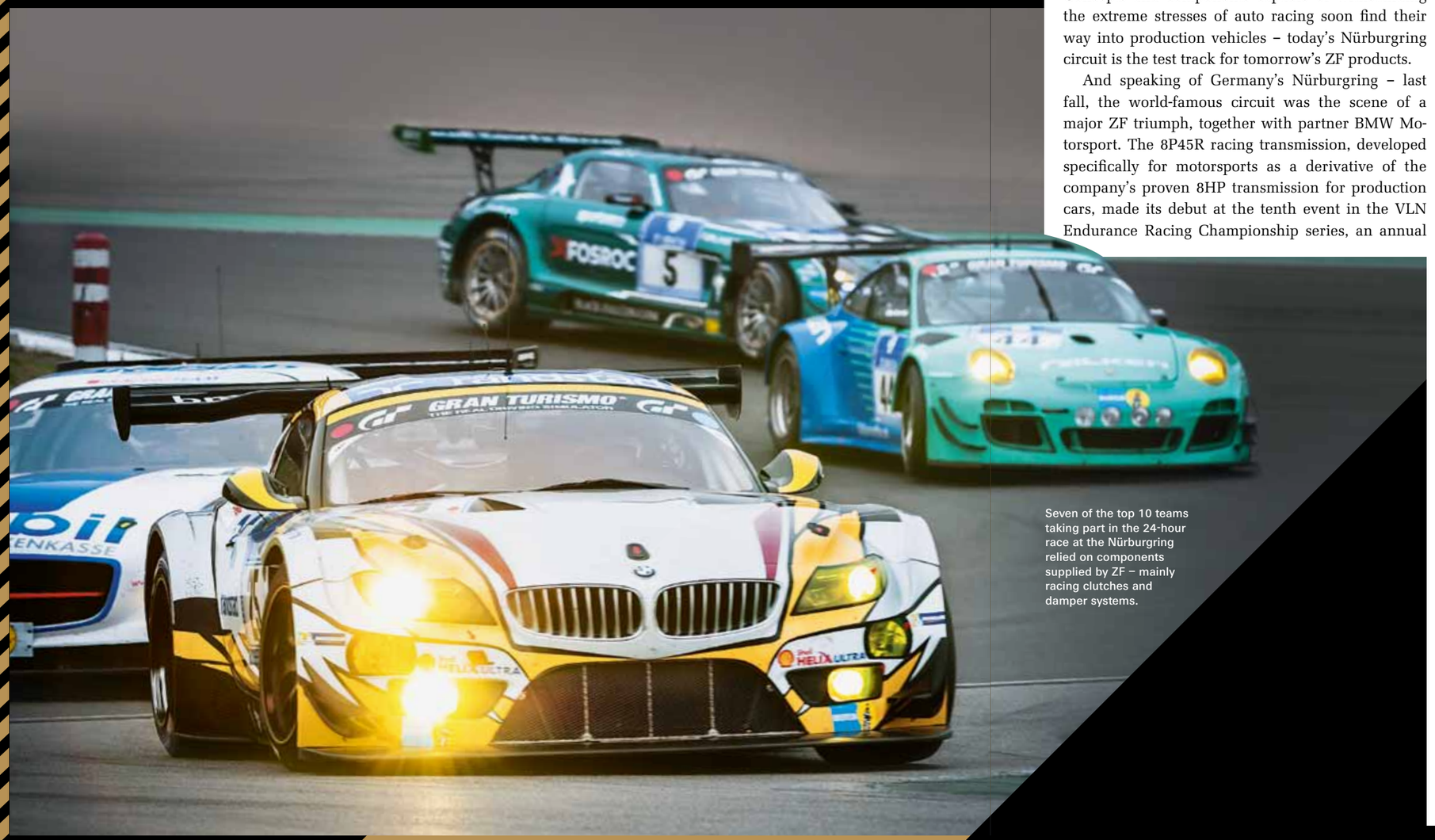
But there is a further stage of development, in which both the combustion engine and electric motor in the hybrid driveline become steadily more specialized. Meaning that in the future, the dimensions and operating ranges of both drive units will be optimized to deliver precisely the system performance required, while minimizing their consumption of energy and fuel. ZF is also working hard on reducing their installation footprint. "Among other things, we're working to package all electrical components in the transmission so they're as space-efficient as possible," is how Ralf Kubalczyk describes one of the company's current development projects.

Many hybrid vehicle are already on the road. ZF is striving to make hybrid technologies even more efficient. One thing is certain: the various types of drives – combustion, hybrid and all-electric – will continue to share our streets for a few years to come. ■

# TESTING ON THE TRACK

Spring heralds the return of hot racing action on tracks and circuits around the world. And ZF Race Engineering is raring to go.

*Text: Michael Scheibe*




Seven of the top 10 teams taking part in the 24-hour race at the Nürburgring relied on components supplied by ZF – mainly racing clutches and damper systems.

Racing teams aren't the only ones looking forward to the new season with great expectations. There's plenty at stake for ZF as well. Formula One, Le Mans, the Deutsche Tourenwagen Masters (DTM), the World Rally Championship, not to mention the Porsche Cup and Super GT in Japan – yes, the racing season is about to start, and ZF Race Engineering is already waiting on the grid. Because many of the top racing thoroughbreds have ZF technology on board!

Celebrating racing successes with automotive partners is fantastic, of course, but at the end of the day, there's much, much more involved for ZF's motorsport subsidiary. While ZF benefits enormously from partnerships with top constructors such as BMW, VW and Porsche, racing events also act as valuable test laboratories for new ZF products and technologies. Concepts and components capable of withstanding the extreme stresses of auto racing soon find their way into production vehicles – today's Nürburgring circuit is the test track for tomorrow's ZF products.

And speaking of Germany's Nürburgring – last fall, the world-famous circuit was the scene of a major ZF triumph, together with partner BMW Motorsport. The 8P45R racing transmission, developed specifically for motorsports as a derivative of the company's proven 8HP transmission for production cars, made its debut at the tenth event in the VLN Endurance Racing Championship series, an annual fixture on the Nürburgring. With the 8P45R, ZF has paved the way for the use of automatic transmissions in auto racing – previously considered a somewhat unorthodox design decision. "The 8P45R is a great example of how motorsports highlight additional development potential in products designed for production vehicles," explains Norbert Odendahl, CEO of ZF Race Engineering. Following the successful trials in the VLN event, he believes it is perfectly realistic to bring the technology to new race categories.

ZF brand ambassador Christian Engelhart secured second place overall in the Porsche Carrera Cup 2015.

### World Rally Championship hat trick

But the 8P45R isn't the only reason Odendahl is looking forward to the new racing season. He wants to build on last year's successes. After all, corks were popping at the ZF subsidiary for all kinds of reasons. In the WRC rally series, ZF partner Volkswagen won a classic hat trick, with drivers Sébastien Ogier and Julien Ingrassia in their Polo R WRC taking the World Rally Championship for the third time in a row. Contributing to the Polo's success: ZF's twin-plate clutch from the Racing Clutch Systems (RCS) family, plus the shock absorbers so vital to rally-car performance – in this case made by ZF in Schweinfurt.

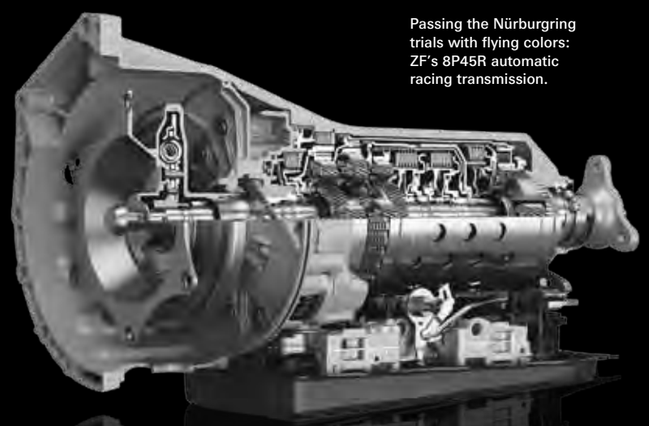
"Together with Volkswagen Motorsport, we managed to develop an engineering benchmark from scratch, in the form of the best chassis in the pack," enthuses Norbert Odendahl. "Thanks to the good impression we made on Volkswagen in the Dakar Rally, they were eager to join forces with us again when they built the brand new Polo R WRC. As a result, we've kicked off a number of new projects," he adds. ▸

**"Our thoroughbred 8P45R racing transmission means we can offer a highly attractive product."**

*Peter Leipold, ZF Race Engineering*

Sébastien Ogier won the World Rally Championship three times in a row in VW's Polo R WRC (left) fitted with ZF technology.

This shock absorber helped Volkswagen's Polo R WRC to victory in the WRC 2015 series.



Passing the Nürburgring trials with flying colors: ZF's 8P45R automatic racing transmission.

As wonderful as it is to celebrate these victories by drivers of cars fitted with ZF technology, not to mention the technical triumphs, ZF Race Engineering also sees itself as an ambassador for ZF – both externally and internally. "Our developments and achievements don't just inspire our customers," explains Odendahl, "they also inspire our current and future employees."

**"Our collaboration with ZF TRW means we can now offer our customers an even more attractive, extensive product portfolio."**

*Norbert Odendahl, ZF Race Engineering*

### Future prospects

Formula E, featuring all-electric vehicles competing on short, attractive street circuits in the world's major cities, is currently attracting a lot of attention. "This season, we're taking part in Formula E for the first time, as a supplier of shock absorbers. Medium term, we're also thinking of developing our own electric motor," reports the Race Engineering CEO. He is also seeking to market the company's high-performance products more widely around the world – in China's growth market, for example.

ZF Race Engineering is also benefiting from the successful integration of TRW Automotive, acquired by ZF last year. "Having added TRW's braking and steering systems to our product range, we can now cover the full spectrum of motorsport requirements, from entry-level amateur racing to the world's top racing elite – both on the racetrack and off-road at the Dakar Rally and World Rally Championship," confirms Norbert Odendahl. It's easy to see why he's looking forward to the upcoming racing season with such optimistic anticipation. ■

Photos: René Ehrhardt, Porsche AG/hoch zwei, www.kraelingbildagentur.de (2), Illustrations: ZF

## Motorsport competitions featuring ZF products:

### FORMULA ONE

Formula One is, of course, the world's top class of auto racing, and ZF supplies no less than four teams with damper technology: Ferrari, Sauber F1, Toro Rosso F1 and the new Haas F1 Team. In his first season with Ferrari, Sebastian Vettel blew through the competition to finish third in the F1 driver standings.

### FIA WEC WORLD ENDURANCE CHAMPIONSHIP AND LE MANS 24 HOURS EVENT

Porsche celebrated its first victory in the most important race on the FIA World Endurance Championship calendar, the Le Mans 24 Hours 2015, since returning to auto racing. The Porsche 919 Hybrid driven by the winning team – Earl Bamber, Nico Hülkenberg and Nick Tandy – is fitted with a ZF clutch. And Porsche's two toughest opponents – Toyota with the TS040 Hybrid and Audi with the R18 e-tron quattro – also depend on ZF clutches. Porsche also claimed the WEC constructors' title for 2015.

### NÜRBURGRING 24-HOUR RACE

Seven of the top 10 teams taking part in the 24-hour endurance race on the Nürburgring were relying on ZF components, mainly racing clutches and damper systems – including the first four overall winners of the 24-hour event. Victory on the famous circuit in Germany's Eifel mountains went to the new Audi R8 LMS, in the car's very first 24-hour race. BMW followed in second place. Both GT3 sportscars are fitted with racing clutches from ZF Race Engineering. And in third place came the Porsche 911 – also equipped with clutches and dampers supplied by ZF.

### PORSCHE CARRERA CUP

All of the 460-horsepower Porsche 911 GT3 cars in the field are equipped with gas-filled shock absorbers and racing clutches supplied by ZF. ZF brand ambassador Christian Engelhart took second place overall in the 2015 driver standings.

### DEUTSCHE TOURENWAGEN MASTERS (DTM)

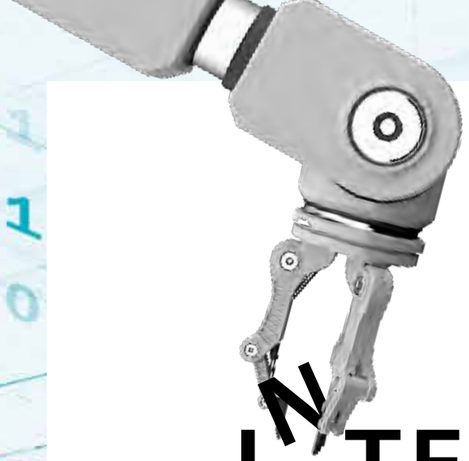
ZF partner BMW won the Constructor's Championship at the DTM 2015. But ZF's Formula Carbon Clutch 4/140Y also featured in the Mercedes driven by DTM Driver's Champion Pascal Wehrlein, as well as all of the Audi, BMW and Mercedes vehicles. ZF brand ambassador Maxime Martin was also a DTM race winner in 2015 in his Samsung BMW M4 DTM.

### PORSCHE MOBIL 1 SUPERCUP

All of the drivers in this series drive the current Porsche 911 GT3, based on the street-legal, lightweight 911 GT3 RS sportscar. ZF supplies the gas-filled shock absorbers and racing clutches for all of these 460-horsepower racers.

### OTHER EVENTS AND COMMITMENTS

In Japan's Super GT series, cars in the GT500 class all drive on clutches made in Schweinfurt. And the Honda Civic in the FIA WTCC World Touring Car Championship is also fitted with clutches and dampers from Schweinfurt. The 560-horsepower Volkswagen Beetle RX racing in the Global RallyCross Championship is equipped with ZF dampers. Other races featuring ZF technology: ADAC Opel Rallye Cup, IMSA WeatherTech SportsCar Championship in the U.S., Formula 3, Formula 4 and Super Formula. ZF Race Engineering is also keen to foster young racing talent. In partnership with the Porsche Junior Program, Deutsche Post Speed Academy and ADAC Sports Foundation, ZF's motorsport subsidiary is passing on technical expertise to the next generation.



# INTELLIGENT VEHICLES?

You can train cars to make certain intelligence-led decisions. But can they also develop the intuition necessary to drive in road traffic? And does this involve artificial intelligence? A visit to the Karlsruhe Institute of Technology provides some answers.

*Text: Michael Hopp*

A total of 32 streets radiate out from the parkland surrounding Karlsruhe Palace, leading deep into the city. Karlsruhe was first founded in 1715, sporting a fan layout typical of the Baroque period. 300 years later, professors and students at Karlsruhe Institute of Technology (KIT) have set an Audi Q5 and a Smart car loose in these same streets – both of them driverless, of course. Because today, KIT is turning the city into the world's leading research and development center for cognitive automobiles.

With 24,800 students and 9,400 staff, KIT is the largest research center in Germany. Professor Rüdiger Dillmann heads the Institute for Anthropomatics and Robotics and cofounded the Cognitive Car (CoCar) research group at the associated FZI Research Center for Information Technology. Does this mean the same thing as "artificial intelligence"? "AI is a sales term that triggers high expectations," says Dillmann. "My advice is to first find out just how far we can get using our own human, natural intelligence. Because that's where I still see plenty of room for further development."

For the scientist, the concept of autonomous driving is by no means a modern trend – it has its origins way back in the last century: "Professor Ernst Dickmanns developed the first driverless vehicles back in 1986, at the Bundeswehr University in Munich, set up by the German Armed Forces." His development efforts were paralleled by researchers at Carnegie Mellon University in Pittsburgh.

### Finding parking spaces without a driver

With countless publications to his name, Dillmann is a pioneer of, well, what we should really call "driving assisted by anthropomatics and robotics". Because as we make the transition from "driver-assist systems" to "fully autonomous automobiles", such terms aren't always very helpful, as they say nothing about the all-important contexts in which they are used. For example, there's a big difference between a car that parks "autonomously" in a parking facility with suitable infrastructure and a car that is capable of finding a parking space unassisted. Dr. Thomas Schamm and his team are working on the second scenario: they've developed their own "CoCar Zero" (Cognitive Car Zero Emission) that is actually capable of locating an empty space in FZI's underground parking garage without any external positioning information.

Autonomous driving won't happen overnight, and it won't be available to everyone simultaneously. "We need to decide who needs the technology, when they need it, and why," insists Dillmann. "Where are the interfaces with railroads, streetcars, waterways and airports? What business models will develop?" And what are society's mobility role models? As Dillmann says: "If you already have an infrastructure complete with landmarks and active street networks that can tell you where the latest traffic jam, black ice or goods traffic is building up, cars can respond accordingly. But if you want to ensure such an infrastructure exists sometime in the future, you need a social consensus."

There will be a range of options for autonomous driving. You could drive yourself into the city, then engage autopilot so the car can park itself and then pick you up later. Or it could return to the car-sharing pool for use by other drivers while you're in town. All of this is predicated on efficient communications between the various systems involved. "To get where we are today, we've spent 30 years researching into the most fundamental issues," explains Dillmann. What we still don't have is the long-term experience, plus of course an analysis of the resulting data.

Autonomous trucks, self-driving electric buses, automatic cruising on long-distance journeys: all of these things are conceivable. "We've already made plenty of progress with long-distance highway travel – if you ignore roadworks and critical traffic situations," says Dillmann, who is perfectly well aware that none of these things can simply be "ignored".

### How do robots learn?

How much more work is needed to turn "automated vehicles" into "cognitive cars" capable of driving swiftly and safely on their own? "There are many traffic situations you can only interpret on the basis of experience," says Dillmann. "What's that old guy about to do? Step off the sidewalk? We can only guess, maybe by catching his eye or observing his body language." While computers can identify the situation, they can't analyze the intention. The problem is always at its most acute when it's not clear what the other person is doing. Which is why driverless cars tend to take least-risk decisions – even though the elderly gent has no intention of crossing the road. Taking calculated risks of the kind that experienced human drivers take every day requires years of practice.

"We humans can gather knowledge from our experiences, apply it to new situations and respond intuitively. Humans don't just have a single behavioral algorithm; we've learned thousands of patterns of behavior we can rapidly activate in different situations. But digital computers only work with binary numbers," explains Dillmann. The researcher would like to investigate how much a robot could learn simply by observing human beings. This is why one of his colleagues at KIT, Professor Tamim Asfour, is using optical sensors to observe his assistants and students interacting in a room. The resulting information is passed on to a humanoid robot, which has already learned to behave like an intern.

How can human intuition be replicated in the form of algorithms? So far, researchers have concentrated on the uppermost abstraction layers. "We know very little about human mental models," admits Dillmann.

> **"Artificial intelligence? Let's first find out just how far we can get with our own natural intelligence. I still see room for development."**
>
> *Professor Rüdiger Dillmann*

"Psychologists and behavioral researchers are all working on them, as are computational linguists. There's a huge amount of data available on the Internet, but why and how human beings apply their experience is still unknown. To find out more, we need to teach machines more about human behavior."

An important step would be to make vehicles aware of their ignorance so they could incorporate this awareness into their decision-making. So are we talking about self-awareness? Dillmann: "By awareness, we mean that the vehicle recognizes what it can't do." To train vehicles to be "aware", they are involved in teamwork. "We practice body language and gestures as a team: one person nods, the other person responds by saying thanks. Or an aggressive driver shakes his fist. How should the car behave?" asks Dillmann. "It's about collecting signals that can be processed by considering conclusions and exclusions."

Dillmann uses the metaphor of the driving instructor who guides the system as if it were a student driver: approach intersections slowly, or stop as a safety precaution. "The key issue is to assess the relative effort involved," says Dillman – who remains convinced that "these are things that a vehicle can learn." ■

Photos: iStockphoto (2), shutterstock

“We’re researching the technologies that will be needed in 15 years’ time.”

*Claudia Hopfensitz*

**CLAUDIA HOPFENSITZ**

POWER ELECTRONICS

Born in Mexico, she now works in Corporate Research and Development at ZF’s head office in Friedrichshafen, developing components that will be used in later generations of electric and hybrid vehicles. For the most part, these consist of power inverters, used to convert the direct current (DC) supplied by batteries into the alternating current (AC) required by electric motors.

# SILENT REVOLUTION

The advance of digitization is causing major upheavals across the automotive industry as a whole and transforming the job profiles of engineers and IT specialists alike. There is a growing demand for interdisciplinary professionals – not least, to work at ZF.

*Text: Axel Kintzinger*
*Photos: Felix Kästle (3), Dominik Gigler (2), Zachary James Johnston*

There’s a small green circuit board sitting on the bench in front of Claudia Hopfensitz. Carefully, she picks up it up. “We’re already doing research into the technologies that will be needed in 15 years’ time,” she says. Born in Mexico, the power electronics engineer is based at ZF’s Corporate Research and Development Center in Friedrichshafen and works on power inverters for hybrid and electric vehicles. “Nowadays, it’s no longer possible for individuals to develop such complex systems on their own,” she insists. “Modern innovations are always the result of collaboration between engineers in different disciplines.”

Volker Vogel works on vehicle connectivity. The software engineer is standing in front of ZF’s concept car, the Advanced Urban Vehicle, illustrating the benefits of a ZF-developed driver-assist system with the help of a tablet. “Braking normally wastes energy. But with PreVision Cloud Assist, we reduce torque as the vehicle is approaching a bend, causing it to slow down without mechanical braking. This saves energy and also makes the vehicle safer,” explains Vogel. This is possible because the vehicle is connected to the Cloud. During each journey, the driver-assist system collects data on the vehicle’s position, current speed, and lateral and linear acceleration (the forces produced while turning, braking and accelerating), and stores this information in the digital Cloud. Using this data, plus previously uploaded GPS map data, the system can calculate the optimum driving style for each section of the route. ▸

**“For an engineer, nothing beats being able to indulge your own creativity!”**

*Volker Vogel*


PreVision Cloud Assist is just one of the many innovations to appear in ZF’s Advanced Urban Vehicle, which attracted considerable attention when it made its debut at the Frankfurt Motor Show in 2015. By fitting the AUV with electric rear-wheel drive, parking assistance and a smart steering wheel capable of detecting whether or not drivers have their hands on the wheel, the company was able to demonstrate the enormous potential inherent in the intelligent networking of chassis, driveline and driver-assist systems. “Increasingly, mobility will be defined by electrification, digitization, safety and connectivity,” is how ZF CEO Dr. Stefan Sommer describes this trend. This is why the company needs more specialists in software and electronics to work alongside traditional engineering disciplines.

### Hardware and software specialists

Farmington Hills, in the U.S. State of Michigan, is the location of a ZF TRW Electronics Engineering Center. Here, Bob Newton heads the application team working on forward-facing camera systems. The cameras help vehicles avoid collisions, stay in lane and identify road signs and traffic lights. “Our cameras are crucial components for automated driving; they help make it safer,” says Newton. This is why his team is composed of hardware and software specialists. “My job is a mixture of both,” explains Jacqueline Hu, who works with Newton’s team and is currently testing how well the camera interacts with software on behalf of a ZF customer.

For CEO Dr. Sommer, this mixture represents one of ZF’s most important and promising strengths. “Our future lies in the intelligent networking of mechanical engineering with electronics and digital systems,” he emphasizes. ZF has been building up in-house electronics expertise for years. Chassis systems such as the company’s AKC active rear-axle steering system and CDC adaptive damping system are managed by intelligent electronic control units. Electronics also play a key role in the Car Driveline Technology division – and again, have done for years. Controllers, power electronics and electric motors are all well-established products in the ZF portfolio. Now, with the acquisition of TRW, the company has also acquired electronic steering and braking systems, as well as a cornucopia of sophisticated driver assistance (“driver-assist”) systems.

The ZF TRW product range includes the Safety Domain ECU (SDE), a central control unit capable of processing millions of bytes of data from environment sensors and analyzing the vehicle’s real-time status as well as the surrounding traffic conditions. ZF also has the perfect solution for customers in need of telematics applications for transferring digital information to and from vehicles, in the form of the company’s independently developed Openmatics platform.

Mathias Döring works at the new E-Mobility division’s head office in Schweinfurt. A mechatronics engineer, he studied Engineering IT before embarking on a professional career with ZF. Döring’s job is designing electric motors. This means that he and his department spring into action right at the start of the development process, when a model of the electric ▸

**VOLKER VOGEL**

CONNECTIVITY

Volker Vogel has already helped develop two ZF concept vehicles – the Advanced Urban Vehicle is his third innovation prototype. This is the kind of work he enjoys. The software engineer studied Engineering Cybernetics in Stuttgart and now works at ZF’s Corporate Research and Development Center in Friedrichshafen.

**BOB NEWTON**

CAMERA SYSTEMS

As a team leader in Farmington Hills, MI, Bob Newton is involved in the ongoing development of driver assistance systems. He coordinates work on the predictive, monocular camera which is a key component in such safety functions as predictive collision warning, following distance indication (FDI) and lane departure warning (LDW) systems, as well as ZF’s Lane Keeping Assist function.

**“We’re definitively breaking new ground. Each day presents us with exciting new challenges.”**

*Bob Newton*

**MATHIAS DÖRING**

ELECTRIC MOTORS

Since graduating in Engineering IT – a combination of electronics, mechanical engineering and computer science – Döring has been working for ZF in Schweinfurt developing electric motors. He was involved in the eTB (Electric Twist Beam) project, an electric drive for cars built into a rear axle with twist-beam suspension. Mounted next to each wheel is a compact unit consisting of a transmission and electric motor in a lightweight aluminum housing.


motor is required. Computers are his most important tools. "All simulations are run on computer," he explains. And thanks to new programs and ever more powerful computers, simulations can be developed faster than ever.

### Interdisciplinary specialists of the future

Experts like Hopfensitz, Vogel, Newton, Hu and Döring represent a new kind of specialist, possessing a sophisticated combination of skills in mechanical engineering and electronics, as well as in analog and digital working methods. "Job profiles are changing," notes Martin Frick; as Head of Employer Branding, he is actively seeking out experts with these new profiles. "We need interdisciplinary engineers and IT specialists capable of acting as interpreters between software and hardware," says Frick. Because the labor market is not delivering enough cross-disciplinary specialists, ZF now relies on its own educational initiatives – such as the work-study program – to train up new recruits. The company also awards bursaries to experienced employees who continue to train alongside their full-time jobs. "Skilled workers are the key to business success in the digitized world," confirms Frick. ■

**"I simply cannot imagine how we could meet $CO_2$ targets without the widespread use of electric motors."**

*Mathias Döring*





# NEW DIRECTIONS

ZF Denkfabrik in Friedrichshafen develops innovative business models in just a handful of months.

In spacious, modern offices near Friedrichshafen Airport sit groups of young people working on notebook computers. Creative games lie piled in corners; the atmosphere is relaxed and unconventional. But what appears to be a Silicon Valley startup is, in reality, an in-house think-and-do tank. At ZF Denkfabrik, engineers, scientists, economists and psychologists work together to develop new products and business models at true start-up speeds. "We could do with a neuroscientist, too – vehicles are becoming increasingly emotional," says Malgorzata Wiklinska, who heads the think tank. She is only 32 years old.

### Wearables for pedestrians

Since January 2015, her team has been busy thinking up and developing new areas of business for ZF, as well as bringing innovative products to market. Among their early successes is an app called uflip, which can be used to create spontaneous transit and mobility communities. With the app's help, users intending to travel from A to B can establish – in real time – which means of transport would be fastest and most cost-effective, whether there are any parking spaces at their destination, and whether any other users are heading in the same direction, so they could travel together.

The think tank took just four months to develop the app from initial concept to market readiness. No project is supposed to take more than six months of team time. Another Denkfabrik idea appeared on ZF's exhibition stand at the Consumer Electronics Show (CES) in Las Vegas – a face and emotion recognition system for streamlining communications between vehicles and their occupants. Now Wiklinska and her team are working on a wearable device for pedestrians and joggers – a small portable unit that could be incorporated into, for example, wristbands or clothing and is capable of communicating with cars to ensure they detect non-motorized road users in good time.

"We're looking for new ways forward. We aim to redefine 'Motion und Mobility' and develop products that supplement ZF's core business activities," says Wiklinska. More or less anything goes, and team members are explicitly encouraged to fail – and then try again. Because traveling down unconventional pathways and thinking outside the box is what the think-and-do tank is all about. ■

The think-and-do tank is currently working on a wearable device for pedestrians and joggers. The photo shows the core of the tiny gadget, which is a platform for human-machine communication.

Visit www.zf.com to view more job profiles and job videos, or just scan the QR code above using your smartphone or mobile device.

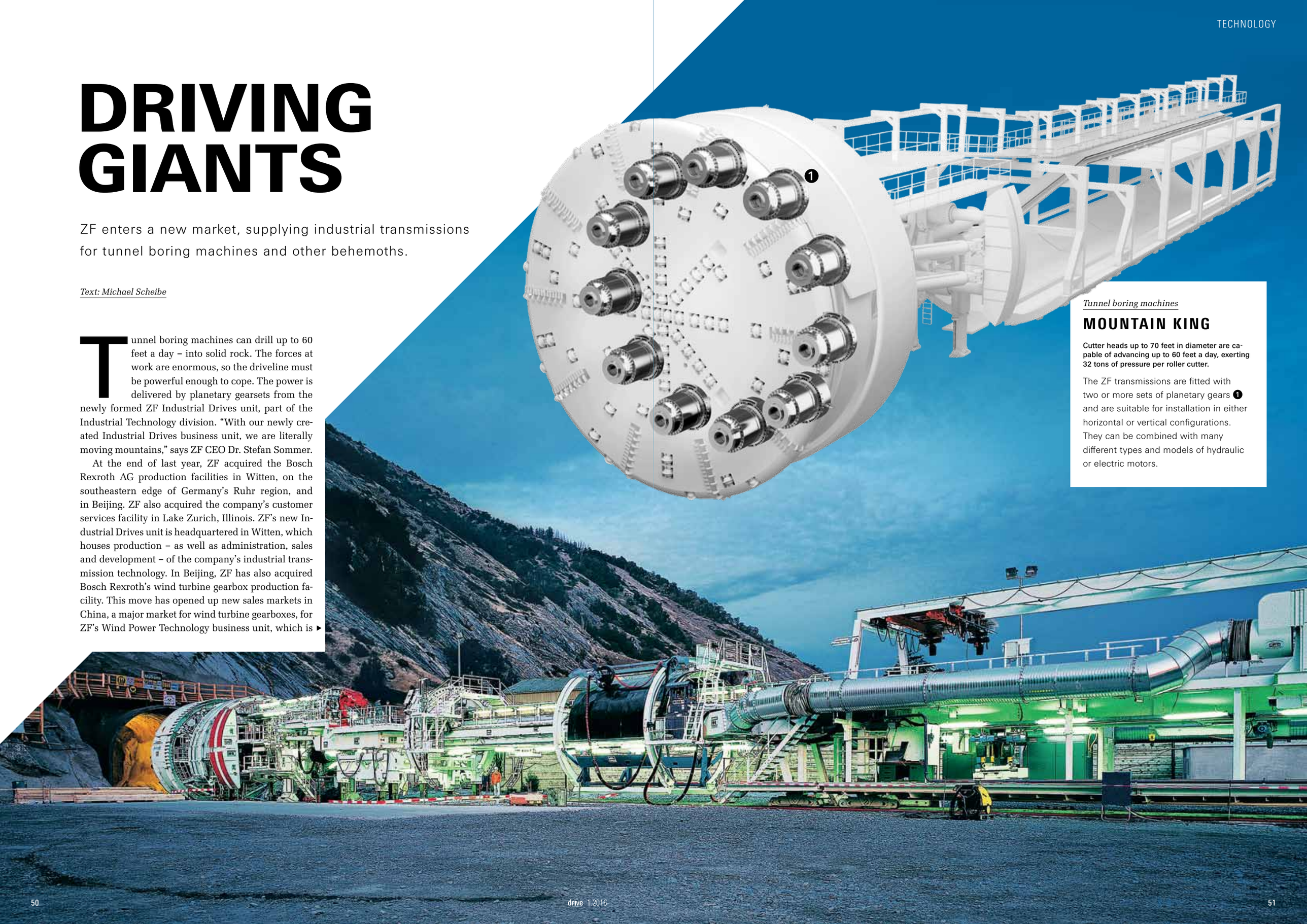
# DRIVING GIANTS

ZF enters a new market, supplying industrial transmissions for tunnel boring machines and other behemoths.

*Text: Michael Scheibe*

Tunnel boring machines can drill up to 60 feet a day – into solid rock. The forces at work are enormous, so the driveline must be powerful enough to cope. The power is delivered by planetary gearsets from the newly formed ZF Industrial Drives unit, part of the Industrial Technology division. "With our newly created Industrial Drives business unit, we are literally moving mountains," says ZF CEO Dr. Stefan Sommer.

At the end of last year, ZF acquired the Bosch Rexroth AG production facilities in Witten, on the southeastern edge of Germany's Ruhr region, and in Beijing. ZF also acquired the company's customer services facility in Lake Zurich, Illinois. ZF's new Industrial Drives unit is headquartered in Witten, which houses production – as well as administration, sales and development – of the company's industrial transmission technology. In Beijing, ZF has also acquired Bosch Rexroth's wind turbine gearbox production facility. This move has opened up new sales markets in China, a major market for wind turbine gearboxes, for ZF's Wind Power Technology business unit, which is ▸



*Tunnel boring machines*

## MOUNTAIN KING

**Cutter heads up to 70 feet in diameter are capable of advancing up to 60 feet a day, exerting 32 tons of pressure per roller cutter.**

The ZF transmissions are fitted with two or more sets of planetary gears ❶ and are suitable for installation in either horizontal or vertical configurations. They can be combined with many different types and models of hydraulic or electric motors.

*Oil rigs*

## OFFSHORE

**Industrial, winch and swing drives for marine and offshore applications are constantly exposed to strong winds and rough weather.**

Jack-up systems comprising motors and planetary gearsets ❶ are used to raise drilling platforms to a safe height above the waves on their enormous legs. Swing or slew drives ❷ are generally used in cranes and winches.

*Mining excavators*

## OPENCAST MINING

**In open-pit mining, around 1600 cubic feet of material may be shoveled up in a single scoop.**

For mining applications, ZF supplies final drive units ❶, slew drives ❷ for precisely positioning excavators and cranes, and power split gearboxes ❸ for hydraulic excavators.

headquartered in Lommel, Belgium. “We’re expanding our portfolio to include large transmissions for industrial applications and mobile machinery ranging from oil rigs to tunnel boring machines and 800-ton mining excavators,” adds Dr. Sommer. “We’ve also further extended our range of Wind Power Technology products by adding gearboxes for turbines capable of generating up to eight megawatts.”

ZF final drives, swing drives and winch drives can handle the largest loads and transfer huge forces, while at the same time delivering precise control over machines such as mining excavators, dozers and heavy transporters that are expected to maneuver or lift gigantic loads with extreme precision.

“We believe the Industrial Technology division has fantastic prospects for the future,” explains Wilhelm Rehm, ZF Board member responsible for Corporate Materials Management and Industrial Technology. “Strengthening ZF’s non-automotive activities is one of the key goals in our long-term corporate strategy. And by acquiring Bosch Rexroth’s industrial transmissions business, we’ve made the perfect addition to our Industrial Technology portfolio, giving us access to new markets and customers.”

The Industrial Drives business unit marks ZF’s entry into the market segment for giant industrial drivelines – and ZF has big plans to match. ■

*Cableways*

## ON THE EDGE

**ZF technology for chairlifts, gondola lifts, funiculars, and cable-propelled transit or tramway systems guarantees high lifting capacities.**

ZF’s planetary bevel transmissions ❶ regulate cableway speeds. Thanks to a flexible modular system, they can be combined and deployed in almost any application scenario.

Photos: Herrenknecht (1), ThinkstockPhotos (1), Kirill Umrikhin/Doppelmayr (1); Illustrations: ZF

# CLASSY CORNERING – THE EASY WAY

Motorcycles are going electronic. Systems such as ABS and traction control help improve safety – as does ZF's CDC adaptive damping system. But CDC has another big advantage: it makes the ride much more fun. For many bikers, that's the key selling point!

*Text: Arnd von de Fenn*
*Photos: ZF*

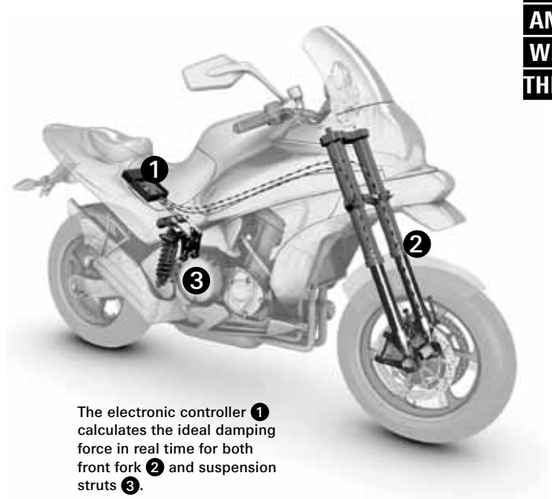
**ON THE APRILIA CAPONORD ADVENTURE TOURER, BOTH *FRONT FORK AND REAR SWINGARM FEATURE CDC* ADAPTIVE DAMPING.**

This is Strada Statale 232, officially a state highway. In reality, it's a mountain road that winds through the Italian Alps northwest of Turin. Unless they've taken a wrong turn and ended up here by accident, this is where bikers come to test out their cornering skills. But those who dare to tackle this legendary ribbon of asphalt need to be at the top of their game.

Over the years, the road surface of the highway between Crocemosso and Rosazza – roughly 19 miles long – has been seamed and warped by seasonal temperature fluctuations and the massive loads towed by mountain farmers' tractors. The result is a very uneven pavement, in many places pitted with potholes, that tests the suspension of most motorcycles to the limit. Meaning that bikers must make some difficult decisions. If their steeds are fitted with conventional suspension – usually adjustable by screws or knobs – they must decide exactly what kind of ride they want before they embark on their journey. Wind down the shocks to their tightest, sportiest setting and you'll corner crisply, but feel every crack in the pavement through your wrists and spine. If you choose the comfortable option, your bones will thank you, but your underdamped bike will weave and wobble, forcing you to constantly correct your line. Clearly both options are a compromise – they both restrict your enjoyment of the ride.

### Solution for all road surfaces

But with its demanding surface and contours, this remote Italian mountain highway is also the perfect proving ground for a very different kind of motorcycle: one equipped with semi-active suspension. Traditional European manufacturers such as Aprilia, BMW, Ducati and MV Agusta are equipping an ever larger number of models with ZF's CDC (Continuous Damping Control) adaptive damping system. This intelligent system is the ideal solution for all road surfaces – even Italy's SS 232 – because it smooths ▸




The electronic controller 1 calculates the ideal damping force in real time for both front fork 2 and suspension struts 3.

**THE DUCATI MULTISTRADA 1200 WAS ONE OF *THE FIRST MOTORCYCLES WITH CDC.* ANOTHER LONG-DISTANCE TOURER FITTED WITH CDC FRONT AND BACK IS THE MV AGUSTA TURISMO VELOCE.**

out the bumpiest surface whenever soft cushioning is needed, but knows precisely when it's time to tighten back up again.

The result is pure riding pleasure. Your bike glides smoothly over the most pitted and pockmarked blacktop, but still provides enough feedback and safety margin so the dampers can react instantly to cracks and crevices in the road or prevent the front fork from diving as you brake sharply before a corner.

Where bikes are equipped with CDC, the onboard electronics offers a selection of settings. Depending on manufacturers' specifications, riders can choose between two or three different graduations, from soft and comfy through to stiff and sporty. There's usually an additional option for bikers carrying a full load or a passenger. Another very attractive feature – useful when switching from highways to country roads, for example, but also in other situations – are the fingertip controls allowing you to adjust settings while you're driving.

Like to know more about ZF's motorcycle technology? Scan the QR code above using your smartphone or mobile device.

**VARIOUS BMW BIKE MODELS SUCH AS THE R 1200 GS ARE FITTED WITH *ZF'S ADAPTIVE DAMPING* SYSTEM.**

### Damping force is electronically adjusted

No matter how an individual motorcycle manufacturer may choose to set up the ZF system, one key aspect remains unchanged: CDC is always working away in the background. The electronic system continuously adjusts the actual damping force in response to current driving conditions – and does so in fractions of a second, in what the bike rider perceives as "real time". This magic is achieved by adjustable valves in the CDC dampers, which increase or restrict the flow of oil as required to harden the suspension (for a more dynamic ride), or soften it (for greater comfort).

The system's electronic brain is fed a constant stream of information on driving conditions by sensors mounted on fork and struts, as well as the ABS function. The software uses this data input to calculate the optimum damping force, adjusting the electromagnetic proportional valves in the dampers in just fractions of a second.

At a stroke, this puts an end to the inevitable compromises and "one size fits all" settings that characterize conventional motorcycle suspension systems. Now bikes always have the right damping in every situation – even at the "soft" default setting, the suspension tightens up neatly when the bike is braking. This isn't just useful for long-distance trips on touring bikes. Riders with track ambitions will also find that the system does all the work and helps cut lap times, sometimes dramatically. Models on which CDC is now available range from thoroughbred racers to luxury tourers – from BMW's S 1000 RR superbike through the Bavarian giant's R 1200 R and R 1200 RS roadsters to the Aprilia Caponord Rally adventure tourer. Oh, and thanks to CDC, you no longer have to get your fingers dirty fiddling with bike suspension. Previously, bikers had to adjust springs manually by twiddling half-concealed grub screws on awkwardly positioned struts in the guts of the machine.

### Technology for two and four wheels

Adaptive damping technology was first designed for cars. Since CDC was first fitted to production cars in 1997, more than 20 million systems have been sold. Even light and heavy commercial vehicles are fitted with CDC, to avoid dangerous swaying and protect their payloads. The damping system is also used in cab suspension for agricultural machines.

So it made sense to adapt the system for motorcycles – although it wasn't easy. "A motorcycle responds to damper compression and rebound in a very different way from four-wheeled vehicles," explains Dr. Andreas Fink, Head of the Active Dampers product line. "The rebound phase, as the damper decompresses, is much more significant for a bike."

The relationship between unladen weight and full load is also different in motorbikes. There are major differences between the damper valves and sensor configurations in two-wheel and four-wheel solutions. But you don't notice any of this while driving. If you're sizzling along the legendary SS 232 on a CDC-equipped bike, one thing is clear: while the way may be winding, the sensation is smooth as silk. ■

Illustrations: ZF

## From suspension struts to heated grips

As well as CDC damping, ZF offers many other useful solutions for motorcycles.

**SUSPENSION STRUT**
The versatile damper delivers optimum roadholding by stabilizing the motorcycle at high speeds and helping prevent destabilizing vibrations and oscillations.

**STEERING DAMPER**
Steering dampers control the front wheel and its movements, absorbing impacts and jolts. This makes riding much less tiring and much more fun – even on bumpy roads.

**NIVOMAT RIDE-HEIGHT CONTROL**
Nivomat is installed on the rear axle, replacing a conventional damper. The device ensures the vehicle always remains at the same height, regardless of load variations.

**HEATED HANDLEBAR GRIP**
No more freezing hands while biking in the cold; heated handlebar grips ensure that hands remain pleasantly warm. Temperatures are controlled by the rotary switch on the left.

**SWITCHES**
Handlebar switches are used to control functions such as lights, indicators and horn. They are tested to ensure they are waterproof, dustproof and protected against ESD.

**TRIPLE CLAMP**
Built out of lightweight aluminum, the triple clamp connects front spring fork to motorcycle frame, guaranteeing high levels of ride and braking stability in all driving conditions.

**SHEAR JOINT**
In motorcycles with duolever chassis geometry, the shear joint transfers steering forces to the wheel carriers and offsets vertical movements, enhancing tracking stability.

# SAFETY FROM ABOVE

In recent years, airbag development has made great strides forward. Now ZF TRW has found a completely new place to mount front passenger airbags in vehicles.

## yesterday ’99

Airbags essentially consist of three components: a gas inflator, a module housing and the airbag itself. In the third-generation BMW 7 Series, all of the front passenger airbag components were housed in the dashboard. The housing itself was made out of steel and the entire module weighed a little more than three kilograms (around seven pounds).

The front passenger airbag module in the BMW 7 Series was significantly larger than today’s models. The gas inflator in particular needed much more space.

## and today

Today’s gas inflators are much smaller and lighter. Most of the module housing is made of plastic. This has almost halved the weight of the module. In any case, modern auto designers are attempting to include more features than ever before in vehicle interiors. Which is why ZF TRW developed a front passenger airbag for the Citroën C4 Cactus that is mounted in the roof of the car. In turn, this liberates more space on the passenger side of the dashboard – ideal for installing infotainment systems, for example.

The Citroën C4 Cactus is the first production car to feature ZF TRW’s roof-mounted airbag for front-seat passengers.

Photos: BMW Classic Archive, ZF (2), Citroën

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**Editors in Chief** Florian Tausch (ZF, V.i.S.d.P.), Michael Hopp (HOFFMANN UND CAMPE VERLAG)
**Editorial Team** Svenja Karl, Heinz-Jürgen Köhler (Senior Editor), Michael Scheibe, Holger Thissen, Jan Wienrich
**Other Contributors to this Issue** Joachim Becker, Arnd von de Fenn, Axel Kintzinger, Tim Moran, Andreas Neemann, Achim Neuwirth, Melanie Stahr
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**drive Reader Service** HOFFMANN UND CAMPE VERLAG GmbH Postfach 130573, 20105 Hamburg, Germany Phone: +49 40 688 79-137 Fax: +49 40 688 79-199 Email: drive-leserservice@hoca.de

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