

vision

# Challenge Accepted!

# SMART MOBILITY

## FARMING 4.0

How ZF revolutionizes field work through artificial intelligence

## SAILING AND SAVING

An innovative transmission reduces fuel consumption



Our promise for  
tomorrow is  
“autonomous  
everything.”

But we've already  
delivered on it today.





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# What role will artificial intelligence play in the transportation solutions of the future?



**AUTOMATION IN VEHICLES IS MOVING FORWARD AT BREAKNECK SPEED. CLASSIC CONTROL SYSTEMS ARE REACHING THE LIMITS OF THEIR PERFORMANCE. THIS IS WHY ZF IS RELYING ON ARTIFICIAL INTELLIGENCE – ACROSS ITS ENTIRE RANGE.**

It was only a year ago that we made a promise at the Consumer Electronics Show (CES) in Las Vegas. Our promise was “autonomous everything.” At the time, we presented the first result of our partnership with Nvidia, an unassuming gray box that contained a prototype of the ZF ProAI supercomputer. For the first time, the processor not only executed programmed commands, but also had the ability to learn. Artificial intelligence (AI) is what makes it possible.

As a result, the supercomputer’s algorithms transform our tried-and-true chassis, steering, drive, and safety systems into intelligent mechanical systems. For example, today, computers connect the steering with the brakes or control driver assistance systems. And tomorrow, the artificial intelligence in the ZF ProAI – which is an order of magnitude more powerful – will revolutionize automotive electronics. This new brain, with its ability to learn, will not only intelligently connect the systems within the vehicle, but also give the car the ability to communicate with the outside world – both of which are necessary for autonomous driving. Our “autonomous everything” promise goes far beyond the automotive sector, however. Since we offer

an extremely wide range of products, we can put our knowledge of AI to use in other fields. As such, we are pairing our ZF ProAI with our equipment in the fields of agriculture and construction, cable cars and railway vehicles, ships, and wind turbines.

So today, only one year after our “autonomous everything” announcement, we are already presenting the first results: leading the list is a concept vehicle on the basis of a mid-range car that we taught to drive autonomously at level 3 using ZF ProAI. The box will enter mass production at a Chinese automaker in 2021. Our joint venture with e.GO Mobile AG will bring autonomous people and cargo movers to market. An Austrian customer, the agricultural-machinery manufacturer Lindner, recently presented a concept tractor that also relies on artificial intelligence “made by ZF”. With its help, the tractor can complete its work in the field autonomously. Be honest – a year ago, did you really think we would accomplish all this?

**Torsten Gollewski**  
Head of Advanced Engineering  
ZF Friedrichshafen AG



ZF MOMENT

# Time travel



Visitors were able to get an idea of the future of mobility in the ZF Brand Tunnel at the IAA. Spectacular video walls and psychedelic mirror effects immersed guests in the five stages of automated driving. Levels one to five were supplemented by level E – because to ZF, “Vision Zero” also means zero emissions. More in-depth information on every aspect was available at the touch of a button. No wonder the ZF Brand Tunnel turned into something of a crowd magnet throughout the eleven days of the show.

LEVEL 1

LEVEL 2

LEVEL 3

LEVEL 4

LEVEL 5

ASSISTED  
DRIVING

PARTIAL  
AUTOMATION

CONDITIONAL  
AUTOMATION

HIGH  
AUTOMATION

FULL  
AUTOMATION



facts and figures



# Smart mobility

# Really clever



STUDIES CONDUCTED BY TRANSPORT EXPERTS REVEAL THAT TRAFFIC ON THE ROADS OF THE FUTURE WILL BE CLEANER AND MORE INTELLIGENT THAN IS CURRENTLY THE CASE.



## MORE TRUCKS WITH ALTERNATIVE DRIVES

By 2026, the proportion of alternative propulsion units among annual sales in the medium-sized commercial vehicle segment will increase worldwide from one percent (2016) to around twenty percent.

Source: Deloitte, "Global Truck Study 2016"

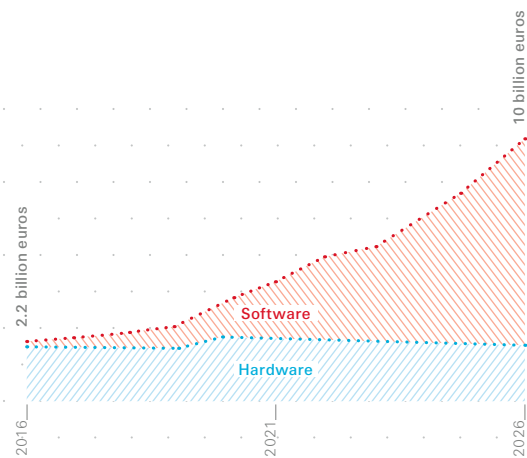
## NEW CARS: SHARED AND ELECTRIC

# 2030

... one in ten new cars sold worldwide will be a shared vehicle and 30 percent of all miles driven in new cars will be from shared mobility.

... the proportion of electric vehicles among global sales of new cars could be between ten percent (in rural areas) and 50 percent (in densely populated areas).

Source: McKinsey&Company, "Automotive revolution – perspective towards 2030", 2016



## SOFTWARE BEATS HARDWARE

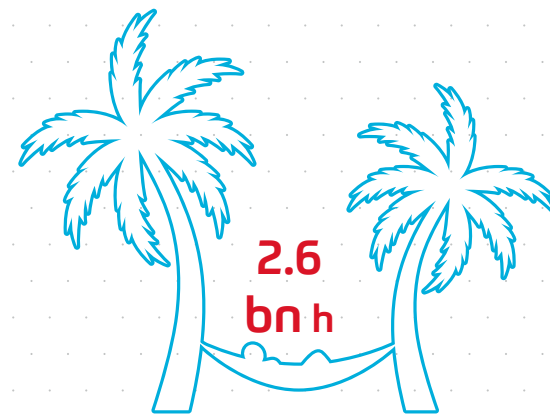
The global market volume for telematics solutions in commercial vehicles is currently around 2.2 billion euros. Of this, 95 percent is attributable to hardware and just five percent to software. By 2026, software will enjoy an 80 percent share of the telematics market, which will have a total volume of ten billion euros.

Source: Deloitte, "Global Truck Study 2016"

## INTELLIGENT SYSTEMS SAVE TIME

Vehicles are already connected in a number of different ways. According to the EU, they will also interact directly with one another and with the road infrastructure in future, contributing to the concept of cooperative intelligent transport systems. This will save energy, cut emissions, reduce accidents and waste less time. As a result, people in the EU will spend 2.6 billion fewer hours in traffic by 2030.

Source: EU Commission, "Europe on the move"



## SERVICES ARE BECOMING EVER MORE IMPORTANT

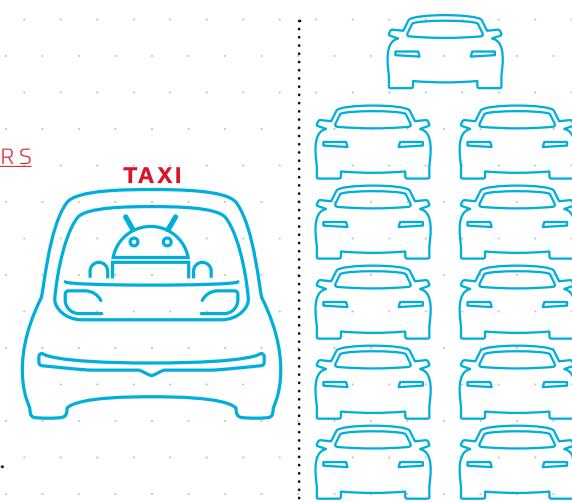
Global car manufacturers currently generate around 0.85 percent (USD 30 billion) of their turnover with regular mobility services such as e-hailing apps. By 2030, this segment is expected to account for 22 percent (USD 1,500 billion) of their turnover.

Source: McKinsey&Company, "Automotive revolution – perspective towards 2030", 2016

## ROBO-TAXIS COULD REPLACE PRIVATE CARS

Around 18,000 autonomous taxis could replace 200,000 private passenger cars in Munich. These robo-taxis would be in use 50 percent of the time, compared to the utilization rate of fewer than five percent for private cars. As such, cars hunting for parking spaces in the city center, which currently account for around 30 percent of all traffic, could be almost entirely eliminated. The mobility flat rate for users in the Munich area would be 99 euros per month.

Source: Berylls Strategy Advisors, Munich, 2017





# On new paths

LIFE HAS CHANGED DRAMATICALLY FOR PEOPLE IN EACH OF THE PAST TWO CENTURIES – AND WITH IT THEIR WAY OF MOVING ON. WE HAVE TO REINVENT MOBILITY ONCE AGAIN IF WE ARE TO MASTER THE CHALLENGES OF THE FUTURE.

Text: Stefan Schrahe



Before looking ahead to the future, let's take a look back to 19<sup>th</sup> century Europe: weav looms and steam engines changed people's lives within a short space of time. Factories mass-produced goods and smaller businesses run by craftsmen were unable to compete. Railroads and steamships not only made the world a smaller place, but also opened up new markets. The professions people pursued and the places where they lived had remained unaltered for generations, but the Industrial Revolution changed all of that. They moved to the cities, where accommodation may have been expensive, cramped, and dirty, but at least it was close to the factories. Traveling was an expensive pleasure and commuting to and from work as we now know it was impossible for the worker in the 19<sup>th</sup> century.

## THE CAR CHANGED THE LANDSCAPE

After the car was invented in 1885, motorization increasingly became something associated with social advancement. In the second half of the 20<sup>th</sup> century urban planners designed the car-friendly city, primarily turned into reality in the sprawling American metropolises, where it remains very much in evidence to this day: "Space is used extensively in the USA and the population density is so low that it is difficult to develop local public transport networks," says Professor Dirk Heinrichs. He is the head of the mobility and urban development research department at Berlin's DLR Institute of Transport Research. In cities with populations



of more than one million, such as Phoenix and Houston, up to 92 percent of people use their own cars for every journey made within the urban area. The car is also bringing about new settlement patterns outside the USA: suburbs and commuter belts around highly populated cities are seen as ideal places to live – with the first and second cars serving as the umbilical cord to the world of work and business. Rural villages are only able to survive because the people who live there are flexible as a result of owning their own cars.

A REAL GROWING  
NEED FOR MOBILITY

Traveling is by no means still a privilege reserved for the rich, but a pleasure enjoyed by the masses. According to figures published by Germany’s main environmental protection agency, the UBA, vacation and leisure traffic accounts for the greatest proportion of mobility at 43 percent; traffic used for work and training purposes accounts for just 22 percent. Each

German citizen covers a distance of around 14,000 kilometers per year in total – it took Marco Polo decades to do the same. Prosperity and mobility are closely intertwined. The US Energy Information Administration (EIA) has identified an almost linear correlation worldwide between economic output per capita and the number of person miles traveled.

However, it is not just people who are more mobile than ever these days. The same can be said of goods to an even greater extent. Global maritime trade has almost quadrupled since the 1970s. Inland transport is also growing as a result of increasing globalization and online market places – by more than 60 percent in some cases over the last 25 years. These goods are normally delivered to their recipients by road; the percentage transported via rail and inland waterways has been in decline for years.

The lifestyle led by Western nations has long since been embraced by emerging economies.

Here, too, mobility is a prerequisite for individual success and social inclusion and progress – and the result of growing economic output. People’s mobility needs will continue to rise. After all, the global population is set to exceed nine billion people by the year 2050. The battle for natural resources, the growing pollution caused by local emissions, and the impact on the climate are the downsides of this development.



SMART MOBILITY DEMANDS

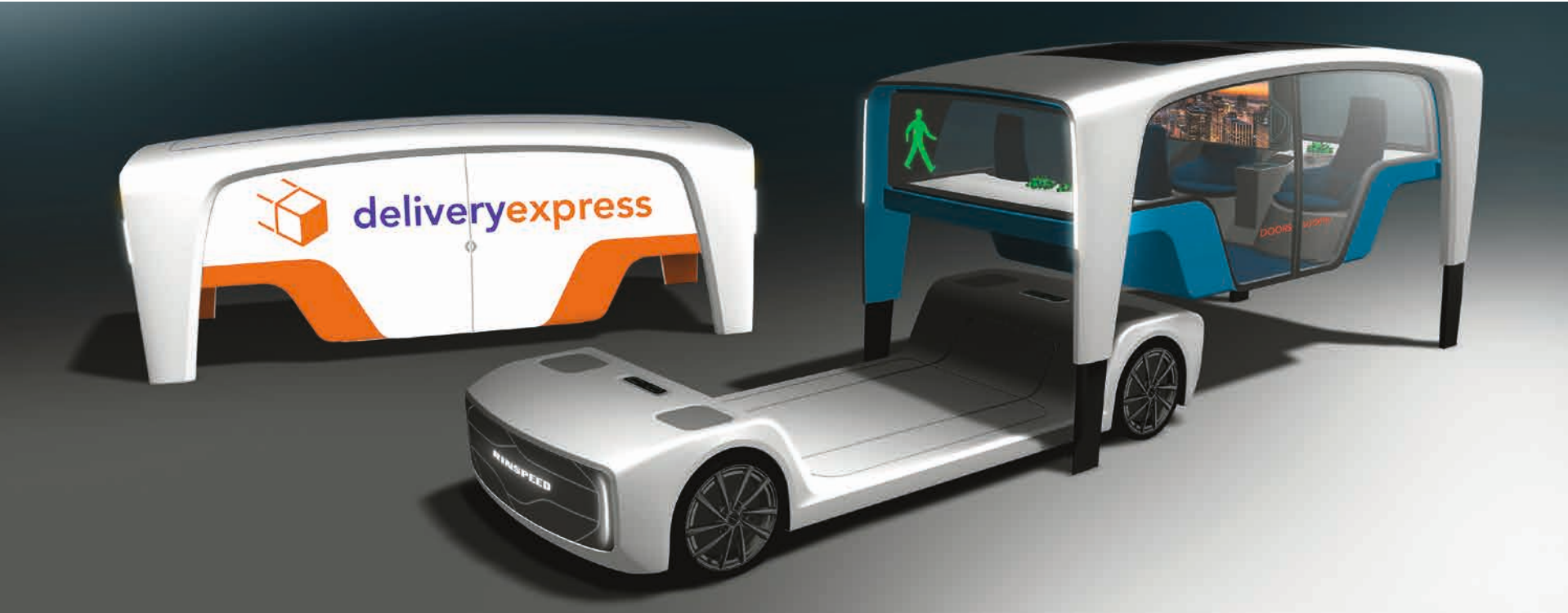
What does all of this mean for the mobility of the future? It is about satisfying a growing number of people’s need for convenient and constantly available mobility – while resources become ever scarcer and environmental protection demands rise.

Journeys to work must become less dependent on rigid timetables in future, not least because working hours are also increasingly breaking out of the classic nine-to-five straitjacket. At the same time, the rampant uncontrolled development of public spaces is resulting in even longer journeys to work, making it all the more important to use the journey time wisely, either for working or relaxing.

It is not all about satisfying work-related requirements, however. Growing urbanization is also increasingly shining the spotlight on mobility when it comes to leisure activities. How can people get to

their favorite climbing wall, mountain bike trail, or lake, for instance, quickly and using the best means of transport in each case?

Changes in our consumer behavior also call for smart mobility concepts. One consequence of online retailing is the huge increase in the amount of goods being delivered. The calls for same-hour delivery are getting ever louder. This is leading to parcel services having to make several deliveries of smaller quantities in increasingly decentralized logistics operations.



The ZF Intelligent Dynamic Driving Chassis (IDDC) provides the basis for the Rinspeed SNAP concept car. At the heart of the idea are electrically driven autonomous platforms. They enter into a temporary marriage with pods – versatile structures that can convey either people or goods. The improved efficiency behind SNAP is designed to relieve cities burdened by emissions and traffic congestion.



SMART MOBILITY SOLUTIONS  
ARE EMERGING AT DIFFER-  
ENT SPEEDS

Conventional mobility concepts in the transportation of passengers and goods are already struggling to meet the demand. The hours spent by commuters stuck in traffic every year say it all. “We are currently seeing a radical shift in the structure of work and transport,” says Chris Urmson. He is the co-founder and CEO of the mobility start-up Aurora and former head of the Google car project. Urmson has identified three disruptive developments that are playing out simultaneously. Together they are paving the way for new concepts

and solutions. They encompass the transition from the combustion engine to the electric motor, the increasing connectivity of vehicles, and autonomous driving. Based on these developments, a study of the future conducted by the ADAC – Germany’s automobile club – has outlined six features that will shape our mobility in future and mutually influence one another.

Regardless of whether smart mobility concepts develop exactly in the way currently predicted by soothsayers like Urmson, the fact is that they will not appear overnight. Old and new solutions will function side by side for at least a decade. Smart mobility solutions will initially

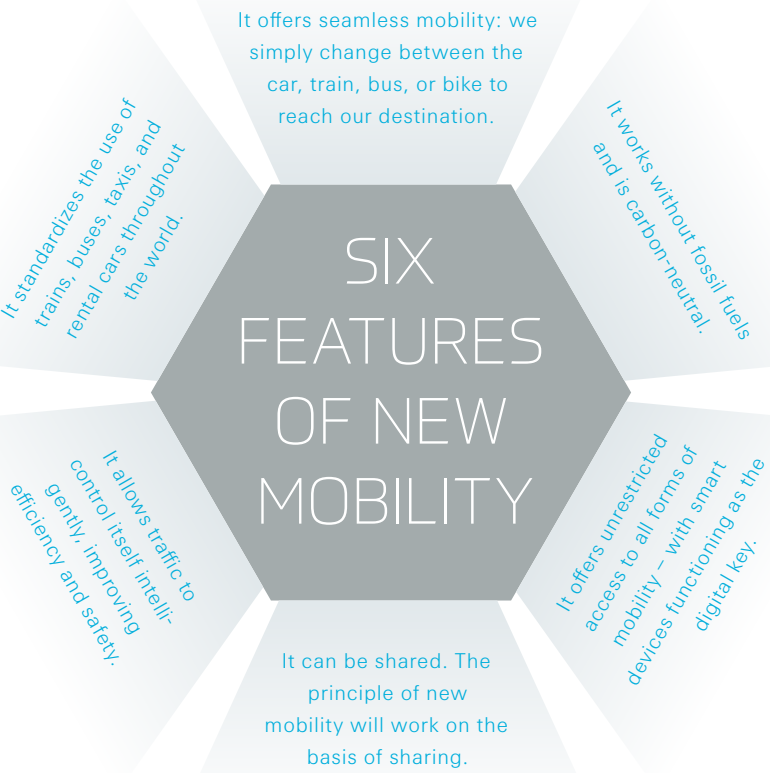
be introduced in areas where the problems are most pressing, the will to find a solution is the greatest, and the requisite economic power exists. While major Chinese cities are completely switching over their public transport systems to electric mobility concepts, for example, a family living in the countryside or other parts of the world will be delighted with the hard-earned two-stroke moped to use as the family vehicle. Smart mobility will nonetheless change our world in the long term. It will be clean, connected, and clever. Let’s embrace it!



...



...



In his study of the future „Evolution of Mobility“ (May 2017) the German automobile club (ADAC) defines among other things these key features of new mobility.

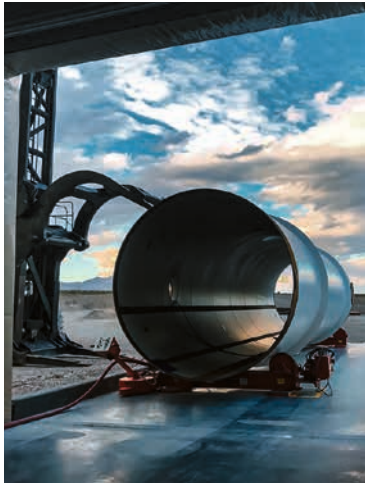
OUTLOOK: MOBILE ON  
THE GROUND AND UNDERGROUND

What will the world of new mobility look like? Here are three examples from the future:



OUT AND ABOUT  
IN THE CITY

Electrically powered autonomous cars and robo-taxis will play a key role in addition to trains and buses. Self-driving cars will become refuges for commuters traveling between work and home. They are at once mobile offices and oases of calm with their digital, multimedia connectivity. Since the vehicle is controlled by artificial intelligence, the driver no longer has to concentrate on the traffic. Robo-taxis whose routes are optimized on a needs basis will be available for journeys in city centers. Roads and parking lots can then be scaled back and transformed into green spaces, because there will be a significant reduction in stationary traffic and the taxis with a top speed of 30 km/h will only take up a third of the space of a “normal” car.



TRAVELING  
BETWEEN CITIES

We will use the Hyperloop for long-distance travel. Instead of boarding planes that damage the climate, we will travel in capsules within a system of tubes – similar to pneumatic mail, but at speeds of up to 1,200 kilometers per hour. The Hyperloop should be capable of completing the 650-kilometer journey between San Francisco and Los Angeles in half an hour. This form of transport is the vision of Tesla boss Elon Musk. A prototype completed its maiden voyage on a test track just a few hundred meters long in July 2017. The Hyperloop requires an incredibly small amount of energy, because an artificial vacuum keeps rolling resistance to a minimum. Built on stilts or buried underground, this system will create a continental subway train network that will bring cities even closer together.



SUBWAY  
FOR GOODS

Cargo sous terrain AG (CST), a company formed in Switzerland in 2017, has created a system designed to relocate the transportation of goods to a network of underground tunnels. Fully automated and unmanned vehicles will travel in tubes 50 meters beneath the earth. Powered by electromagnetic induction, they have a top speed of 30 km/h. CST transports euro-pallets and smaller standard containers and can be used to deliver fresh produce and other goods and remove waste and recyclable materials. At the heart of the transport system are the hubs in the major cities and in the companies’ central warehouses, where goods are loaded and unloaded. An overground city distribution concept with electric delivery vehicles is part of the overall logistics system. Transit traffic will disappear from sight thanks to Cargo sous terrain.



did  
you  
know?

# Testing the future

NEW MOBILITY IS NOT JUST RESTRICTED TO THE ROAD.  
INTELLIGENT SOLUTIONS CAN ALSO BE FOUND ON WATER, AT  
AIRPORTS, ON SIDEWALKS, AND IN THE AIR.

## TO CHECK-→IN DESK WITH WHILL NEXT

Autonomous wheelchairs can help to transport people with disabilities from A to B. Such technology is currently in use at Tokyo Airport, for example, where "Whill Next" – an autonomous wheelchair developed by Panasonic and the wheelchair manufacturer Whill – is being trialed. Users order the smart vehicle by app; the wheelchair then arrives and chooses its route to the destination. Sensors detect potential obstacles. The wheelchair drives itself to the charging station when it needs recharging. Electric wheelchairs also navigate their way around Changi General Hospital in Singapore and take patients to their wards. Due to their aging populations, Asian countries in particular are embracing automation in the health-care sector, with robots already distributing medication and meals in hospitals.



## CARRYING IS SO YESTERDAY

A smart transport and delivery robot called "Gita" follows people on foot and can take home shopping weighing up to 18 kilos. The round robot developed by Piaggio subsidiary PFF rolls on two wheels and, with a top speed of 35 km/h, can even autonomously follow bikes. Gita navigates using SLAM (simultaneous localization and mapping). It uses several cameras to visualize its surroundings. Gita's owner wears a belt equipped with stereo cameras and relays the image data to the transport robot, which compares the images with the information from its cameras so that it can find its bearings.



## TAKE OFF IN A DRONE TAXI

Take to the skies and escape the congestion – autonomous drone taxis could take some traffic off the roads in just a few years from now. Singapore and Dubai are leading the way here. The city on the Persian Gulf wants to trial the Volocopter 2X from the German start-up Volocopter for five years. Passengers order the flying taxi by app, climb aboard, select one of the preset destinations on a built-in tablet, and press the start button. The drone taxis for two people are driven

by 18 rotors mounted on a circular frame and fully redundant power trains. They have a top speed of 100 km/h and the batteries last around 30 minutes. Daimler AG and other investors have got involved in order to speed up the launch of a production model. In Dubai, the Volocopter prevailed over its Chinese competitor, the Ehang 184. The first unmanned test flight over Dubai was successfully completed in September 2017.

Traffic jams, air pollution and vehicle bans. The start-up "SeaBubbles" wants to ease the situation with eco-friendly electric water taxis. The hydrofoils are four meters long and two meters wide and can carry up to five passengers, who can book the mini boat by app and board and disembark at specially designated stops. Power is supplied by turbines installed at the docks and solar modules mounted on the vehicles. A trial run with an initial fleet of five Bubbles is planned for 2018 in Geneva, at first with a helmsman and later autonomously.

## SEABUBBLES AS WATER TAXIS







# Mobility for cities and overland – newly defined

IN DISCUSSIONS ABOUT THE TRAFFIC OF TOMORROW, THE WORD “CITY” IS MOST COMMONLY HEARD. BUT WHAT HAPPENS IN SMALLER TOWNS AND RURAL REGIONS? TOM KIRSCHBAUM, FOUNDER AND HEAD OF THE MOBILITY START-UP DOOR2DOOR, ON CHANGING DEMANDS AND THE SUCCESS FACTORS INVOLVED IN TRAFFIC CONCEPTS.

Text: Kathrin Wildemann

## What are the attributes of a successful smart mobility concept?

The way in which individual modes of transport currently work is incredibly inefficient. The key is to better organize transport, particularly by combining journeys – the watchword here is ride sharing. I think it is very important that new concepts do not cannibalize the classic transport infrastructure. It is more about supplementing them with digital options in order to make optimal use of them.

## What happens if this principle is violated?

In this case it is ultimately the city that suffers. The popularity of companies such as Uber and Lyft in New York has led to even more cars taking to the roads there. Mobility is also a very regional product. Each city has its own topography, its own culture, and

different underlying economic conditions. These local factors must be taken into consideration. This may make the development of new technologies highly challenging, but rigid one-size-fits-all solutions will not work.

## door2door

*A world without privately owned cars – that is the vision of door2door. The Berlin start-up has developed an on-demand mobility platform that complements the existing local transport system by offering needs-based ride-sharing solutions. Two pilot projects have been running since fall 2017 in Duisburg and the Bavarian town of Freyung, with its population of 7,000. The company founded in 2012 employs more than 100 people and has a second office in Porto Alegre (Brazil).*

## In your view, what are currently the most important developments in the mobility sector?

We have three megatrends in terms of products: electric drives, networking, and autonomous driving. The networking of vehicles among one another or with platforms is very much changing the way in which fleets are coordinated. Even though autonomous driving is the one development among the aforementioned three that is still furthest away, it will have the most significant influence.

## Thus far, you have only mentioned technical aspects.

That's right, but user behavior is also changing: mobility is increasingly becoming a commodity. This is where the subject of sharing plays a key role. People will no longer want to own a car, but simply use what they need. From both of these directions we are

seeing the emergence of innovative mobility systems that are geared towards people's needs in a highly agile manner.

## Does this mean that there will soon be no more privately owned cars?

I think this is conceivable in the medium term. In cities with networked on-demand solutions there will no longer be a reason for someone to drive around in their own car. It will take somewhat longer in rural areas. The staff costs for drivers carry more

car. Local public transport networks are fragmented; routes and timetables are underdeveloped. The bus maybe stops at one bus stop in the village – and an elderly lady has to get there first.

## How can this be changed in future?

On-demand solutions can also be utilized in the countryside. It simply involves analyzing beforehand, which routes are actually profitable for large buses and where funds can be allocated more efficiently for solutions such as ride-sharing vans.

to the nearest train station, for example. An intermodal transport concept of this kind effectively increases the catchment area of the local transport system. This is especially interesting to commuters.

## When will we see the first autonomous vehicles on the roads?

It certainly won't be long! By 2021 I think we will see the first cities in which autonomous vehicles are driving around on a larger scale. In around ten years' time it will be commonplace in inner city areas. There will be certain parts of cities

“As soon as cars drive autonomously, there will no longer be a reason to own your own vehicle.”

weight here. As such, individual modes of transport can only be completely replaced in a scenario with autonomous vehicles.

## In what other ways do rural areas differ from the cities?

Driving your own car in the city is often purely a matter of convenience and comfort. Rural regions, on the other hand, are frequently so severely spoilt by sprawling development that there is simply no alternative to using your own

In the first instance, the aim here is not to do away with people's own cars, but make the second car superfluous.

## You have cooperated with small to medium-sized towns and cities in the pilot projects you have run to date. Are they even more suitable for new mobility concepts than larger cities?

One solution could be the provision of shuttle services: you pick up the passenger at home and take them

in which the authorities will only permit the use of autonomous vehicles. This will help them to circumvent the challenges associated with having a mix of traffic on the roads – autonomous vehicles and people who drive their own cars.



# Moving on stress-free

OUR CITIES CONTINUE TO GROW UNABATED – AND WITH THEM, NOISE AND AIR POLLUTION. ONE SOLUTION IS AN INTELLIGENT MIX OF EMISSION-FREE, ELECTRIC-POWERED VEHICLES, FOR WHICH ZF ALREADY OFFERS NUMEROUS COMPONENTS AND SYSTEMS TODAY.

Text: Kathrin Wildemann

It is not so much the car in and of itself, but instead the way it is used that is reaching its limits in today's modern metropolitan areas, says Dr. Jennifer Dungs. She is the former institute director for Mobility and Urban Systems Engineering at the Fraunhofer Institute for Industrial Engineering IAO in Stuttgart: "The desire to have fun driving is going to become less important. In the future, the focus is going to be on the enjoyment of getting to your destination – and doing so seamlessly, without waiting, and in a way that perfectly meets your needs."

## ELECTRIFIED MOBILITY

The solution we see emerging for urban centers and the surrounding areas is one of many different parts, such as the increasing interconnection of all forms of transportation and new, complementary mobility services built around autonomous, electric-powered vehicles. But one thing is also clear – robo-taxis alone are not going to solve the cities' mobility problems. Efficient forms of public transportation will still be needed – but they will also have to be as interconnected and emission-free as possible.

This is why many municipal transport services specifically plan to rely on electric-powered vehicles for future local transportation, particularly buses, which remain the most flexible and important passenger transportation vehicle. Leading the way is China, which at the end of 2015 already had more than 173,000 fully electric buses in use in urban public transportation, primarily in the metropolitan regions of Beijing, Shanghai, and Shenzhen. A report from the International Association of Public Transport IUTP names 25 cities in Europe that either will expand their fleet of electric buses to a total of 2,500 by 2020, or have already done so. A further 13 major cities plan to electrify their fleet by 2025, and will acquire an

*In the project Seun CityWalk of AVOID Obvious Architects, residential buildings and road networks will form a cohesive unit.*

My foray into the mobility of the future began with a short walk. An app on my phone guided me to a compact electric car from a car-sharing service parked a couple streets away. Thanks to car sharing, I am still flexible and can get around easily, even without my own car. I need to go to the furniture store to check out a new bookshelf for the living room. After entering my PIN, the car hums to life. The entire trip is paid for in the background without me having to do anything, billed by the minute and only for as long as I am actually using the vehicle.

## CITIES NEED NEW MOBILITY CONCEPTS

This form of transportation is simply perfect for a late morning trip through the city. Emissions? Zero.

The car drives on battery power. For the ride home in the afternoon, I hop on public transportation – I am having the shelf delivered and the streets are already filling up with commuters. A combination of the subway and a fuel cell-powered hybrid bus takes me to one of countless electric bike-sharing stations. This personal experiment with a mobility app proves that big things are happening in the local public transportation sector. The key words here are "seamless" and "intermodal", and they refer to the ability to complete a trip without interruptions by intelligently switching between different modes of transport.

The demand for new solutions for local transportation in urban areas is huge. Over the last few decades, the urbanization megatrend has resulted in the

formation of megacities, the largest of which have more than ten million residents. And this trend has shown no sign of stopping. The residents of many major cities already suffer from the effects of the traffic chaos today. During rush hour in São Paulo (population approx. 12 million), commuters can need up to an additional two hours to get to their destination. Anyone living in the greater Los Angeles area and on the road between 5 p.m. and 6 p.m. needs to plan for their trip to take 84 percent longer on average. In Bangkok, that number jumps to 118 percent longer than during off-peak times. And cars in the city cause other problems – cities need to set aside between 5 and 15 percent of their total space for parking. And yet drivers still spend up to 30 percent of their driving time looking for a space – which further increases congestion and emissions.



additional 6,100 e-buses by then – which means that fully electric vehicles will comprise a not-so-shabby 43 percent share. The UITP estimates that in light of increasing demand, European manufacturers will be mass-producing fully electric buses at full capacity between 2018 and 2020.

ZF has already prepared for this change. “We have systematically expanded our portfolio of products for electric drive systems in recent years, and today, we completely cover the entire range of electric vehicles for urban mobility, from articulated buses to electric bicycles,” says Jörg Grotendorst, head of the E-Mobility division at ZF Friedrichshafen AG. For example, the company presented a new central electric drive for buses last fall. CeTrax’s greatest advantage is that existing vehicle platforms can be adapted to the electric drive system without requiring significant changes – offering manufacturers more flexibility in production. With its AVE 130 electric portal axle, ZF already offers a classic that has proven itself in mass production – the axle is equipped with two water-cooled induction motors next to each wheel, which power low-floor buses around the world through city traffic, efficiently and emission-free.

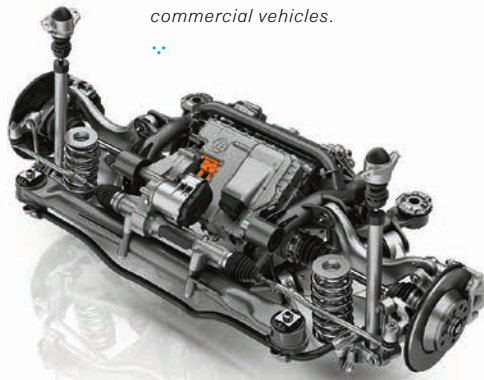
For the electric car sector, the company presented the newly developed mSTARS system in 2016 – a complete axle system that, thanks to a modular design unlike anything else in the industry, allows the electric drive to be integrated directly into the axle. With a power output of up to 150 kilowatts, the system is perfect for mid-range sedans and light commercial vehicles. At the lower end of the scale, ZF’s smallest electric drive has a diameter of only nine centimeters – the extremely compact, 48-volt, mid-mounted e-bike motor only weighs two kilograms, instead of the usual four. For ZF, that is a first step in the direction of micromobility.



⚙️  
ZF’s test vehicle with central electric drive for local, emission-free public transportation.



ZF’s modular axle system mSTARS, with its integrated electric drive, brings emission-free power to cars and small commercial vehicles.



We will not be able to solve the megacities’ mobility problem with robo-taxis alone.



### A SHARED VEHICLE IS TWICE AS EFFICIENT

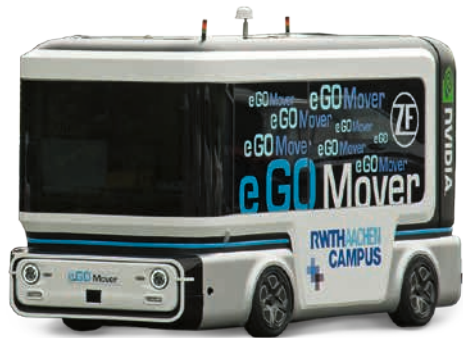
Which leaves the challenge of clearing the congested streets of the bumper-to-bumper lines of cars. All of the approaches to making city traffic more efficient and flow more smoothly share one fundamental idea – moving away from privately owned cars towards sharing solutions. This not only includes the previously described car-sharing model, but also ride sharing, a kind of modern, collective, on-call taxi service. Here, an algorithm groups passengers with similar routes together and drives them to their destinations in one vehicle instead of several. A study conducted by the OECD in early 2017 showed that this model could cut the total number of miles driven – which is used as a measure of traffic volume – in half in major European cities like Lisbon. To make sharing

a ride like this user-friendly, all of the vehicles would need to be connected both with each other and with different platforms that coordinate the trips and the users. And ZF also offers innovative solutions in this space, which complement the introduction of modern mobility concepts. For example, the “Car eWallet” developed by ZF in conjunction with UBS and IBM not only allows vehicles to complete payment transactions autonomously at charging stations, but also offers a secure transaction solution for car sharing.

### ROBO-TAXIS, PEOPLE MOVERS, AND AUTONOMOUS DELIVERY TRUCKS

One mobility solution with significant potential for the future remains completely unseen on today’s city streets, despite already being technologically feasible: autonomous buses and taxis. Particularly in combination ⚙️





The e.GO Mover will transport people and cargo from 2019. Apart from the ZF e-drive, it also boasts the artificial intelligence platform ZF ProAI.

with sharing concepts, autonomous vehicles will fundamentally change the face of urban transportation. These vehicles can be on the road around the clock (except when charging or undergoing maintenance), and as such, would not ever require a parking space. A study conducted by the Munich-based consulting firm Berylls concluded that in the Bavarian capital, 200,000 privately owned cars could be replaced by 18,000 autonomous taxis.

To advance this development, ZF has invested in the Aachen-based start-up e.GO Mobile AG. The fully electric, modular vehicle named the e.GO Mover can transport people or cargo depending on its configuration, and drives completely autonomously. A semi-autonomous preliminary version of this people and cargo mover is already set to ship in 2019. ZF technology is what allows this vehicle to see, think, and act – the company is supplying the e-drive, as well as ZF ProAI artificial intelligence platform it developed together with Nvidia, plus cameras, radar sensors, steering systems, and brake systems.

When I decide to repeat this experiment in a couple of years, I will most likely make it across town even more efficiently, thanks to robo-taxis. And the same type of vehicle, in its configuration as a cargo mover, will deliver my new bookshelf right to my doorstep – emission-free and just-in-time.



Whether self-driving mini buses or vehicles from car-sharing providers, for cities the future will see electric powertrains in high demand.

# The robot always rings twice

THE INTERNET HAS PROFOUNDLY CHANGED OUR SHOPPING HABITS. INTELLIGENT DELIVERY VEHICLES CAN MAKE SHOPPING MORE CONVENIENT AND SIMULTANEOUSLY RELIEVE TRAFFIC CONGESTION.

Text: Lars Weitbrecht

First, the good news. The number of commuters in London has declined, which is good for the capital of Britain, a city notorious for its air pollution. But with the good comes the bad: despite this decline, the city’s traffic volume has in fact increased, because changing consumer behavior has caused a logistics boom within the city. Next-day, same-day, and even same-hour delivery, as well as online grocery shopping, are now the norm. This has led to an increase in the number of delivery trucks on the road. Since the delivery drivers often double-park (and leave the engine running), the heavily congested London streets get jammed up even more than they already are.

This is a good example of why traffic planners not only need to rethink private car use and public transportation, but delivery logistics as well. It is a good thing that electric vehicles and autonomous driving can also solve many of the problems in this field as well. Particularly the last mile, e.g. the final leg of delivery from a distribution hub to the recipient, offers interesting challenges and space for innovation, as the results of a study on the future conducted by ZF in 2016 show. For example, the people that are most likely to fill up their shopping cart on Amazon and at other online retailers are also the ones least likely to be home during normal delivery hours. Self-driving delivery robots, under consideration by start-ups and traditional companies alike, could ring the doorbell at the recipient’s desired time – even if the mail carrier had long finished for the day.

Autonomous delivery vehicles can also assist delivery workers and make them more efficient. The German postal service Deutsche Post will conduct an initial trial in this area from 2018 onwards, when it will send a small fleet of electric scooters onto the streets. The plan is for these scooters to autonomously complete parts of the route thanks to the AI-capable ZF ProAI control unit, and as a result, take some of the mail carriers’ work off of their hands. The bottom line: when it comes to delivery logistics in the city of the future, highly automated and locally operated emission-free vehicles can both enhance existing processes and even complete some of the work themselves.

Small autonomous vehicles, like those from Starship Technologies (right), can deliver goods precisely when the customer wants to receive them.





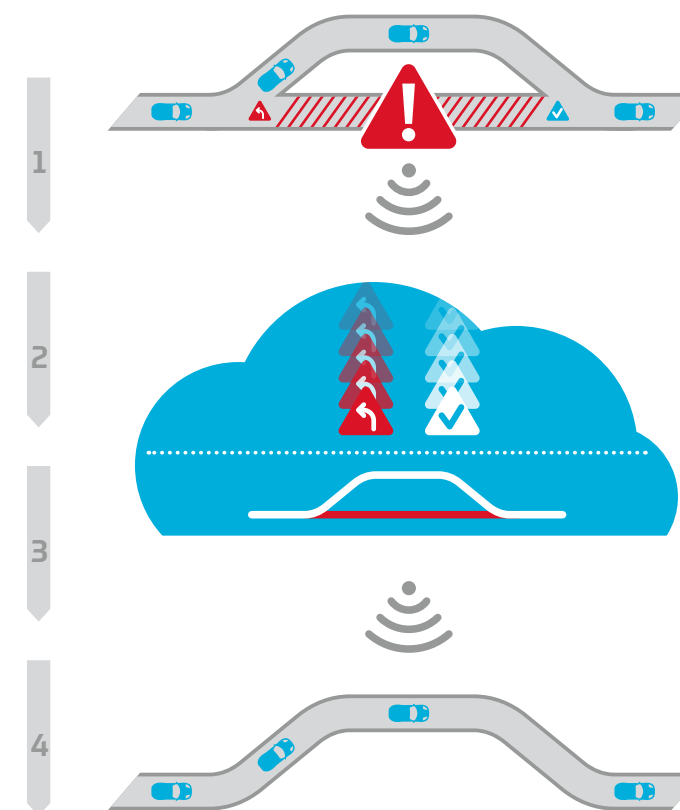
# Highly precise and up-to-date

AUTONOMOUS DRIVING IS IMPOSSIBLE WITHOUT HIGH-DEFINITION MAPS. BUT ENSURING THAT THE MAPS ALWAYS ACCURATELY REFLECT REALITY IS A REAL CHALLENGE.

Text: Christoph Reifenrath

Where am I? Where is my destination? How can I get there quickly and safely? These are questions that even cavemen asked themselves over 20,000 years ago. This is also when humans created the first maps, which included important waypoints. And the high-definition maps that will be necessary for autonomous driving in the future also more or less use the same guidance and positioning mechanisms as our ancestors did thousands of years ago. They rely on points of interest along a route.

The key difference to the maps from back then is the number and precise position of the included locations. Today's high-definition maps include the road itself, but also lanes, the radius of curves, lane widths, street signs, bridges, inclines or declines, guardrails, trees, embankments, ditches, and buildings, as well as their distance from one another. These billions of data points are then used to create a machine-readable image of the road surface as well as the entire surrounding environment – and as such, a nearly unique “fingerprint”



## How the HD maps stay up-to-date

1. Vehicles equipped with the necessary sensors, GPS, and an Internet connection report a change in traffic routing on a specific section of road.
2. The information is aggregated and its validity is verified in the cloud.
3. The system uses this information to automatically generate new map data for the section of road in question.
4. The update is transferred to all compatible vehicles.

of every stretch of road. Map provider TomTom calls this “RoadDNA,” competitor Here speaks of an “HD Live Map”. “When it comes to the development of autonomous driving in China, in the company Baidu (see page 26), we have found an extremely knowledgeable provider, which develops high-definition (HD) maps and the services built on them,” says Matthias Benz. The head of Sales & Customer Development within the ZF Group is responsible for this partnership.

The information needed to create these maps is currently being supplied by special vehicles operated across the globe by the map providers themselves. They are equipped with state-of-the-art radar, lidar, and camera technology as well as differential GPS, which significantly improves positioning accuracy. As the cars drive around, they scan and record their surroundings – in their entirety and with centimeter-level precision. So far, this has primarily taken place on US and European highways, but

projects to scan and capture fast-growing urban areas are currently in the works.

## AN HD MAP AS A POSITIONING TOOL

Since high-definition maps are not made for people, but instead for machines, the traditional way of presenting a map is no longer important. After all, for the purposes of autonomous driving, HD maps are performing a completely new task. Since positioning based solely on GPS is not accurate enough, and cameras can't always provide the information needed – like when it's snowing, for example – the maps themselves will become a localization tool. For instance, by comparing the input from sensors with the “fingerprint” of the street stored in the map, the vehicle can locate itself with centimeter-level precision, and even do so completely without GPS, if need be.

“People also develop a map in their mind's eye when they regularly drive down the same street,” says Dietmar Rabel, Director Product Management, Autonomous Driving Product Portfolio, from the map specialist Here Technologies, and adds: “This mental map combines experiences from previous drives with whatever is happening right now. With our HD Live Map, we're basically doing the same thing.”

But this will only work if map providers constantly keep their HD maps up-to-date. With a global road network that currently spans a total of 32 million kilometers (approx. 20 million miles), this will take more than just the mapmakers' own street-scanning cars, however. To create an up-to-date scan of all of the streets once daily, they would need about 160,000 such mapping vehicles – an unimaginable number.





# AUTONOMOUS DRIVING WITH PROJECT “APOLLO”

*In September 2017, ZF and the Chinese web services company Baidu entered into a partnership. Baidu is a leading provider of high-definition maps in China. But the two companies’ collaboration goes far beyond HD mapping. Both partners want to work together in the field of artificial intelligence, Big Data, and cloud-based solutions to make significant advancements to autonomous driving in China. To achieve this goal, ZF is contributing ZF ProAI, the vehicle control system it developed with Nvidia, to the strategic cooperation. The basis for the partnership is “Project Apollo”, an open development platform launched by Baidu in April 2017, which can be used to rapidly build systems for autonomous driving.*



The answer could be connected, mass-produced vehicles that capture the relevant data with their sensors while they are out on the road. Today, millions of mass-market vehicles suitable for this purpose are already driving around.

### MASS-PRODUCED VEHICLES CONTRIBUTE TO MAP UPDATES

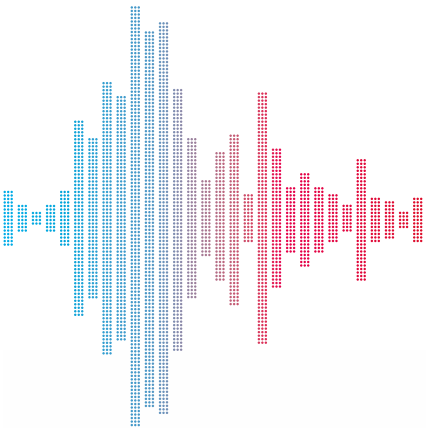
The plan is to take the sensor data from mass-market vehicles and compare it to the HD map in the cloud, use the data to update the map (if necessary), and then sync it back down to the vehicles. The goal

is to keep the size of the updates as small as possible when doing so. This is why the HD maps will be divided into individual tiles measuring a few square miles in size, and the number of map updates from mass-produced vehicles will be kept to a minimum. Defining sensor categories and a standardized interface format should ensure that this works smoothly across vehicles from different manufacturers. In 2015, map provider Here drew up an appropriate specification together with its partners, and unveiled the standard they developed one year later. For the purpose of collaborative development, Here founded the

innovation platform “Sensoris,” which is currently supported by more than 20 different companies.

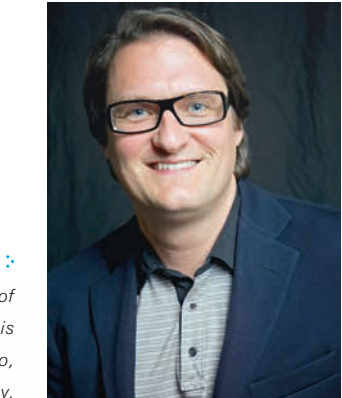
### ADDED BENEFIT THANKS TO REAL-TIME DATA SERVICES

The first real-time services based on data from the field built on the Sensoris data standard were presented back in 2016. For example, they show available parking spaces on the street and provide more accurate information about traffic congestion. In addition, these real-time data services speed up the announcement of warnings, like if a broken-down vehicle is blocking a lane on the highway.



## SPEAKER’S CORNER

*Robert C. Wolcott, Ph.D., is Clinical Professor of Innovation at Northwestern University in Illinois (USA). He is also Managing Partner with Clareo, a foresight and growth strategy consultancy.*



# Navigating fundamental transitions

CURRENT DEVELOPMENTS IN ELECTRIC PROPULSION AND AUTONOMOUS DRIVING ARE RESHAPING HUMAN MOBILITY. PREDICTING TECHNOLOGY DEVELOPMENT AND CUSTOMER DEMAND, HOWEVER, PRESENTS ITS OWN SET OF CHALLENGES FOR INDUSTRY LEADERS.

History repeats itself. At the turn of the last century, steam energy provided the vast majority of man-made mobility in the US and Europe, primarily in the form of rail travel. By 1960, steam locomotives were mostly phased out in favor of diesel power. Meanwhile, the internal combustion engine in cars and trucks had risen to dominance. In 1900, it must have seemed unthinkable that other technologies would one day dethrone “King Steam”. After all, nearly 60,000 steam-powered automobiles were produced in the US prior to 1927. Similar transitions are occurring today, such as the shift to electric power in cars, and more profoundly, to autonomous driving. What does this mean for a company like ZF? In stable markets, it makes sense for a company to eliminate distractions and drive out uncertainty. When the underlying technologies and business models of an industry are transforming at a rapid pace, being too focused is a path to extinction. Here are three ways to thrive through change.

1. Become a two-speed organization. This requires maintaining a healthy core business but at the same time recognizing that doing more of the same isn’t a long-term strategy. Every organization needs a complementary capability that moves fast and engages early with customers – existing and potential – to decipher future market demands. However, this initiative cannot be led by a company’s core business. The traditional business should remain focused on exceptional near-term performance and enable others

to focus on new horizons for the company. Great organizations have a place for both. These “two speeds” collaborate or remain independent as appropriate – dictated by their objectives – but all supporting the company’s long-term success. ZF rigorously operates its core business while simultaneously developing and promoting the future with programs such as Zukunft Ventures.

2. Aggressively encourage experimentation. When someone tests a theory, which turns out to be wrong, that’s not failure. It’s an experiment. Teams focused on the future must have the freedom to rapidly experiment with new concepts at low cost. This allows them to develop a portfolio of opportunities essential for thriving through change. As specific opportunities prove their value, leadership can decide to ramp up commitments. Without a vital experimentation capability this process cannot succeed – risking the company’s long-term viability.

3. Focus on values. Companies with a strong heritage of stewardship, quality and customer focus should apply these values when exploring and entering new markets. Failure to do so could result in a loss of business and perhaps even present challenges for society as a whole. Remaining committed to the right values provides the bedrock upon which to build a company’s legacy. As the world transitions towards electric propulsion and autonomous vehicles, consider the legacies you will help create. Future generations certainly will.





# Split-second decision

AUTONOMOUS VEHICLES HAVE TO DEAL WITH AN INFINITE VARIETY OF SITUATIONS IN ROAD TRAFFIC. THIS REQUIRES AN INTEGRATED SUPERCOMPUTER THAT HAS THE ABILITY TO LEARN AND ACT LIKE HUMANS.

*Text: Stefan Schrahe*

For his 2001 movie A.I. Artificial Intelligence, Steven Spielberg created the humanoid robot David. With childlike curiosity, it tried to find its way in the world. In actual fact, artificial intelligence (AI) works in very much the same way as young children learn. A two-year-old, for example, who shoots down a slide with a wooden stair tower and straight slide for the first time will also immediately recognize the spiral-shaped metal structure on the neighboring play area as a slide without the need for any further explanation. The brain connects relevant images of both objects in neural networks: the stairs, the semicircular chute, the location of both slides on a sand play area, and children who are standing at the top or already sliding down. Experts talk of semantic segmentation. No human being would be able to find their way in the world without this process.

## TRAINING NOT PROGRAMING

Artificial intelligence also involves learning from images. It's all about training rather than programing. When a growing number of images in artificial neural networks link up with stored experiences and earlier decisions, this is known as deep learning. This enables AI to make its own decisions and means that it no longer has to rely on the programing of every conceivable possibility. To use the same metaphor: if human learning were programed rather than acquired, it would never even occur to a small child who had previously only slid down a red slide that it was possible to do the same on a blue one.

In road traffic, with its infinite variety of situations, artificial intelligence and deep learning are a funda- ∴





mental prerequisite for autonomous driving. No code, however comprehensive, could anticipate every scenario. Instead, AI has to assess each situation, interpret it on the basis of all previous experience, and then react.

HUGE COMPUTING POWER REQUIRED

To this end, neural networks must be simulated and vast amounts of data have to be processed within the shortest space of time. Only computers with extremely fast processors, such as the ZF ProAI, are able to manage this. This mobile supercomputer was created in cooperation with Nvidia, the world's leading supplier of graphics processing units. The US company specializes in the creation of artificial worlds such as the scenarios found in computer games. The ZF ProAI computer platform uses this ability the other way round. Instead of creating an artificial image, the computer translates the real world into a data model in which the algorithm gets increasingly better at finding its way around. Every single learning experience is shared in the cloud and is made available to all other systems the next time the algorithm is updated. As such, every ZF ProAI benefits from swarm intelligence.

CAMERA RAW  
DATA PROCESSING

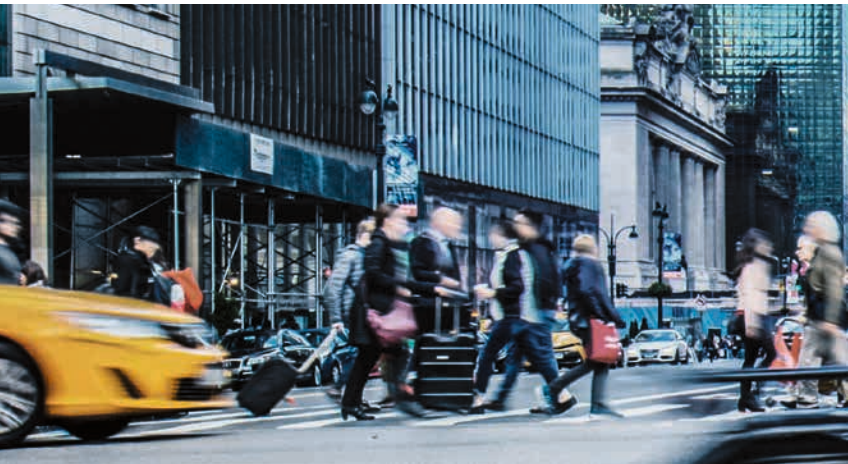
According to a study conducted by McKinsey, up to 15 percent of newly registered vehicles could be driving autonomously by the year 2030, with significant growth rates expected up until 2040. Before autonomous driving becomes reality, manufacturers are increasingly equipping their vehicle systems with artificial intelligence.

EVER MORE AI IN CARS

Dr. Jochen Abhau, deep learning expert at ZF, believes that a vehicle's safety technology is an outstanding field of application for artificial intelligence. With conventional interior airbags, the impulse of a crash sensor is all it takes to inflate them – a classically programmed stimulus-response model. At present, however, the focus is increasingly shifting towards exterior airbags fitted on the bodywork in order to protect the batteries of electric vehicles in the event of a crash, for example. However, an exterior airbag must inflate before the crash has occurred – a clear case for artificial intelligence. "It is important to know whether the object with which the vehicle collides is a small conifer tree or a solid concrete post in order to establish the right inflation strategy for exterior airbags," says Abhau. The ZF ProAI can tell precisely this with the aid of images from the vehicle's camera. As such, it is able to inflate them when the vehicle collides with a lamppost or tree trunk, but not with an ornamental palm.

The vehicle's occupants also benefit from AI. For instance, artificial intelligence can make an assumption with an extremely high degree of probability as to whether a car driver is alert and following the road traffic. This assumption is based on the images of the driver's face gathered by the computer. In addition, the computer's acquired knowledge helps it to establish how concentrated and alert people look in contrast to those who desperately need to take a break.

AUTOMATED DRIVING  
DECISIONS+PREDICTIONS



Intelligent decisions are requested from the computer in order to react to rapid changes in the behavior of other road users.

However, AI is also changing passive safety systems. At present, for instance, front, side, and head airbags always react equally, because the occupants' seating positions are clearly defined: upright and facing forward. This will change. Since autonomous vehicles will allow more flexible seating positions, seat belt and airbag systems as we currently know them will be ineffective if the worst comes to the worst. In the event of a crash, artificial intelligence helps to assess the situation at lightning speed and take appropriate action in each case.

ZF PROAI IN THE PRODUCTION CAR

Using a simple example, Adam Coates explains the extent to which artificial intelligence has already made inroads into our daily lives: "In 2017, around 100 million people around the world had Internet access for the first time; almost all of them via a mobile end device. As such, they have encountered AI in the course of their first online experience." Coates is director of the Silicon Valley AI Lab established by the Chinese Internet firm Baidu.

The fact that artificial intelligence is by no means a distant vision when it comes to autonomous driving is demonstrated by the team around Oliver Briemle, Project Leader ProAI. At an early stage, a plan was devised to take a production vehicle with artificial intelligence to level 4 (fully automated driving). At the heart of the Opel Astra, which undertook its first autonomous driving exercises on ZF's testing ground in August 2017, is the ZF ProAI. This supercomputer processes camera, radar, and lidar information to control the compact vehicle, which remains virtually unchanged on the outside. Only the larger exterior rear-view mirrors – due to the integrated cameras – betray the fact that this is a special kind of Opel Astra. The car's training is now so far advanced that it will be able to drive on public roads at the Consumer Electronic Show (CES) in January 2018.

RADAR+LIDAR  
RAW DATA PROCESSING



The core of deep learning and artificial intelligence in cars: the ProAI supercomputer created by Nvidia and ZF.



GENERAL DATA

The fact that artificial intelligence processes information visually, but doesn't necessarily have to rely on photos gives Jochen Abhau a new perspective: "We can relay radar scans from the immediate vicinity to a data grid and process them as patterns, for example. The principle is very similar to the concept of battleships played on paper. The system can use the pattern to ascertain whether a playground or parking lot is located behind a row of houses along the edge of the road."

Thanks to this semantic segmentation, the car knows whether it is able to park in the immediate vicinity and will navigate its own way there if necessary. However, the AI experts can only speculate as to whether the algorithm will be as pleased to find the parking space as the young child is when it discovers the slide.



# Silent running

ZF IS REDUCING FUEL CONSUMPTION WITH TECHNOLOGY THAT TEMPORARILY ALLOWS A CAR TO SAIL AS QUIETLY AS A TWO-MASTED SHIP. FOR THE FIRST TIME, IT IS NOW AVAILABLE FOR AUTOMATIC TRANSMISSIONS. WHAT EXACTLY IS BEHIND THE CONCEPT?

Text: Achim Neuwirth

Just imagine two new cars, and one of them can suddenly freewheel; the other is even able to switch off the engine completely, then it can be said that everything is literally in the green range – assuming that both vehicles are equipped with ZF's fuel-saving sailing function. This separates the engine from the rest of the driveline in suitable situations and automatically engages the clutch. ZF has now also made this possible for automated manual transmission (AMT). The clutch-by-wire system had already established the basis for sailing on vehicles with manual transmission. "And also ZF's dual clutch systems and automatic transmissions are ready to sail," says Jörg Buhl, who oversees the design of control systems for manual and automatic car transmissions at ZF. "All in all, this probably makes us the only partner that supplies a sailing concept for every car segment and virtually all commonly used transmission types."

A ZF test vehicle recently demonstrated the potential of the AMT sailing function: it consumed up to 8.5 percent less fuel than an identical car without this feature – recorded in normal road traffic conditions with the engine running at idle speed while sailing. An assumed actual consumption rate of 5.9 liters per 100 kilometers could therefore drop to 5.4 liters in future. "In view of the ever stricter emissions standards being imposed around the world, sailing could soon play a key role," says Buhl. The EU, for instance, has set a fleet fuel economy target for manufacturers of just 95 grams of CO<sub>2</sub> per kilometer by 2021, which is equivalent to around 4.1 liters of petrol and 3.6 liters of diesel per 100 kilometers.

## CLEVER CLUTCH ACTUATION

The sailing function makes the most of situations in which the car also has sufficient momentum to freewheel forward. Such situations include country roads with a slight downward gradient or longer stretches of straight road

approaching city limit signs. Intelligent clutch actuation systems from ZF then temporarily disengage the combustion engine so that it doesn't suppress this kinetic energy. These can be electronically controlled and activated by wire, providing the basic prerequisite for the sailing function.

The disengaged engine can then idle while consuming a minimal amount of fuel. Ideally, however, it stops completely for a short period of time, because this is the only way in which zero emissions can really be achieved. "It is ultimately the vehicle manufacturers who decide how this concept is integrated into a car," says Buhl. "Meanwhile, we have further developed the sailing function, turning it into a sailing manager that can react even better to each driving situation." Modular software elements make it possible, for example, to connect the feature to a navigation system or ZF's adaptive cruise control (ACC) and also enhance it by adding a traffic flow or rolling resistance detection system.

8.5%

less fuel burns a car with ZF's AMT sailing function compared to an identical vehicle without this feature.



*ZF's clutch-by-wire system actuates the clutch electronically and, if necessary, without driver interaction.*

## SYSTEMATICALLY EXPLOITING THE ADVANTAGE

Besides the sailing function itself, ZF also manages the electric peripheral equipment, including the electric power steering (EPS) and integrated brake control (IBC). As such, every individual component within the system architecture ultimately interconnects in concert. This also proves advantageous at the end of the sailing phase when the restarted engine re-engages without jolting the moving car. In the case of automated manual transmissions, ZF has been working since the 1990s on continuously improving clutch actuators and their control systems. This wealth of experience benefits both customers and car drivers when it comes to sailing.



# System meets component

THE WHOLE CAN BE MORE THAN JUST THE SUM OF ITS PARTS, AND THIS IS ESPECIALLY TRUE WHEN IT COMES TO THE CONNECTED CAR. VISION SPOKE WITH TWO ENGINEERS THAT ARE GETTING THE CHASSIS READY FOR AUTONOMOUS DRIVING – AND REQUIRE EQUAL PARTS SYSTEMS EXPERTISE AND COMPONENT KNOW-HOW TO DO SO.

Interview: Andreas Neemann

**H**istorically, ZF got its start as a component supplier, yet for many decades the company has also viewed itself as a systems supplier. Where does the component end and the system begin?

**Lovell:** Those are both flexible terms, which makes them hard to define. Many products that ZF develops and sells have the characteristics of systems: a vehicle's brakes, steering, and transmission, for example, are all built from many different electronic and mechanical parts. So we could actually refer to them as individual systems – and we often do. For our customers, however – the automobile manufacturers – these are all components that are a part of the system that is the entire vehicle. So it always depends on your frame of reference. At ZF, we are also active at this system level – we support the integration of our products into the vehicle. And we combine our

.....

**The System Integrator:**  
**Dr. Caspar Lovell**

*has become extremely familiar with ZF's range of products since earning a degree in automotive engineering and mechatronics and a doctorate in electric vehicle transmission technology. He began working for ZF five years ago and is currently the project manager of the Mechatronic Systems product line in the Car Chassis Technology Division at ZF's Dielingen location.*

.....

**The Component Developer:**

**Dominik Vogt**

*came to ZF in 2005 as a trainee after earning a degree in electrical engineering in Ulm. Since then, he has worked as an engineer in various positions in electronics development in Friedrichshafen. As head of systems in chassis electronics, he played a role in the development of Active Kinematics Control (AKC).*

individual systems into a group that can do a whole lot more. Adding this level of functional value, like we have done with our Integral Chassis Control (ICC) software, is usually only possible at the system level.

**Vogt:** In general terms, I would describe a current ZF OEM component as such: an electro-mechanical actuator that can be controlled digitally and therefore has a software interface. So specifically, an absorber whose damping force can be varied electronically or our AKC, which adjusts the steering at the rear axle. But it's only this interface, this ability to be controlled electronically, that makes the components interesting for systems integrators – regardless of whether they work here or at the OEM.

**How much does the interaction between systems and components shape development activities at ZF?**

**Vogt:** Both depend on each other. Our knowledge when it comes to components enhances our integration know-how or makes it possible

in the first place. Since we are familiar with our AKC product, we can also think about how best to incorporate it into a chassis within the terms of connecting the entire system. The Active and Passive Safety Technology Division (formerly TRW) was especially responsible for strong growth – when it comes to components that we offer, but also with regard to systems expertise.

**What does that mean specifically?**

**Vogt:** On the one hand, we can now offer an entire dynamic driving chassis from one source with the brakes, front-axle and rear-axle steering, active chassis, and electric drive. On the other hand, we now know everything there is to know about all these components, you could say from the "inside view of the developers". What, for example, do the brakes and their wheel speed sensors and accelerometers tell us about the road condition, and how can we use this information within the terms of the connected system?

**What makes this kind of additional systems know-how valuable? It's not like this will cause ZF to suddenly sell more absorbers or brakes than before ...**

**Lovell:** Maybe it will, if indirectly. The idea isn't to just develop and then sell products. We are seeing increasing demand for our services as systems integrators, because OEMs also want to outsource these





#### The System: Integral Chassis Control (ICC)

The ZF software connects all of the assistance systems that have an impact on driving dynamics via defined interfaces – similar to how a PC can be connected to a variety of peripheral devices via USB.

When advanced driver-assistance systems (ADAS) – such as emergency braking and collision avoidance systems – take action in critical driving situations, ICC ensures that they don't "step on each other's toes" when taking control of the vehicle's steering and brakes. The ICC operates between the ADAS and the actuators and transmits the calculated planned course of movement to each actuator that can actually implement it.

Despite not adding any additional hardware to the vehicle's steering, brake system, or chassis, the vehicle operates significantly more safely and more agile thanks to the integrated control software alone. This higher-level control software can also be integrated into the ZF ProAI, the control box that ZF developed together with chip manufacturer Nvidia. Thanks to high-performance computing, it brings artificial intelligence and deep learning to the automobile.

jobs to qualified suppliers. And as a result, we aren't only generating additional revenue. Suppliers that can provide these services also play a more prominent role in the manufacturers' strategic planning. In fact, this expertise is mandatory

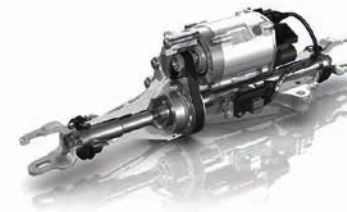
if we want to stay at the top of list and ahead of competitors in the future. Furthermore, it can open a lot of doors when it comes to selling additional components that specifically support this system integration.

#### *Which means this must work even better with the new players in the mobility market ...*

**Lovell:** You're absolutely right, our strength in components and systems is truly a major advantage. Start-ups or IT companies simply can't match our experience from decades of automotive development, at least not in the short term. Today we can offer them a complete dynamic driving chassis. In contrast to traditional OEMs, who usually hire multiple suppliers for the drivetrain and chassis, start-ups would benefit from obtaining the base vehicle from one source and then concentrating on the various additional pieces of equipment as well as sales. This close relationship with start-ups or IT companies would have the added benefit of giving us early insights into their strategic focuses. These new market players especially are in a position to bring about a paradigm shift through their innovative technologies.

#### *And how do the components benefit from this game?*

**Vogt:** A deep understanding of the system also furthers the development of its components. We have the ability to design parts in a less complex manner, and in doing so, make them more competitive. For example, we don't need individual sensors built into single components when the information can be obtained just as well from somewhere else in the system. Component development must also meet the demands of autonomous driving – we need a new understanding of fail safety, for example.



#### The Component: Active Kinematics Control (AKC)

An actuator unit integrated into the rear axle electromechanically adjusts axle kinematics based on the driving situation. As a result, the toe angle can vary by plus or minus five degrees and more – meaning the rear axle steers too. A control software combines this additional steering adjustment with the front axle's steering activity. The result is a clearly noticeable, positive impact on the vehicle's handling.



*A giant pick-up maneuvers like a small car? AKC makes it possible – as you can see in this video.*

#### *And what would this entail?*

**Vogt:** A good example of this is steering – if the power-assisted steering fails, you still have the ability to steer the vehicle, you just need to turn the wheel with a bit more muscle. A computer-operated vehicle that drives autonomously could no longer be controlled at all, however. Which means redundancy would need to be built into certain features. The most expensive version would be to have everything twice. Systems expertise supports us in developing appropriate redundancies. For example, an autonomous vehicle whose front-axle steering has failed could still be guided to a safe stop on the side of the road via rear-axle steering and brakes.

#### *Staying on the subject of autonomous driving: how are you dealing with the increasing complexity?*

**Lovell:** In principle, we work with the same system architecture here as we do with the Integral Chassis Control – here driver assistance systems define a trajectory, a corridor, which represents the vehicle's desired path of movement. Our ICC then calculates, which actuators need to take action, and how, in order to carry out the driving tasks. It interacts with the assistance systems, providing information from a variety of different sensor sources about the physical limits within which the vehicle is currently moving. In general, this could also be carried out within a system in which the trajectory isn't defined by different assistance systems, but instead by a high-performance computer with artificial intelligence – and we are currently working on such an experimental vehicle.

*Two experts, one goal:  
Dr. Caspar Lovell (l.) and  
Dominik Vogt discuss  
systems and components for  
autonomous driving.*





# In focus: Farming 4.0

AUTONOMOUS DRIVING AND E-MOBILITY ARE FUTURE TRENDS THAT WILL PLAY OUT ON MORE THAN JUST PUBLIC ROADS. ZF IS TAKING THE BENEFITS OF TECHNOLOGICAL SOLUTIONS IN THESE FIELDS AND ALSO APPLYING THEM TO INNOVATIVE AGRICULTURAL VEHICLE PROTOTYPES.

Text: Lars Weitbrecht

Imagine that it's harvesting time but the farmer doesn't gather the crops. This is a scenario that could soon be a reality on farms around the world. Together with the Austrian agricultural machinery manufacturer Lindner, ZF has developed a semi-autonomous concept tractor that can take over this job.

"Our prototype shows how the agricultural sector can benefit from the automotive megatrends of connectivity, artificial intelligence, and automation," says Mark Mohr, head of the Automated Operations project center at ZF. The experimental vehicle is based

on the Lindner Lintrac 90, a compact tractor that ZF equipped with a range of intelligent mechanical systems. Thanks to the combination of cameras with lidar and radar sensors, whose signals are processed by the ZF ProAI control platform that is capable of deep learning, this tractor now has a 360-degree, all-round view with person recognition, which is also connected to the driveline controller.

An additional GPS system connected to the steering and hydraulic system as well as the TMT09 continuously variable transmission from ZF make it possible to



✚ "Follow me": the intelligent tractor automatically follows the tractor ahead of it. This means it can be equipped with a different tool.

automate processes in the agricultural sector – processes that can even be activated via an app. The technology contained in this concept tractor opens the door to many innovative features.

## A TRACTOR CAPABLE OF LEARNING

One such possibility is process optimization, for example: an assistance system detects cutting edges, field borders, and swath – i.e. the rows of fallen crops – and automatically keeps the tractor on track. This makes the system and the process more efficient and easier for the driver.

And the ride itself is safer thanks to the system's aforementioned all-round view in the tractor. The farmer can still see what's going on around the vehicle through the tractor's large windows, but can also easily follow along using a practical tablet PC in the driver cabin. While working out on the field, the tractor "learns" the route taken and stores it for later use. This means that after completing its first tour, the tractor can work the field automatically, without even needing a driver. Thanks to person and object detection, the system constantly monitors safety as it moves through its surroundings.

Who might be interested in intelligent tractors like this prototype? "This technology will particularly make work easier for farming operations with large farm-lands, such as those found in North and South America, for example," says Mr. Mohr. Farms in the United States have cropland that stretches over 430 acres on average, while the average farm in Europe has less than 30 acres. And the time and labor cost savings are even higher on megafarms like those often found in Russia, Brazil, and the US. But even smaller farms can benefit from the concept tractor's features, however. One that is particularly practical is the "Follow me" feature. With

this activated, the tractor autonomously follows another tractor driving ahead of it. If both vehicles are equipped with different tools, this can be used to save time by completing two different steps while traveling the route only once, for example.

## PLOWING WITH ELECTRIC ASSISTANCE

And yet there are also other approaches to increasing the efficiency of field work, reducing fuel consumption, and operating in a more environmentally friendly manner. For example, ZF integrated its eTRAC close-to-the-wheel electric drive system into a plow. The generator module TERRA+, which was also developed by ZF, powers the e-drive unit. The result is additional traction, which makes it easier to work in difficult conditions, such as when the ground is soft. The additional power provided by eTRAC also means that a tractor with a smaller engine can still pull a larger plow – which is good for the soil. After all, the soil being compacted by increasingly heavier equipment is a widespread problem for farmers.



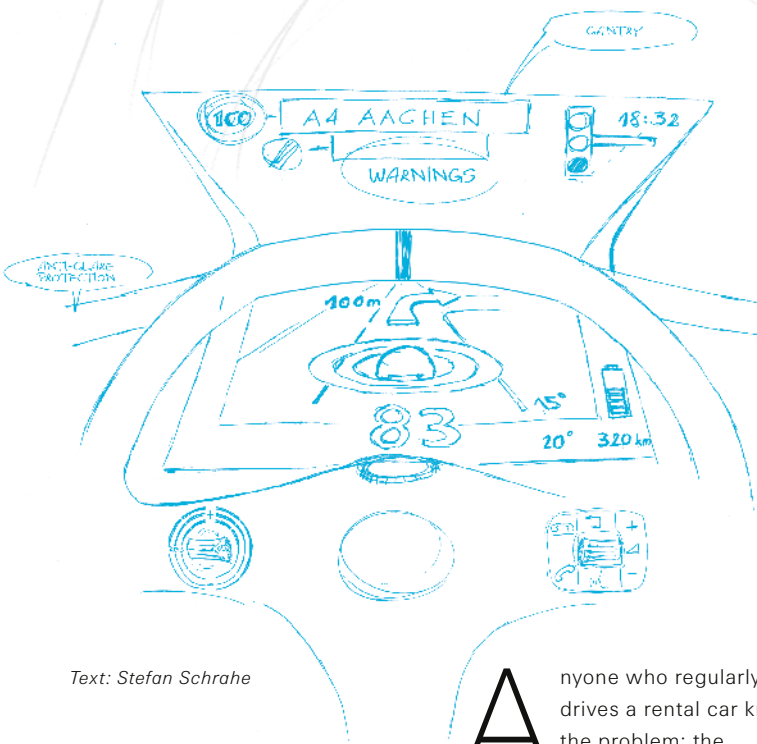
✚ The eTRAC close-to-the-wheel electric drive unit integrated into a plow makes field work easier and is good for the soil.





# Many assistants – one logic

ASSISTANCE SYSTEMS MAKE LIFE EASIER FOR THE DRIVER AND HELP TO PREVENT ACCIDENTS. FREQUENTLY, HOWEVER, IT IS DIFFICULT TO ACTIVATE, SET, AND MONITOR THE MANY DIFFERENT SYSTEMS. A NEW INTERACTIVE CONCEPT COULD CHANGE THIS.



Text: Stefan Schrahe

Anyone who regularly drives a rental car knows the problem: the numerous activation and setting menus of assistance systems installed in modern vehicles often cannot be operated intuitively. Comfort and safety systems work in isolation from one another and controls and displays are installed in different places – from the warning signal in the exterior rear-view mirror and the switch on the indicator arm to the pictogram in the cockpit and the LED on the center console. Yet this no longer has to be the case.

With the support of fka, a vehicle research company based in Aachen, ZF has developed the “Concept 2020” – a vehicle cockpit designed to be as simple as possible to operate. The university team led by Professor Lutz Eckstein works with images here: the driver sees a bird’s-eye view of the vehicle on the Head-Up Display Instrument Cluster (HUDIC) – a centrally installed monitor. This screen informs the driver about the activation or intervention of assistance systems. “Airplane pilots have been familiar with graphic representations such as the artificial horizon for almost 100 years and still use the principle to this day,” says Uwe Class, project manager of “Concept 2020” at ZF. “In future, car drivers are set to benefit from the same concept that helps these pilots to take in an incredibly high amount of information.”

## ILLUSTRATION OF REALITY

Other road users, buildings, and road signs are intuitively displayed and arranged in the same way that the driver sees them in reality. Important traffic information – such as the current speed limit or the

remaining time before a traffic light changes from its red phase – completes the displayed content.

The screen also follows the concept of central information: the vehicle display zooms in or out in moving traffic as and when necessary – when choosing navigation routes, for instance, or when parking in order to establish the distance from obstacles. Just one display gives the driver all the relevant information.

The particularly good thing about the display is the way in which it visualizes the safety features of the various assistants. In its normal state, for example, a kind of virtual protective shield around the car can be seen on the display – represented by oval-shaped gray lines. If the driver begins to change lanes, even though another road user is right over their shoulder in the blind spot, the lines distort and change color in the corresponding place on the screen. At the same

time, the assistance system intervenes by applying the brakes to individual wheels in order to prevent the maneuver, while the steering wheel – in contrast to conventional solutions – does not move. “This allows us to avoid the feeling of having no control over the vehicle,” says Professor Eckstein, “because around 50 percent of car drivers resist corresponding corrective impulses, thereby overriding the intended intervention.”

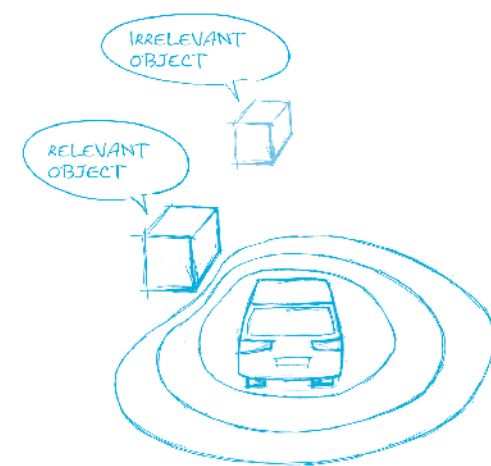
## ADJUSTABLE PROTECTIVE SHIELD

The sensitivity of the virtual protective shield can be adjusted from the steering wheel and embraces all assistance systems. The following principle generally applies: early intervention – gentle control; late intervention – very noticeable control. This is comparable with the adjustable traction control assistance systems. “This

arrangement allows us to ensure that all assistance systems in a vehicle follow one philosophy with one adjustment,” says Uwe Class. It is an approach that is only possible thanks to ZF’s extensive portfolio as a system supplier.

Different applications, such as a blind spot assistance system, adaptive cruise control, or a lane-keeping assistance system, can thus be viewed and operated from a central location. “Concept 2020” is designed for semi-automated driving at level 2, but also important for levels 3 and 4.

The development team likes to point out the role played by icons such as the trash can in helping the first Macintosh computers from Apple to achieve their breakthrough. At any rate, project manager Uwe Class is convinced that the future also belongs to graphic representations in vehicle cockpits.



The vehicle – as well as its virtual protective shield – is shown within its surrounding environment in the head-up display instrument cluster.





# Comfortable and efficient



Whether fitted on trucks like the DAF XF that has recently been awarded „Truck of the Year 2018“, or buses, the TraXon transmission system is proving highly popular on the market. Featuring the highest transmission efficiency in its class, the ZF product makes a key contribution to more efficient drivelines. It has enabled the Dutch commercial vehicle manufacturer DAF to cut its fuel consumption figures for its new XF series by a total of up to seven percent. IVECO's Evadys bus is also available with TraXon. At the Busworld exhibition in Belgium the manufacturer showcased a version specially designed for short excursions. A high level of shifting comfort was an important factor when choosing the transmission.



Two additional commercial vehicles are now available with the TraXon transmission system: DAF's XF truck series and IVECO's Evadys coach.

The integrated iSG48 starter generator from ZF provides a high-performance and inexpensive introduction to the world of hybridization.

## Compact mild hybrid module

ZF is making it easier to take the first steps into electrification with the integrated iSG48 starter generator. The mild hybrid module consists of an electric motor with 48-volt inverter. It can be installed directly in the transmission housing, saving space and simplifying assembly at the vehicle manufacturing plant. Hybrid functions such as boosting or optimization of the engine operation point are made possible by the 15 kilowatts of drive power, allowing the combustion engine to be run at the highest possible level of efficiency. With 20 kilowatts of alternator output power, the recuperation potential is almost as high as that of high-voltage systems, but the costs are considerably less.

“In just three years, one of the biggest parts and technology suppliers in the world has undergone a fundamental shift.”

Automotive News, USA, on ZF





# Cleaner mobility with CeTrax

ZF's CeTrax electric drive delivers around twice as much torque as current diesel engines for city buses. With a powerful 4,400 newton meters, it demonstrates just what is possible with electric drives alone. Its maximum power output of 300 kilowatts (408 hp) is a match for any conventional drive. The great thing about CeTrax is that it can be integrated into the existing platforms of high- and low-floor buses. There is no need to modify the chassis, axles, statics, or differential. As such, ZF's electric drive can play a key role in making cities cleaner and quieter.



With a maximum of 300 kW, CeTrax delivers the same amount of power as conventional bus drives.

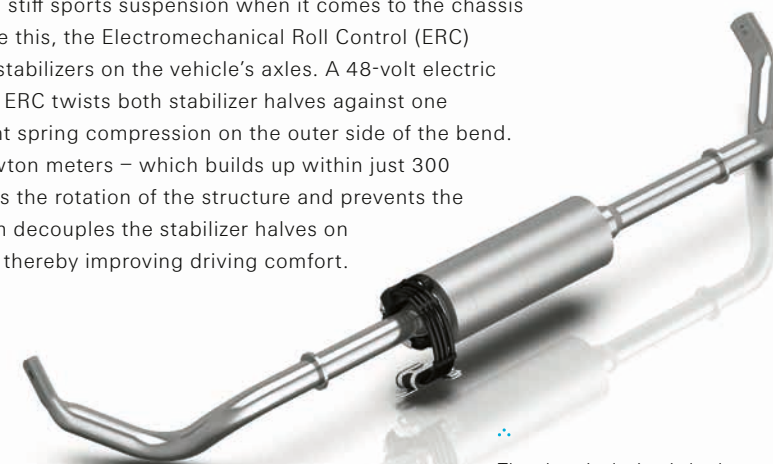
# A seat belt that warns

The first car to feature ZF's ACR 8 Active Control Retractor entered production at the end of 2017. Like its tried-and-trusted predecessors, it increases the seat belt's tension before potentially hazardous situations in order to protect the occupants as best as possible. There is now also the option to use it as a man-machine interface. Accordingly, when linked to other safety systems, the ACR 8 can prompt the driver to act by tensioning the seat belt in a pulsing motion.



# Greater stability

ZF's Active Roll Stabilization system helps to solve the classic trade-off between comfortable and stiff sports suspension when it comes to the chassis design. In order to achieve this, the Electromechanical Roll Control (ERC) replaces the passive stiff stabilizers on the vehicle's axles. A 48-volt electric motor in the center of the ERC twists both stabilizer halves against one another in order to prevent spring compression on the outer side of the bend. Torque of up to 1,400 newton meters – which builds up within just 300 milliseconds – counteracts the rotation of the structure and prevents the rolling motion. The system decouples the stabilizer halves on uneven stretches of road, thereby improving driving comfort.



The chassis design is both sporty and comfortable with the Electromechanical Roll Control from ZF.

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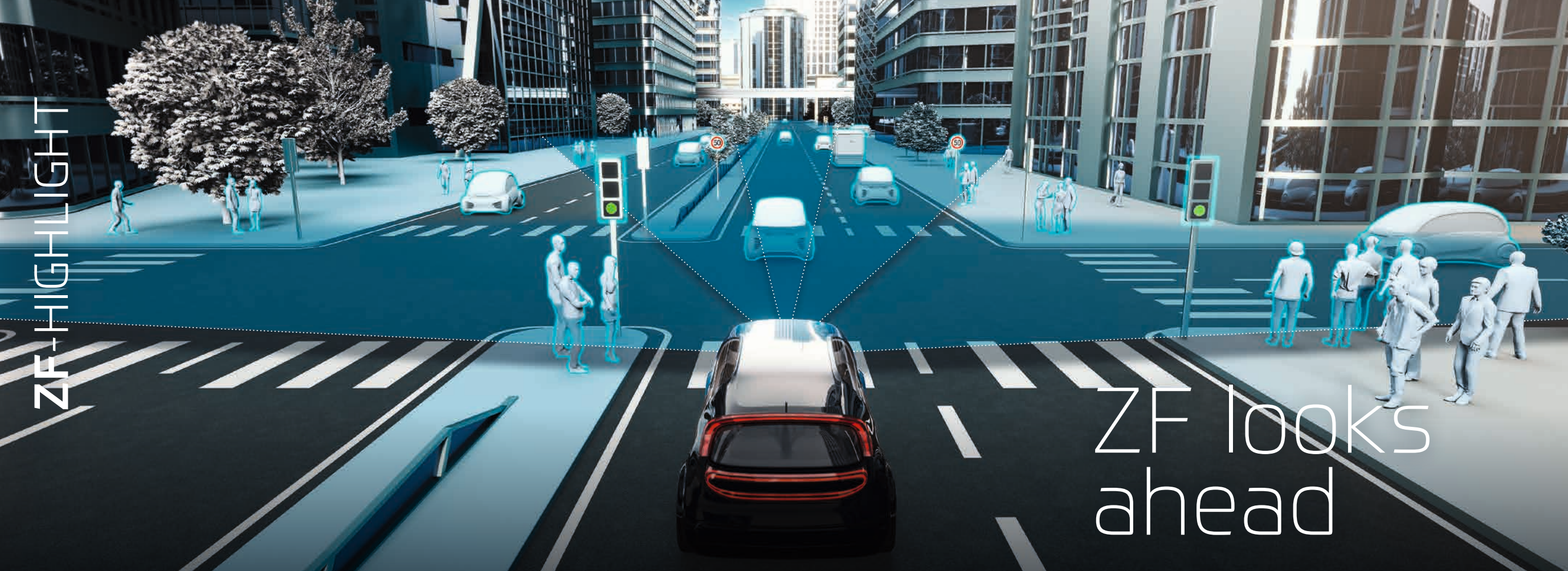
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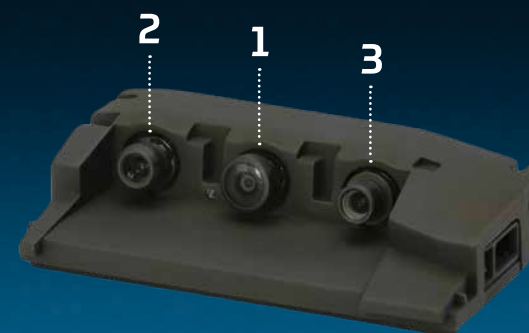
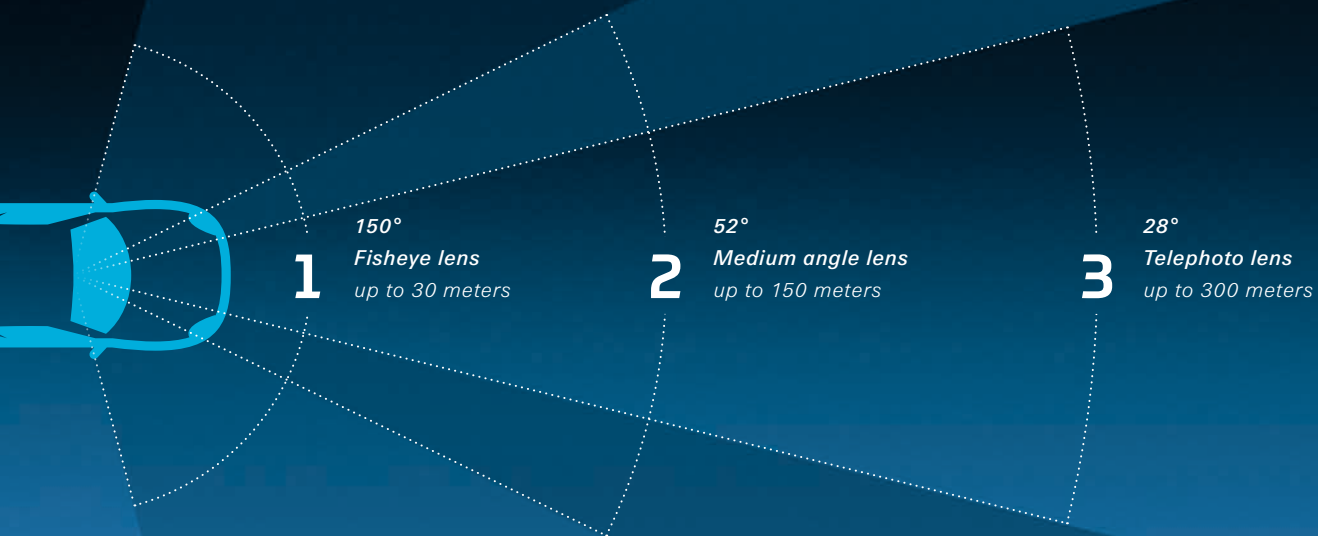






# ZF looks ahead

THE TRI-CAM FRONT CAMERA NOT ONLY PROVIDES A VIEW OF THE ROAD, BUT ALSO A LOOK INTO THE FUTURE OF AUTOMATED DRIVING.



*The compact design makes it possible to install the Tri-Cam across a wide variety of vehicles from small cars to large SUVs.*

The Tri-Cam monitors the vehicle's surroundings using three high-resolution lens/imagers. In addition to a 52-degree lens – as fitted in current generation ZF monocular cameras – a telephoto lens provides more long-range information and is capable of identifying objects up to 300 meters away. There is also a fisheye lens with an extremely wide field of view for detecting vehicles, pedestrians, and cyclists at close range.

Thanks to these capabilities, the Tri-Cam will soon be making a key contribution to automated driving features. When combined with the vehicle's braking system, for example, it will represent a significant step forward in detection for the automatic emergency brake systems to meet increasingly challenging market safety requirements. In future, ZF will link the three-lens front camera to AI-compatible control units such as the ZF ProAI, further developing a platform for automated driving features.





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