tomorrow

EXPERIENCING TECHNOLOGY WITH SCHAEFFLER

Machines with an IQ

Factories of the future, nanobots, artificial intelligence, big data

Trailblazers

Heavy-duty equipment working for mobility for tomorrow

Issue 3/2017 · Machines

SCHAEFFLER

Ma|chine [mə-´shēn]

(1) An assemblage of parts that transmit forces, motion, and energy one to another in a predetermined manner

(2) An instrument (such as a lever) designed to transmit or modify the application of power, force, or motion

(3) A mechanically, electrically, or electronically operated device for performing a task

(4) A coin-operated device

Source: Merriam Webster (excerpt only)

DEAR **READER,**

At Wimbledon, tennis players return serves “like machines.” Marathon runners run mile after mile “like machines.” These comparisons suggest what positive properties we attribute to machines. They deliver precise, fast, untiring and reliable performance. The logical consequence is that machines are indispensable “players” not only at Schaeffler, but substantially anchored in practically all areas of life. In the current issue of our technology magazine “tomorrow,” to which I’d like to warmly welcome you with these lines, they’re featured as the principal performers as well.

Although all of us have no doubt occasionally been frustrated with some imperfection of technology – what would our everyday lives at work and at home be like without machines? Without washing machines or dishwashers for example? More difficult, to say the least. Another example: Where would the cultural and the news sectors be without the invention of the printing press? Gutenberg’s feat is just one of many technological milestones that have decisively shaped progress – with effects continuing to this day. You’ll find other examples of such pioneering importance starting on page 56.

Without machines, mobility wouldn’t be the same either. Above and beyond vehicles – a wide variety of which you’ll find in various places of this issue – there are countless machines that produce means of transportation – or those that pave ways. More on this starting on page 14.

That machines build other machines has long become common practice in manufacturing operations, albeit with humans in the proverbial driver’s seat. Humans are in control, but the question is: how much longer? Machines are acting with increasing autonomy and communicate with each other in networks. Starting on page 86, “tomorrow” takes a look at the factory halls of tomorrow. Factories, though, are not the place to go for anyone interested in watching nanobots at work. These minute machines are so small that they can only be detected under a microscope. In spite of being so tiny, they have enormous potential to change the world, as you can see starting on page 102.

How innovative technology lends wings to us on two wheels, in a manner of speaking, is shown by our 50 km/h (31-mph) comparison starting on page 36. Modern pedelecs achieve speed ranges that 100 years ago were still reserved to motorcycles, although electric bicycles are as easy to handle as normal ones – a clever and eco-friendly mobility solution for tomorrow that can already be experienced today.

Even the development and design of industrial goods has long gone beyond being purely focused on “inner values.” Starting on page 64, “tomorrow” explains why form and function ideally merge into a unit. After all, even Johann Wolfgang von Goethe already knew that “Beauty is everywhere a welcome guest.” So it is in a factory hall – or in an engine compartment. True masterpieces of the art of engine design are displayed starting on page 42.

We’re delighted that you’re taking the time to delve into the multi-faced technology worlds presented in our magazine “tomorrow.” Enjoy the read.

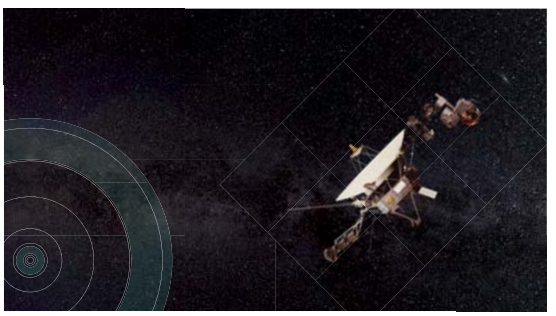
Klaus Rosenfeld
Chief Executive Officer

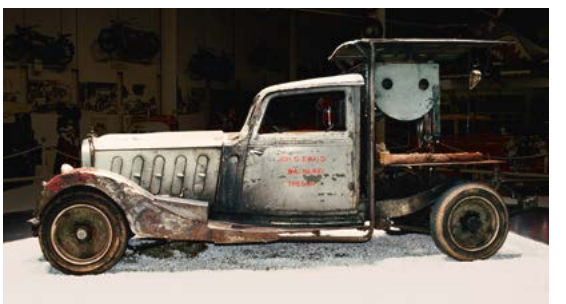
global

A glimpse of the world

in motion

Innovations in the course of time





here and now

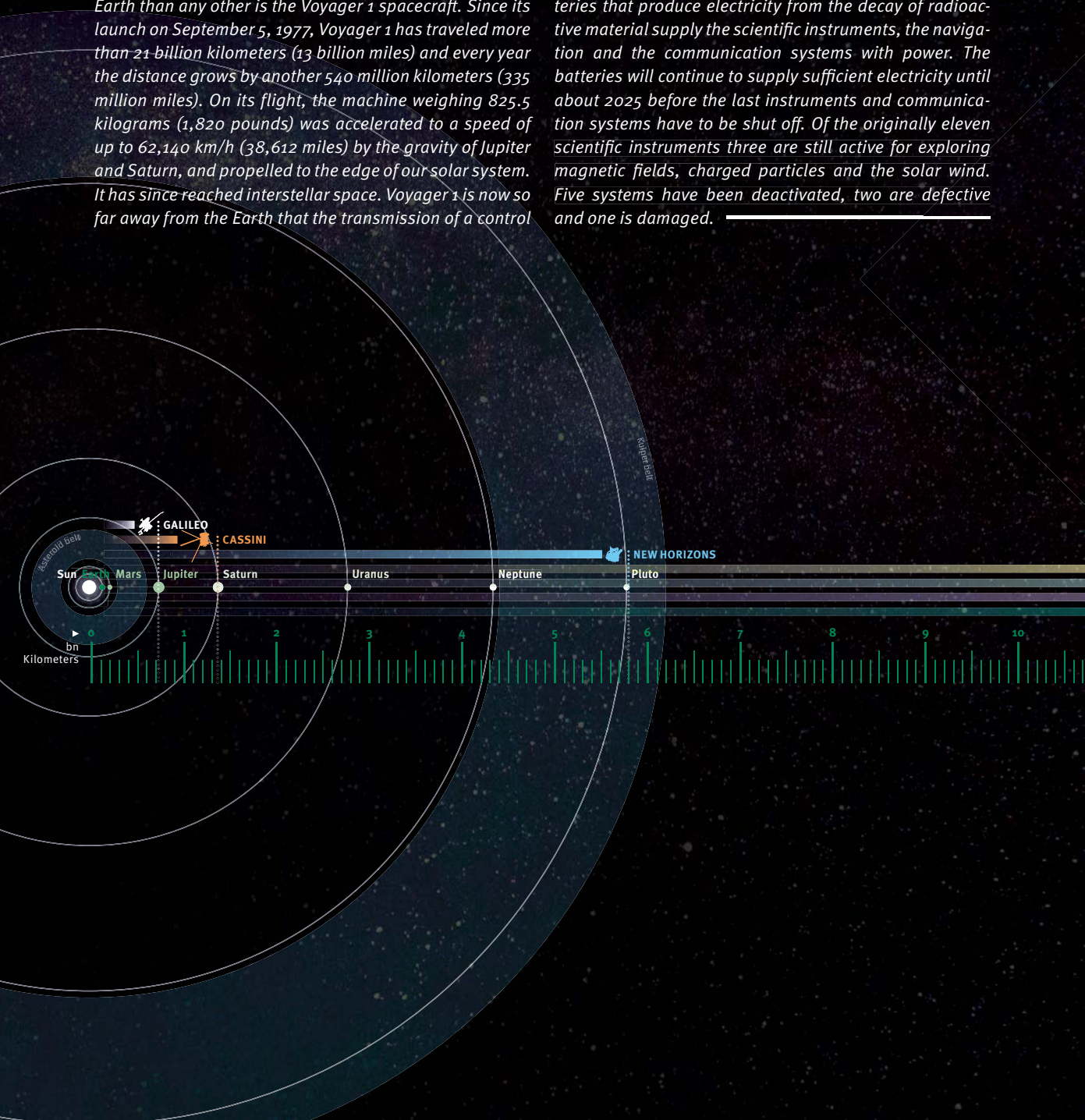
Living with progress

outlook

Technology for tomorrow

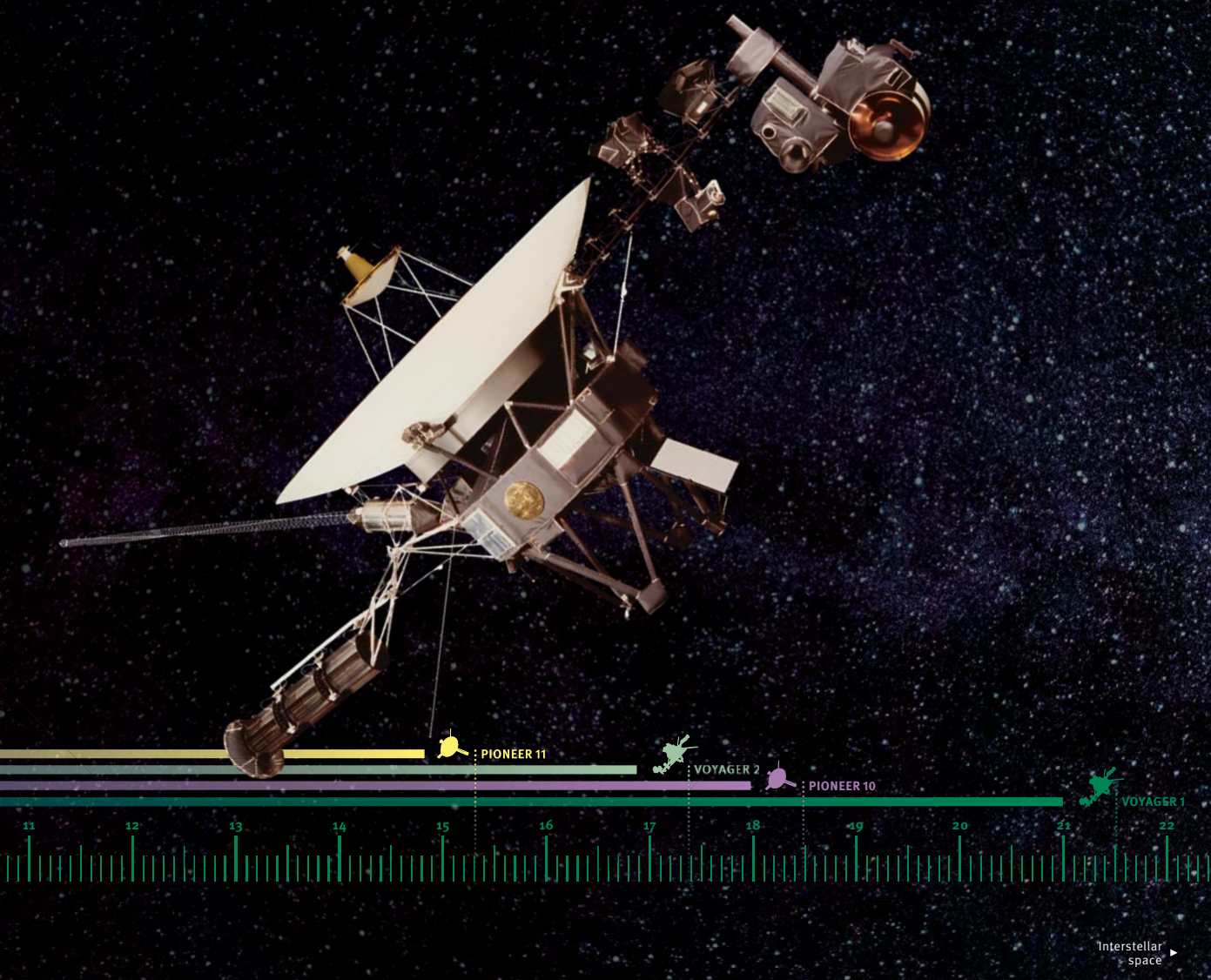
SPACE, **THE FINAL FRONTIER**

Machines are part of our lives – even outside the human habitat. The machine that's farther away from the Earth than any other is the Voyager 1 spacecraft. Since its launch on September 5, 1977, Voyager 1 has traveled more than 21 billion kilometers (13 billion miles) and every year the distance grows by another 540 million kilometers (335 million miles). On its flight, the machine weighing 825.5 kilograms (1,820 pounds) was accelerated to a speed of up to 62,140 km/h (38,612 miles) by the gravity of Jupiter and Saturn, and propelled to the edge of our solar system. It has since reached interstellar space. Voyager 1 is now so far away from the Earth that the transmission of a control signal takes 19 hours and 32 minutes – in spite of data transmission at the speed of light. Three radionuclide batteries that produce electricity from the decay of radioactive material supply the scientific instruments, the navigation and the communication systems with power. The batteries will continue to supply sufficient electricity until about 2025 before the last instruments and communication systems have to be shut off. Of the originally eleven scientific instruments three are still active for exploring magnetic fields, charged particles and the solar wind. Five systems have been deactivated, two are defective and one is damaged.



global

a glimpse of the world



» Our two greatest problems in the conquest of space are gravity and paperwork. We can lick gravity, but sometimes the paperwork is overwhelming

Wernher von Braun in response to the question of why the USSR launched a spacecraft before the U.S. did

360° MACHINES

Facts, figures, oddities – a 360-degree view of the world of machines.

by Carsten Paulun

UNUSUAL TIME MACHINE

The Beverly Clock named after its inventor and situated in the Department of Physics at the University of Otago in Dunedin, New Zealand, has been ticking since 1864 without ever having been manually wound or supplied with electricity. Kinetic energy is strictly generated by the expansion or contraction of air via a diaphragm.

NO “MACHINE” WITHOUT THE GREEKS

THE WORD “MACHINE” DERIVES FROM THE OLD GREEK WORDS “MĒCHANḖ” (“CONTRIVANCE, MACHINE, ENGINE”) AND “MEKHOS“ (“MEANS, EXPEDIENT, REMEDY”). THE ORIGIN OF THE WORD CAN BE RECOGNIZED IN MANY LANGUAGES:

AFRIKAANS: MASJIEN
ALBANIAN: MAKINË
BULGARIAN/RUSSIAN: MASHINA
DANISH: MASKINE
FRENCH: MACHINE
GERMAN: MASCHINE
ITALIAN: MACCHINA
POLISH: MASZYNA
PORTUGUESE/SPANISH: MÁQUINA
TURKISH: MAKINE

2,224.558 RACE KILOMETERS

(1,382.27 MI) IS THE DISTANCE COVERED BY THE FORMULA E RACE CARS SUPPORTED BY SCHAEFFLER IN THE 2017 SEASON. MORE ON SCHAEFFLER’S TITLE DEFENSE MISSION ON PAGE 22.

70 percent of Germans fear that computers and robots will be taking their jobs away from them. In the United States, the percentage, at 72, is even higher. **Austrians, at 18 %, have clearly less concerns in this respect.**

ELECTRIC GIANT

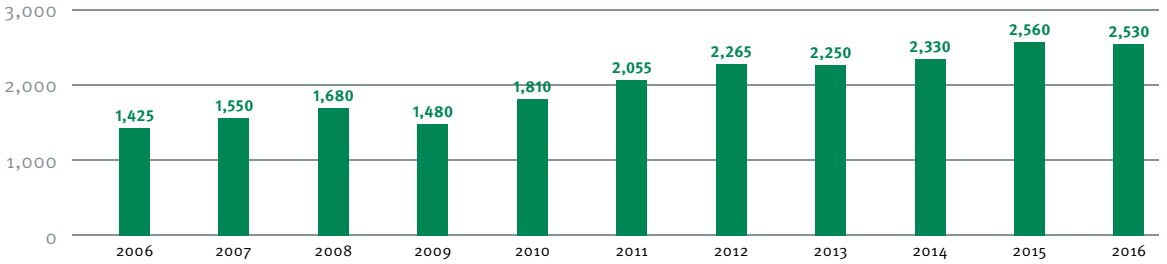
This heavy-duty dumper will be the world’s biggest electric vehicle: 45 metric tons (49.6 short tons) of curb weight, 65 metric tons (71.65 short tons) of payload – plus a battery pack with 700 kWh of storage capacity equaling that of eight Tesla Model S cars. The driver climbs nine steps to get into the cabin; the tires of the electric vehicle have a diameter of nearly two meters (6.56 feet). The electrically powered Komatsu HD 605-7 is intended to haul material down into the valley 20 times per day – from a quarry on the slopes of the Swiss Chasseral to a cement factory near Biel.

ONE CABLE CAR – THREE WORLD RECORDS

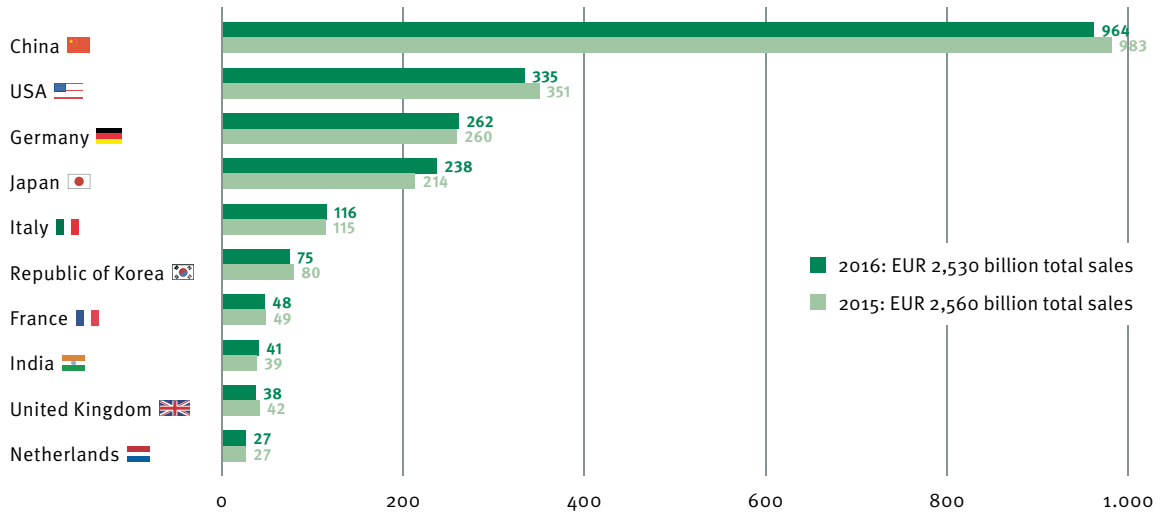
Following six years of planning and construction, a new cable car climbs up to the 2,962-meter (96,004-feet) summit of the Zugspitze, Germany’s highest mountain, setting three world records. The glazed cabins pass the world’s tallest ropeway tower (127 meters/417 feet), overcome the greatest elevation gain of 1,945 meters (6,381 feet) within one section and the longest free span of 3,213 meters (10,5 feet), a panoramic view of Lake Eibsee, the Waxenstein mountains and the Albspitze peak included!

WORLD MACHINE SALES

WORLDWIDE[1] EUR billion, estimated

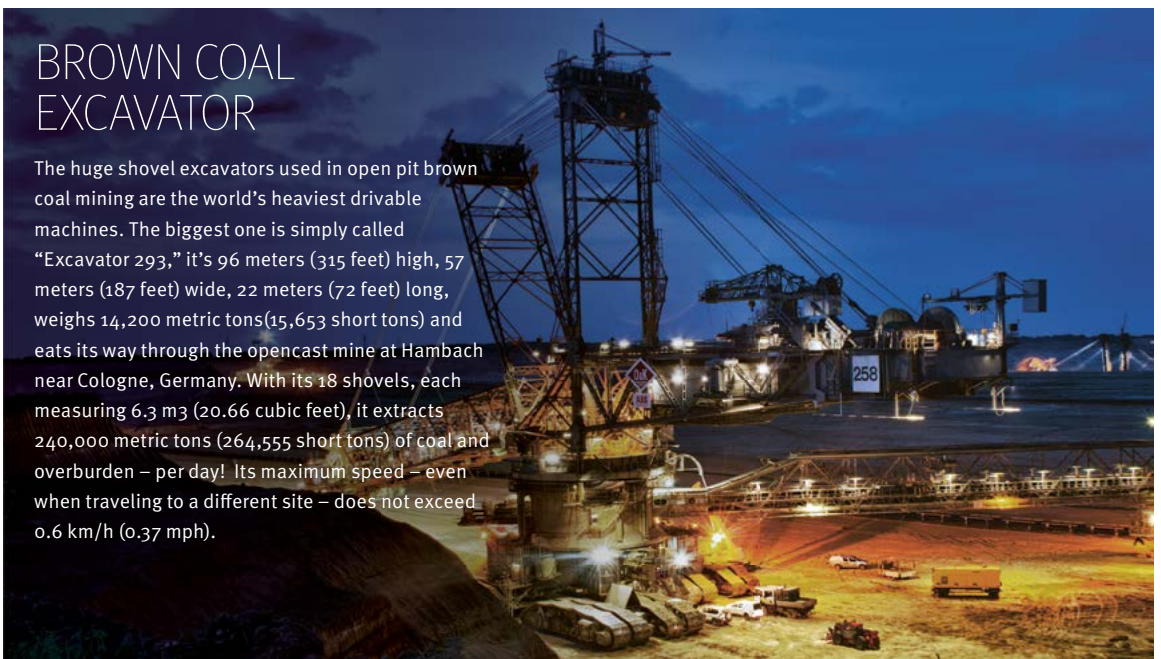


TOP-10 COUNTRY RANKING[2] EUR billion, partly estimated



[1] Source: VDMA estimates

[2] Source: VDMA estimates based on national statistics



BROWN COAL EXCAVATOR

The huge shovel excavators used in open pit brown coal mining are the world's heaviest drivable machines. The biggest one is simply called "Excavator 293," it's 96 meters (315 feet) high, 57 meters (187 feet) wide, 22 meters (72 feet) long, weighs 14,200 metric tons(15,653 short tons) and eats its way through the opencast mine at Hambach near Cologne, Germany. With its 18 shovels, each measuring 6.3 m3 (20.66 cubic feet), it extracts 240,000 metric tons (264,555 short tons) of coal and overburden – per day! Its maximum speed – even when traveling to a different site – does not exceed 0.6 km/h (0.37 mph).

FANTASTIC MACHINES

In Nantes, France, machines on the one side and flora and fauna on the other merge into a truly fantastic unit à la Jules Vernes. At the "Les Machines" park, mechanical mythical creatures from steel and wood come to life: turtles, octopuses and insects. The most spectacular creature is an elephant weighing 48 metric tons (53 short tons). A 450-hp engine, 2,000 liters (528 gallons) of hydraulic oil and 62 hydraulic and pneumatic cylinders breathe life into the twelve meter high metallic frame creature. The mechanical system of the skeleton allows the creature to move at a slow trot of up to 3 km/h (1.86 mph).

lesmachines-nantes.fr

AHEAD OF ITS TIME

IN 1900, GREEK SPONGE DIVERS DISCOVERED A DEVICE IN A SHIP WRECK THAT EVEN BAFFLED THE EXPERT WORLD. THE "ANTIKYTHERA MECHANISM" DATING TO ROUGHLY 100 B.C. IS AN ASTRONOMICAL CLOCK OF A KIND THAT EVEN INVENTORS IN THE RENAISSANCE PERIOD 1,500 YEARS LATER WERE HARDLY ABLE TO DESIGN. THE HISTORIAN OF SCIENCE DEREK DE SOLLA PRICE EVEN CONSIDERED THE MECHANISM THAT HAS THE SIZE OF A SHOE BOX HUMANITY'S FIRST COMPUTER.

1.5 BILLION

readings – per second – are recorded by the test benches of the German Aerospace Center in Lampoldshausen. This is where rocket engines are tested under extraterrestrial conditions (e.g. pressure, temperatures).

TWO ARE BETTER THAN ONE

THE SWISS ABB GROUP HAS DEVELOPED YUMI (STANDING FOR "YOU" AND "ME"), A TWO-ARMED ROBOT SAID TO REQUIRE LESS SPACE COMBINED WITH OFFERING GREATER VERSATILITY THAN CONVENTIONAL ONE-ARMED ROBOTS. YUMI RECENTLY DEMONSTRATED ITS SKILLS IN AN UNUSUAL SETTING, AT TEATRO VERDI IN PISA, ITALY. THERE THE ROBOT CONDUCTED THE LUCCA PHILHARMONIC ORCHESTRA THROUGH "LA DONNA È MOBILE," THE FAMOUS ARIA FROM VERDI'S "RIGOLETTO."

LIKE TOY WORKERS ...

... This is how the men in this picture look compared to the world's heaviest milling machine that boasts 500 metric tons (551 short tons) of weight, 19 meters (62 feet) in length, 7.25 meters (23.78 feet) between columns and 7.3 meters (24 feet) in height. In spite of these impressive dimensions, the machine is energy-efficient. Roller monorail guidance systems reduce consumption and cut costs. Energy efficiency is enhanced even further by a reduction of engineering complexity. In Schaeffler, SORALUCE, a well-established company that designs and manufactures milling, boring and vertical turning machines has selected exactly the right partner because Schaeffler Iberia supplies the roller monorail guidance system for this huge machine.

LEONARDO DA VINCI

The Italian genius lived from 1452 to 1519 as a painter, sculptor, architect, anatomist, natural philosopher – and inventor! These machines are attributed to him:

INFINITY MACHINE
GLIDER
MUSCLE-POWERED ORNITHOPTER
PARACHUTE
MACHINE GUN
STREAMLINED BULLETS
DIVING HELMET
BREATHING TUBE FOR DIVING
ARMORED VEHICLE
HOWITZER
SUBMARINE
BULLET-PROOF VEST
AUTOMOBILE
CLOCKWORK
HYDRAULIC MACHINES
SCOOP WHEEL
LEVER MECHANISMS
BALL BEARING
WEAVING MACHINE
MUSICAL INSTRUMENTS

LEVITATING ON A MAGNETIC CARPET ARRIVO, THOUGHT UP BY A FORMER HYPERLOOP DEVELOPER, IS AIMING TO REVOLUTIONIZE URBAN AND INTER-URBAN TRANSPORTATION – WITH PODS THAT CAN CARRY CARS, PEOPLE OR CARGO USING MAGNETIC LEVITATION LANES BUILT IN PARALLEL TO EXISTING HIGHWAYS. THE GOVERNOR OF THE U.S. STATE OF COLORADO, JON HICKENLOOPER, IS PLANNING TO DEPLOY THE ARRIVO MAGNETIC LEVITATION PODS IN DENVER STARTING IN 2020.

ARRIVO-LOOP.COM

BIO ROBOTS AS EVOLUTION SAVIORS

Developers of bio robots, aka BioBots, take their cues from nature. Their creations, for instance, include artificial dragonflies that are able to search for survivors in areas struck by disasters. ***BioBots can also perform the functions of displaced or extinct species,*** *such as the pollination work done by bees if global bee death should continue. Given that the economic value of the pollination done by busy bees is estimated at an enormous 300 billion dollars, this is no doubt a lucrative field.*

TO ERR IS HUMAN

» I think there is a world market for maybe five computers
Harold Watson, CEO of IBM, 1946

» The worldwide demand for motor vehicles will not exceed one million – if for no other reason than the lack of available chauffeurs
Gottlieb Daimler, design engineer, 1901

» Television won't be able to hold on to any market it captures after the first six months
Darryl Zanuck,
20th Century Fox, 1946

MACHINES FOR MOBILITY

Our need for mobility keeps growing. To satisfy it, we use machines that are increasingly smart and in some cases more powerful than ever. To ensure their efficient and trouble-free operation in typically harsh, heavy-duty conditions, all components – including Schaeffler's rolling and friction bearings utilized around the globe – have to deliver top performance.

by Carsten Paulun

THE **TRACK LAYER**

An awesome weight of 650 metric tons (716.5 short tons) and an incredible length of 177 meters (580.7 feet) – the nondescript abbreviation RU 800 S stands for a veritable multi-talent. *The tracklaying giant renews complete railroad tracks including the ballast bed, crossties (sleepers) and rails in a single pass. At the front, the behemoth spreads the old rails apart and picks up the crossties and the ballast bed. Belts then convey the track ballast to a screening system for cleaning. While the RU 800 S continues to travel, it levels the ground, and deposits and compacts the cleaned track ballast. At the same time, the new crossties are laid, filled with new track ballast, followed by laying the new rails on which the work train can already travel again. In a 10-hour shift, the RU 800 S lays nearly 2,000 meters (6,562 feet) of track this way.*

SCHAEFFLER TECHNOLOGY SAVES TIME AND MONEY

A tunnel boring machine cuts its way through Iceland in 2012. *During the subsequent rebuild, the custom-made main bearing would actually be due for replacement. Lead time: approx. two years. Therefore, Schaeffler's experts opted for an extensive overhaul of the huge bearing with a diameter of 5.2 meters (17.06 feet). Duration: eight weeks. As a result of this action, Schaeffler enables its customer, Robbins GmbH, to achieve cost savings of 60 percent compared with a new part and to deploy the machine in time for a tunnel project in China.*

THE **TUNNEL DIGGER**

They dig themselves through soil, cut their way through rock and crack concrete like a piece of cake: tunnel boring machines are man-made high-tech moles. *It took these underground monsters a full 17 years to nibble themselves through the Swiss Alps, creating the two tubes underneath the Saint-Gotthard Massif that make up the world's longest railroad tunnel with a length of 57 kilometers (35.4 miles). Tunnel boring machines have a diameter of up to 20 meters (65.6 feet), can be up to 400 meters (1,312 feet) long and cost between 30 and 100 million euros a piece. In most cases, they're universal machines that bore the tunnel, convey the excavated material rearward on belts, and line the tunnel with steel plates and shotcrete in the process. Many tunnel boring machines are purpose-built for a particular tunnel and after completion of the project, which may take several years, typically scrapped right on site. If the machines are used only for short periods of time, they're dismantled and subjected to a complex complete overhaul.*

THE **ASPHALT PAVER**

The Super 3000-2 paver by German construction equipment specialist Vögele is a world leader in its class. In a single pass, the unique machine achieves a maximum pave width of 16 meters (52.5 feet) – without any joints whatsoever. *That's enough for a three-lane highway including a filter lane and shoulder. The achievable layer thickness of half a meter (1.64 feet) is impressive as well. The same applies to the pave speed of the Super 3000-2 which can amount to as much as 24 meters (78.7 feet) per minute. And as becomes a true behemoth, the Super 3000-2 expects to be fed well, devouring up to 1,600 metric tons (1,763.7 short tons) of mix per hour which equates to more than 20 truckloads of material. Traveling in front of the paver is a so-called feeder that picks up the mix from the trucks and supplies the Super 3000-2 with a homogenous compound that's kept at a consistent temperature. The trucks back up against the feeder at three-minute intervals and dump the mix into the feeder's hopper. All this happens while the paver-feeder combination keeps moving forward.*

THE **BRIDGE BUILDER**

Everything in China is a little larger than elsewhere and sometimes a bit more unusual as well. *To manage the booming construction of new highways and railroads, the engineers in the Middle Kingdom have standardized the bridge building projects – and in the process developed bridge building machines to suit their needs. The Beijing Wowjoint Machinery Company alone has more than 100 different types of these purpose-built machines in its portfolio. The largest ones are nearly 100 meters (328 feet) long and weigh 580 metric tons (639.3 short tons). During the construction project, they'll travel to the edge of the bridge, pushing steel girders onto the next free piers. Then the finished bridge element is pulled by a sliding crane system to the place where it will be installed, lowered and mounted in the corresponding bearings. Subsequently, the gigantic machine travels back to pick up the next bridge section.*

THE **TREE TRANSPLANTER**

You can't shift an old tree without it dying? Says who? If a tree that's worth preserving gets in the way during road construction or track-laying projects, it's time to deploy the Optimal 2500. *Officially, it's called a "hydraulic tree spade," but we can simply call it a tree transplanter, because that's exactly what the Optimal 2500 does. It digs up a root ball around the plant, just like any gardener would when replanting a plant. It's just that these plants are a little bigger than usual. Instead of one spade, the Optimal 2500 has an amazing five of them, each of them tapered and sitting on a massive ring. This ring has an opening that closes as soon as the ring has enclosed the tree. Subsequently, the spade ring will push into the ground with pressure of 260 bar (26 Mpa) to dig up the root ball. With a noticeable smacking sound, the root ball is lifted and, depending on the construction project, either loaded onto a truck or transplanted into a nearby hole which the Optimal 2500 has previously dug as well.*

THE **DRY-DOCKER**

Even the biggest ships have to proverbially visit a garage from time to time. *However, to work on its underwater hull, one of these floating behemoths cannot simply be lifted out of the water. That's why the ship is dry-docked. A dry dock is like a dead-end lock. The lock's gate is closed behind the ship after it has entered and the water pumped out. Now the ship is on dry ground and all the work on the normally submerged hull can be performed without the workers having to dive. Elbe 17 of Blohm+Voss in the Hamburg harbor is one of Europe's largest dry docks. Even gigantic cruise ships like the Quantum of the Seas (347 m/1,138.45 ft long, 41.4 m/135.83 ft wide) and the Souvereign Maersk (347 m/1,138.45 ft long, 42.8 m/140.42 ft wide) container vessel have been dry-docked in this concrete monster measuring 351.2 meters (1,152.23 feet) in length and 59.2 meters (194.23 feet) in width. To support the awesome weight of such ships, the base plate is made of nine-meter (29.53-foot) thick reinforced concrete.*

THE **BRICK-ROAD LAYER**

This is a machine thousands of construction workers around the globe have been waiting for: *Instead of tediously squatting and kneeling while laying paving bricks, all the construction workers have to do is feed the Tiger-Stone with the bricks in the desired pattern. The machine, which is 1.60 meters (5.25 feet) high and equally long, then lays a finished pattern on the previously prepared subsoil like a carpet. Brick roads laid this way can be up to 6 meters (19.7 feet) wide. To ensure a neat result, the machine has built-in sensors that follow the curb which has been laid in advance. Traveling on electrically powered tracks, the Tiger-Stone is capable of paving up to 300 square meters (3,229 square feet) per day – three times more than a seasoned bricklayer could. The machine designed by a Dutchman has won an innovation award and is a huge success in the United States.*

THE **TRAFFIC MANAGER**

Jersey barriers secure road construction sites and managed lanes more effectively than simple traffic cones, but the concrete sections weighing some 700 kilograms (1,543.24 pounds) are hard to handle. *This is the where the Road Zipper comes into play. This special machine, weighing 30 metric tons (33 short tons), has been used in the United States since the mid-1980s. On the Golden Gate Bridge in San Francisco, the Road Zipper transfers a row of concrete sections in the morning to create an additional inbound lane, and an outbound lane in the evening. The zipper lifts the concrete barrier sections and passes them through a conveyor system to the place where they're set down. The transfer width is between 1.2 and 5.5 meters (3.94 and 18.04 feet). It takes the zipper about 30 minutes to transfer 2,800 of these concrete barrier sections, while it would take a crane truck several days to do the same job. The 15-meter (49.21-foot) long Road Zipper is used by road authorities and contractors around the world, including several European countries.*

THE **LICENSE PLATE PRINTER**

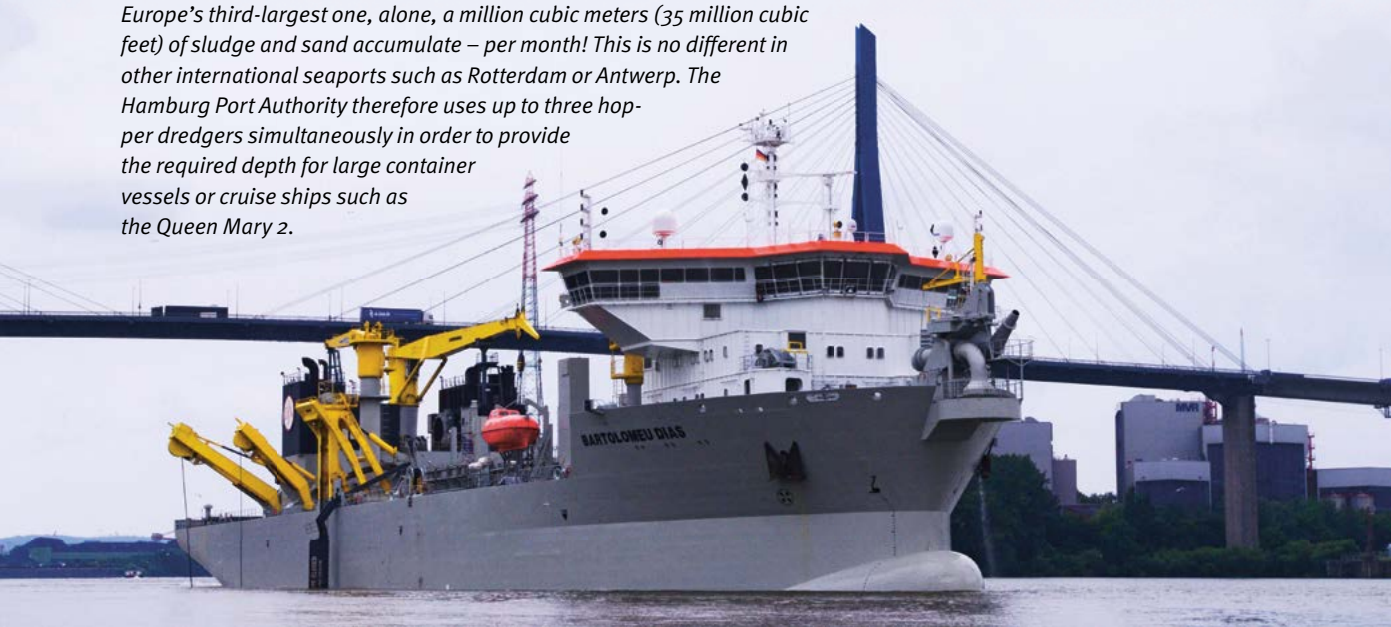
License plates are the personal ID of any passenger car. *They're mandatory in (nearly) all countries of the world and, like the registration documents, serve as proof of an automobile's identity. In Germany alone, some 22 million license plates are embossed every year, typically using on-site manual embossing presses. However, license plates can also be embossed in large volumes with the fully automated embossing press from German vehicle identification specialist Utsch. This machine performs all process steps in fully automated mode, embossing up to 650 license plates per hour. If desired, the embossed inscription of the license plate can be automatically inked using hot stamping foil. Such computer-controlled lines are used, for instance, by operators of large fleets like car rental companies, as well as government authorities in countries that centrally issue license plates.*

THE **RIVER VACUUM CLEANER**

Waterways rank among our most important transportation routes. They not only allow ships to travel on their surface but carry along plenty of "stowaways" *such as sand and sludge. For navigable rivers, harbors and channels, these stowaways can pose a problem in places where they settle as sediment. That's why waterways and shipping authorities regularly use so-called hopper dredgers to remove sand and sludge. A suction head loosens the sediment at the bottom which is then aspirated via a large pipe on board of the dredger, similar to the way a vacuum cleaner works. The solid particles such as sand and sludge are deposited in the dredger's cargo bay and either returned to the water at a different place or flushed ashore. In the Hamburg harbor, Europe's third-largest one, alone, a million cubic meters (35 million cubic feet) of sludge and sand accumulate – per month! This is no different in other international seaports such as Rotterdam or Antwerp. The Hamburg Port Authority therefore uses up to three hopper dredgers simultaneously in order to provide the required depth for large container vessels or cruise ships such as the Queen Mary 2.*

THE AUTHOR

Why do something yourself if there's a machine that can do the job for you? ***Carsten Paulun*** *(50) has always been prone to delegate work: be it to a drill powered by a steam engine as a child, to a Kettcar tuned with a moped engine as a teenager or to a fully automated lawn-mowing robot at a riper age.*



HEAVY-DUTY **MONSTERS**

When they're deployed, they typically leave no stone unturned. Heavy-duty construction machines are veritable monsters made of steel. When appropriately utilized, one of these machines is capable of delivering higher output in an hour than an entire construction crew in a year. To do so, even the most delicate components have to withstand hundreds of tons of pressure – preferably without requiring maintenance. Schaeffler has developed special bearings for this purpose because every repair costs time – and time at which these giants are down for maintenance is money.

Bearings for movable parts play a particular role, be they wheel bearings on mining trucks, pendulum-type articulated joints of construction machines or cable sheave bearings of mobile cranes – they all call for the know-how of Schaeffler's specialists, as the demands made on the bearing, depending on the application, not only change in terms of static and dynamic loading capacity. Equally in focus are weather resistance and low maintenance requirements, as well as ease of assembly and, if necessary, easy re-lubrication. Reliable sealing and corrosion protection throughout the component's service life complement the specifications for most bearings.

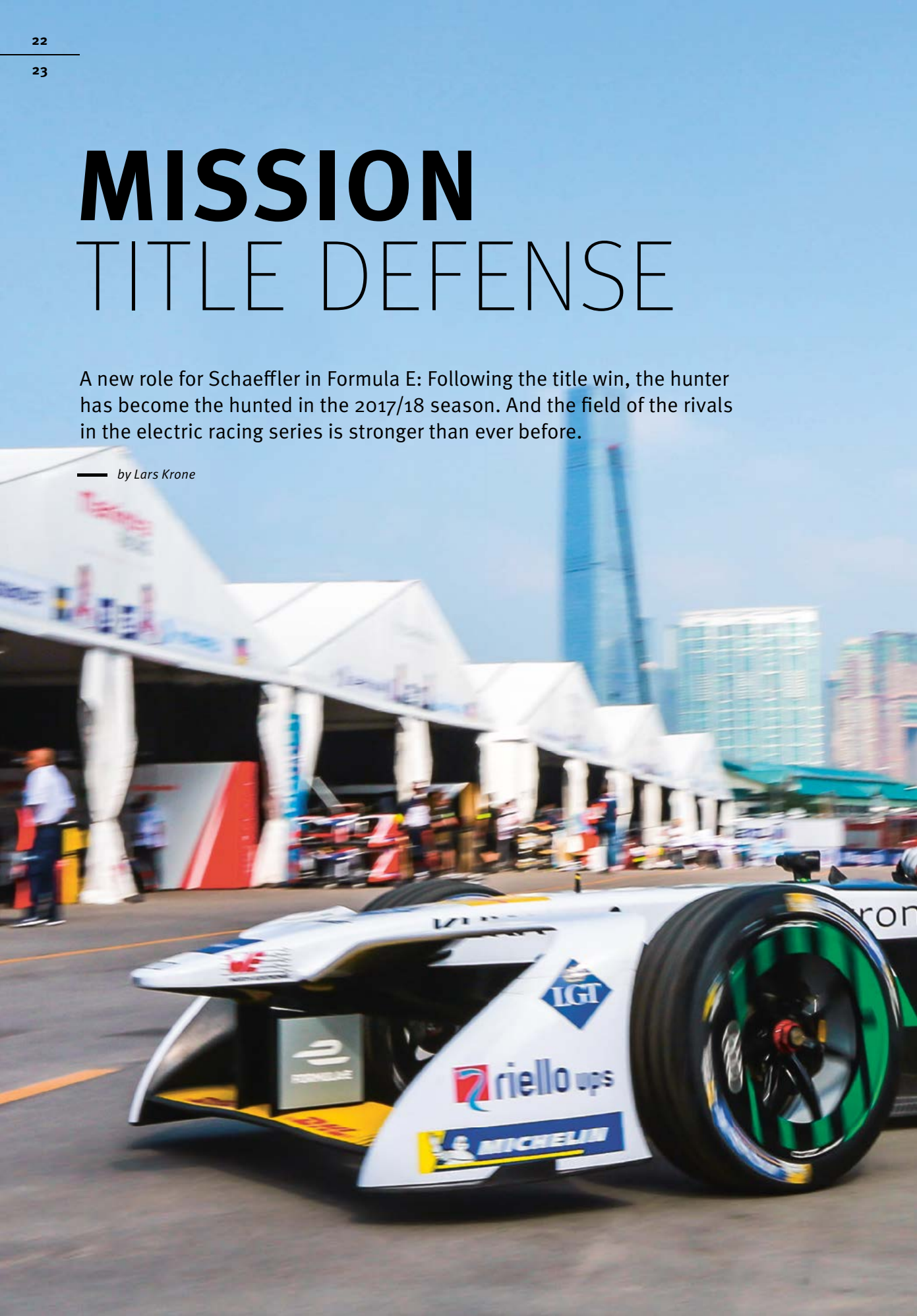
Special coatings used by Schaeffler such as Corrotect are a cost-effective alternative to stainless steel in heavy-duty applications, resulting in dramatic reductions in corrosion-induced maintenance and assembly costs. Elgoglide-coated bearings in the lifting frame of a wheel loader even guarantee completely maintenance-free operation and eliminate the need for lubricants across the unit's entire service life.

Behind bars, as it were: the solid MPAX brass cage protects these Schaeffler cylinder rollers against impact loads and vibrations

MISSION
TITLE DEFENSE

A new role for Schaeffler in Formula E: Following the title win, the hunter has become the hunted in the 2017/18 season. And the field of the rivals in the electric racing series is stronger than ever before.

by Lars Krone



If you don't move forward, you go backward. Even before Lucas di Grassi's title win in July Team Audi Sport ABT Schaeffler began to prepare for Formula E Season Four that has been under way since the season opened in Hong Kong in early December.

Schaeffler and Audi have developed a new race car, the Audi e-tron FE04, which has an all-new powertrain compared with last season's championship-winning car and once again sets the technological benchmark. "The car is mega," di Grassi is convinced. Schaeffler's engineers primarily focused on achieving a further efficiency increase of the motor-generator unit (MGU), which in particular improves acceleration out of corners. To transfer power output to the wheels, a single-speed transmission is used for the first time. It was specifically developed for the new powertrain.

Daniel Abt, who is title defender di Grassi's teammate again, is enthusiastic about the new transmission: "A clearly faster solution than the previous three-speed unit. You no longer have any power interruption when shifting gears and braking. As a result, the car has greater stability and handling is more fluid." Additionally, the power output of the cars in the races has been raised to 180 kW (245 hp).

With new venues such as Rome, Santiago de Chile and Zurich the calendar in Season Four has become even more attractive. "For me, Formula E is already the second-most relevant racing series after Formula 1," di Grassi enthuses. "It meets all the prerequisites for further future growth."

Strong competition

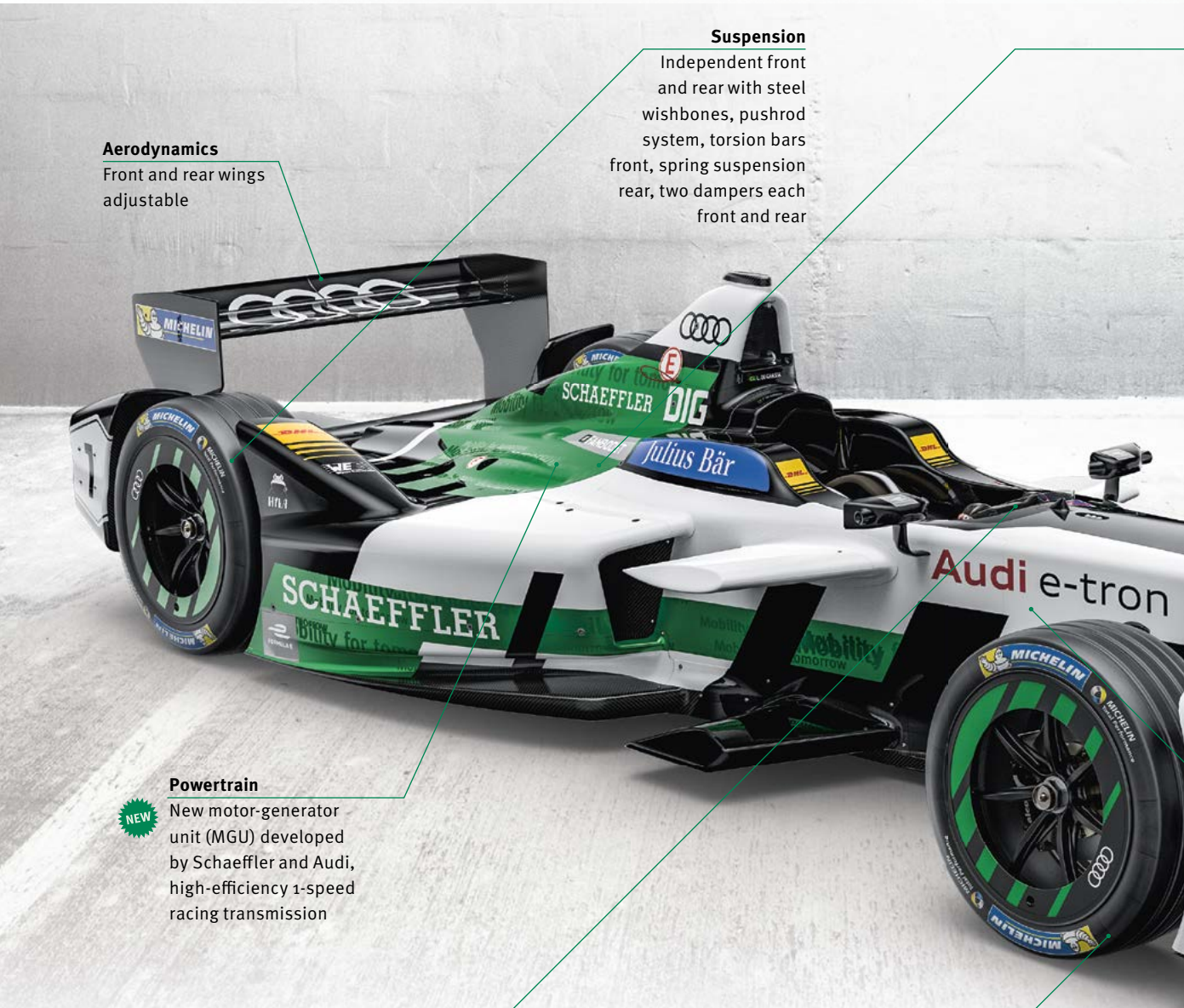
The 2017/18 season again promises highly thrilling racing. "There'll no doubt be five or six teams in contention for victory," di Grassi predicts. "The title race will be extremely close." Favorites obviously include permanent rivals Renault e.dams. The squad around ex-champion Sébastien Buemi has been the most successful one in the racing series to date. But the Andretti team that receives intensive support from BMW, plus Mahindra Racing, DS Virgin Racing and Jaguar Racing have high expectations as well. Following a year of learning, the Britons intend to join the battle at the very front. The driver field is again a high-caliber one. Prominent newcomers include Le Mans winners André Lotterer and Neel Jani. Ex-F1 campaigner Kamui Kobayashi and DTM star Edoardo Mortara further enhance the field. The title defense mission will not be an easy challenge for Audi Sport ABT Schaeffler.

» In Formula E, we're able to explore extremes. At Schaeffler, we have and continue to gather a wealth of know-how in the combination and interaction of systems. In Formula E, it's between the electric motor and the transmission

Prof. Peter Gutzmer,
Schaeffler Chief Technology Officer

MORE EFFICIENT AND POWERFUL

For Formula E Season Four, the championship-winning car was updated in major ways. The new Audi e-tron FE04 jointly developed by Schaeffler and Audi has an innovative, all-new powertrain, among other things.



Aerodynamics
Front and rear wings adjustable

Suspension
Independent front and rear with steel wishbones, pushrod system, torsion bars front, spring suspension rear, two dampers each front and rear

Powertrain
NEW
New motor-generator unit (MGU) developed by Schaeffler and Audi, high-efficiency 1-speed racing transmission

Steering wheel
Individually programmable specification steering wheel with paddles for shifting and recuperation, controls for various motor settings and a display with all key data

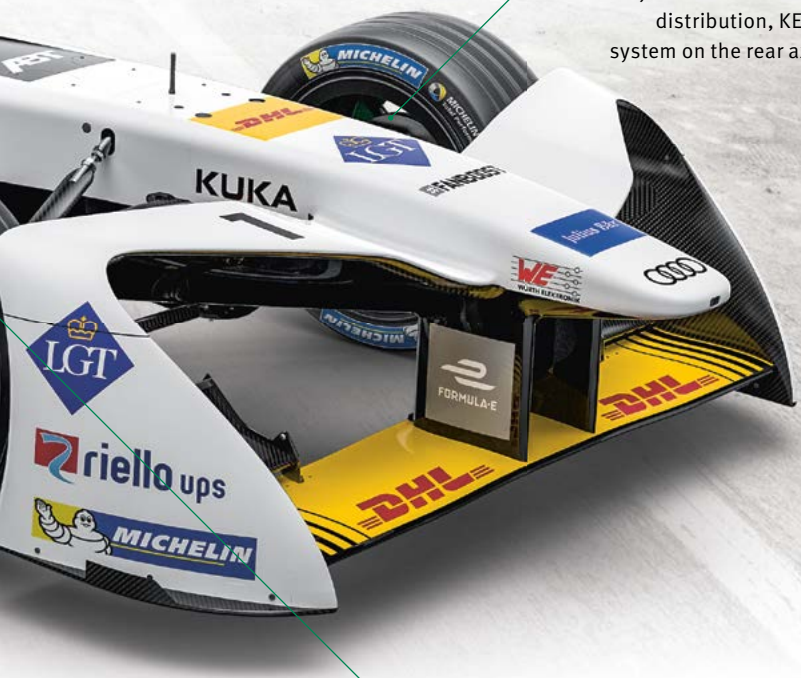
Tires
18-inch wheels with Michelin all-weather specification tires (with profile as for production cars)

Dimensions
Length: 5,000 mm
Width: 1,790 mm
Height: 1,070 mm
Weight: 880 kg minimum including driver

Power output
Practice and qualifying: 200 kW (272 hp)
Race: 180 kW (245 hp) plus FanBoost NEW

Battery
Battery capacity 34 kWh, of which 28 kWh is usable. Charging time: approx. 45 minutes. Made by Williams Advanced Engineering

Brakes
Hydraulic dual-circuit braking system, adjustable brake force distribution, KERS system on the rear axle



Chassis
Spark specification chassis featuring a carbon fiber construction with aluminum honeycomb, manufactured by Dallara

"NO TIME LOSS DUE TO SHIFTING EVENTS"

Dr. Simon Opel,
Director Special Projects Motorsports at Schaeffler

The Formula E car has received an all-new powertrain. What are the reasons?
We managed to develop an electric motor which, on the one hand, achieves high torque in a wide speed range and, on the other, is very efficient, in other words its efficiency is above 95 percent. This makes it possible for us to use a single-speed transmission so that we're no longer losing any time due to shifting events.

What are the secrets of the new transmission?
We've increased the efficiency of this unit as well. By using a unit with only one speed, we were able to reduce inertia of the rotating components. In addition, the transmission now has a carbon housing that also serves as a structural element.

In the races, the drivers can now use more power output. What effects does this have?
Essentially, none for the motor because the motors could deliver even higher output. However, the battery becomes warmer when you draw more power from it. After a certain temperature has been reached, there's a risk of power loss. This has to be taken into account.

AROUND **THE GLOBE**

Africa, North and South America, Asia, Europe – Formula E stops on five continents on its world tour. With 14 races at eleven events the program is as extensive as never before.

1/2 HONG KONG
CHINA
December 2/3, 2017

Start with double-header. The 1.86-kilometer (1.15-mile) long and technically challenging circuit is located at famous Victoria Harbour.

3 MARRAKESH
MOROCCO
January 13, 2018

The Marrakesh E-Prix was launched in 2017 as an official partner event of the COP22 UN climate conference.

4 SANTIAGO
CHILE
February 3, 2018

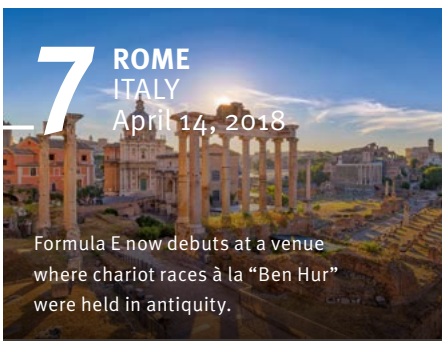
Spectacular: the race track in Chile's capital city crosses a river at its inaugural event.

5 MEXICO CITY
MEXICO
March 3, 2018

The fans are going to experience a unique stadium atmosphere at the only permanent circuit on the calendar.

6 PUNTA DEL ESTE
URUGUAY
March 17, 2018

The small town is one of Uruguay's most popular tourist destinations. The circuit is in a picturesque setting directly at the beach.



7 ROME
ITALY
April 14, 2018

Formula E now debuts at a venue where chariot races à la "Ben Hur" were held in antiquity.

8 PARIS
FRANCE
April 28, 2018

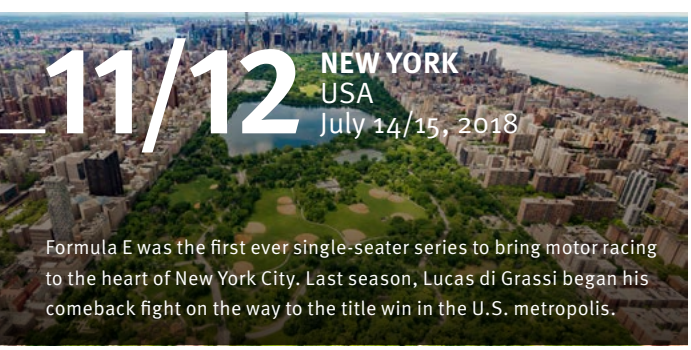
In 2015, the UN countries agreed on better environmental protection here. With plenty of ideas, Paris is trying to counter total gridlock.

9 BERLIN
GERMANY
May 19, 2018

The race track on the former Tempelhof airport is located only about ten kilometers away from the Berlin government district.

10 ZURICH
SWITZERLAND
June 10, 2018

Circuit racing has been prohibited here since 1955. Formula E is the first series to receive a permit for racing.



11/12 NEW YORK
USA
July 14/15, 2018

Formula E was the first ever single-seater series to bring motor racing to the heart of New York City. Last season, Lucas di Grassi began his comeback fight on the way to the title win in the U.S. metropolis.

13/14 TBA

SUCCESSFUL DUO

Never change a winning team. With one championship title, six victories, 24 podium places and four pole positions to their credit, Lucas di Grassi and Daniel Abt are one of the most successful driver pairings in Formula E. 2017/18 will be their fourth year of contesting the series as teammates.

Lucas di Grassi

lucasdigrassi.com.br lucasdigrassiofficial @LucasdiGrassi
lucasdigrassi LucasDiGrassi

"By entering Formula E four years ago, Schaeffler demonstrated great foresight"

#1

Date of birth August 11, 1984
Place of birth São Paulo (BR)
Residence Monaco (MC)
Height 1.80 m
Weight 75 kg

Highlights

2007 2nd GP2 Series, Formula 1 test driver
2014 2nd 24 Hours of Le Mans, 4th WEC
2015 3rd Formula E
2016 2nd Formula E
2017 1st Formula E

Daniel Abt

danielabt.de abtdaniel @Daniel_Abt
daniel_abt AbtDaniel

"We wouldn't be standing here today if Schaeffler hadn't believed in this project"

#66

Date of birth Dezember 3, 1992
Place of birth Kempten (D)
Residence Kempten (D)
Height 1,79 m
Weight 72 kg

Highlights

2009 1st ADAC Formel Masters
2012 2nd GP3 Series
2015 1st 24 Hours of Le Mans (class)
2016 7th Formula E
2017 8th Formula E

MACHINE FANTASIES

Flying cars, time reversal, invisibility cloaks, hoverboards and humanoid robots … our imagination is full of machines that don't exist. But wait a minute: a closer look reveals that a lot of these things are already in the making – at least in the laboratories of scientists.

by Ulrich Eberl

In books and movies, it all seems so simple: Harry Potter dons his magical cloak and becomes invisible. Luke Skywalker in the battle against Darth Vader loses a hand and replaces it with a prosthetic one that has artificial skin and allows him to grip and feel just like it were his own. Captain Kirk zips through space with warp drive and has his crew beam him onto far-away planets. Marty McFly rides a hoverboard across a pond and uses a time machine to travel "back to the future." And the Blade Runner in a flying taxi chases replicants that are machines that look like humans through the street canyons of Los Angeles.

Unresolvable contradictions

Are all these just visions of science fiction writers gifted with imagination galore? Or will we have a chance after all to actually experience such machines of the future some day – and if so, when? Some of them can no doubt be regarded as being at home in the realm of fairy tales: those that are technically unfeasible or physically impossible, like the perpetual motion machine, that fabulous device which is supposed to move and simultaneously perform work indefinitely without an external energy source (see also "tomorrow", 01/2017). For centuries, ingenious inventors would come up with such machines time and again until several scientists in the 19th century demonstrated that a perpetual motion machine would violate the law of conservation of energy – one of the most cast-iron laws of physics. The situation with time travel is similar. According to Einstein's theory of relativity, it would be possible to travel into the future if rockets were successfully built that could come close to the speed of light. However, a journey into the past would immediately result in unresolvable contradictions, as McFly had to learn as well: a person preventing their own conception would never be born and, consequently, could not travel into the past in order to… A vicious circle that cannot be resolved in our universe!

Warp drives and beaming belong in this category as well. Although they don't contradict the laws of nature the resources that would have to be invested in them practically render them impossible. A warp drive would have to curve space in the universe so heavily that the distance between the departure point and destination would shrink to that of a stone's throw. Physicists have calculated that this would require energy densities of the kind that existed shortly after the Big Bang and generate deadly radiation. In the case of "classic beaming," the energy and location data of every single atom in the body would have to be known and reconstructed – the information volume required for just this purpose is a million times that of all data currently stored on Earth.

Now in view of overpopulation and resource scarcity, the ability to simply shrink people would be really practical, wouldn't it? A single cob of corn, a single chicken could feed entire villages and an area of a square meter or 10 square feet could easily accommodate a whole neighborhood of townhouses: an intriguing scenario, cinematized dozens of times. Unfortunately, this is another example of an idea that is prevented from becoming reality by several laws of nature. For instance, there's no machine which – as would be necessary for downsizing living creatures – could cause atoms to shrink and thus override the Pauli Exclusion Principle, which not only manifests the composition of the atom but also the resistance which condensed matter puts up against further compression. The alternative of reducing the number of atoms would cause the complex structures of the human body system to collapse. Homo sapiens, after all, is not a monad.

True miracles of science

Not science fiction but real science is behind the "philosopher's stone," an idea of turning base metals such as mercury into precious gold pursued by alchemists once upon a time. Countless swindlers tried their luck with it and quite often ended up being sent to prison or to the block. Johann Friedrich Böttger in his quest for the philosopher's stone in 1707 at least managed to produce porcelain, but gold was never made – which is not surprising because the transformation of one chemical element into another one is not possible by means of chemical methods but only by attacking the nuclei of atoms themselves. And this either requires nuclear reactors or particle accelerators. In the 1950s, tiny quantities of gold were produced this way in a reactor in the United States and in 1980 physicists shot atomic nuclei against bismuth that subsequently transformed into gold as well – albeit at the price of some 30 million dollars per millionth gram of gold.

Beaming necessitates the reconstruction of the data of every atom in the body – an inconceivable proposition if for no other reason than the required memory volume

» Any sufficiently advanced technology is indistinguishable from magic

Science fiction author Arthur C. Clarke

Caps of invisibility might become less costly. Known for a number of years have been so-called metamaterials that are able to conduct electromagnetic waves around an object. Scientists have already achieved this with microwaves but for light tailored metamaterials would have to be downsized to thousandths of a hair's diameter – difficult but doable. However, there's an easier way to become invisible as shown by a look at nature. Octopuses are able to perfectly adapt their appearance to their surroundings so that they'll look like a plant or the rock behind them. Something like this could be emulated with sensors, artificial skin and muscles of a kind that would make the pigments appear and disappear again. The necessary 3D printers are now available for all sorts of materials: for plastics, metals and even for human skin. Many sectors, from medical to military technology through to the automotive industry, are working on projection technologies to achieve invisibility as well. They allow the image of the respective background to be projected onto an object so that it will appear to be transparent. Initial successes on internet platforms like YouTube can already be marveled at. Just gimmicks? Not at all. Invisible automotive body parts for instance would massively enhance circumferential visibility in vehicles and thus safety. Blind spots would be a thing of the past.

Robots – your friends and willing hands

By contrast, Luke Skywalker's prosthetic hand has already become reality. In 2015, scientists in the United States connected a robotic hand directly with a microchip implanted in the brain of a paraplegic patient. Just by using the power of his thoughts, the patient could move the hand. In addition, the hand's pressure sensors fed back its signals to the part of his brain where tactile impressions are normally perceived. The resulting feeling, said the 28-year-old patient, was the same as the one before his accident when he was still able to grip objects with his own hand.

Robots and smart machines using artificial intelligence have seen greater advances in the past five years than in all the preceding decades. Machines beat

Amazingly human: robot lady Sophia at a panel discussion with her humanoid colleague Han

humans in the Go board game as well as in a game of poker and they read emotions such as anger, joy or surprise from human faces. Even the babel fish from "The Hitchhiker's Guide to the Galaxy" that you can plug into your ear and that translates all languages is no longer a distant dream. The speech recognition software keeps learning with every spoken computer input and translation programs such as DeepL are rapidly approaching suitability for everyday uses.

In October 2017, Sophia, a robotic lady, debuted before the United Nations, and in Osaka, Japan, androids exist that can hardly be distinguished from humans – with eyes, gestures and facial expressions that provide the impression of being truly alive and skin that feels warm and soft. In the future, such humanoid machines as congenial, willing hands might be able to carry out all kinds of services to assist us in our personal and professional lives. But it will no doubt be a while before that happens as every home and every service is different and a "RoboNet" from which the machines could autonomously download knowledge and new skills is not online yet. That said, who would have thought 15 years ago that today – albeit still in a testing stage – autonomous vehicles would already be traveling on public roads? In the air, the first autonomous flying taxis already exist as well. In late September 2017, for instance, a large drone with 18 rotors was autonomously flying through Dubai. Still without passengers on board for the test flight but the Arab emirate is planning to shift one fourth of its transportation volume to autonomous vehicles by 2030: on the roads as well as in the air. And above the Dubai bay, a fire fighter recently floated toward a bridge to extinguish a blaze there, borne by two strong jets of water on a hoverboard! The event, no doubt, must have reminded a number of spectators of "Back to the Future."

If, at the end of the day, you ask yourself why some of the fantastic machines thought up by humans are not (yet) on sale, one of the following three answers typically applies:

— The machine goes against fundamental laws of nature or is technically unfeasible, like the perpetual motion machine, the time machine, the warp drive or beaming.

— The machine may be feasible but is simply too costly for practical use, such as the transformation of base metals into gold.

— Or scientists are working on such a machine and initial prototypes already exist but they're still a long way away from becoming mass market products – such as the hoverboard, the flying cars, the caps of invisibility and the exoskeletons. —

DO IT YOURSELF

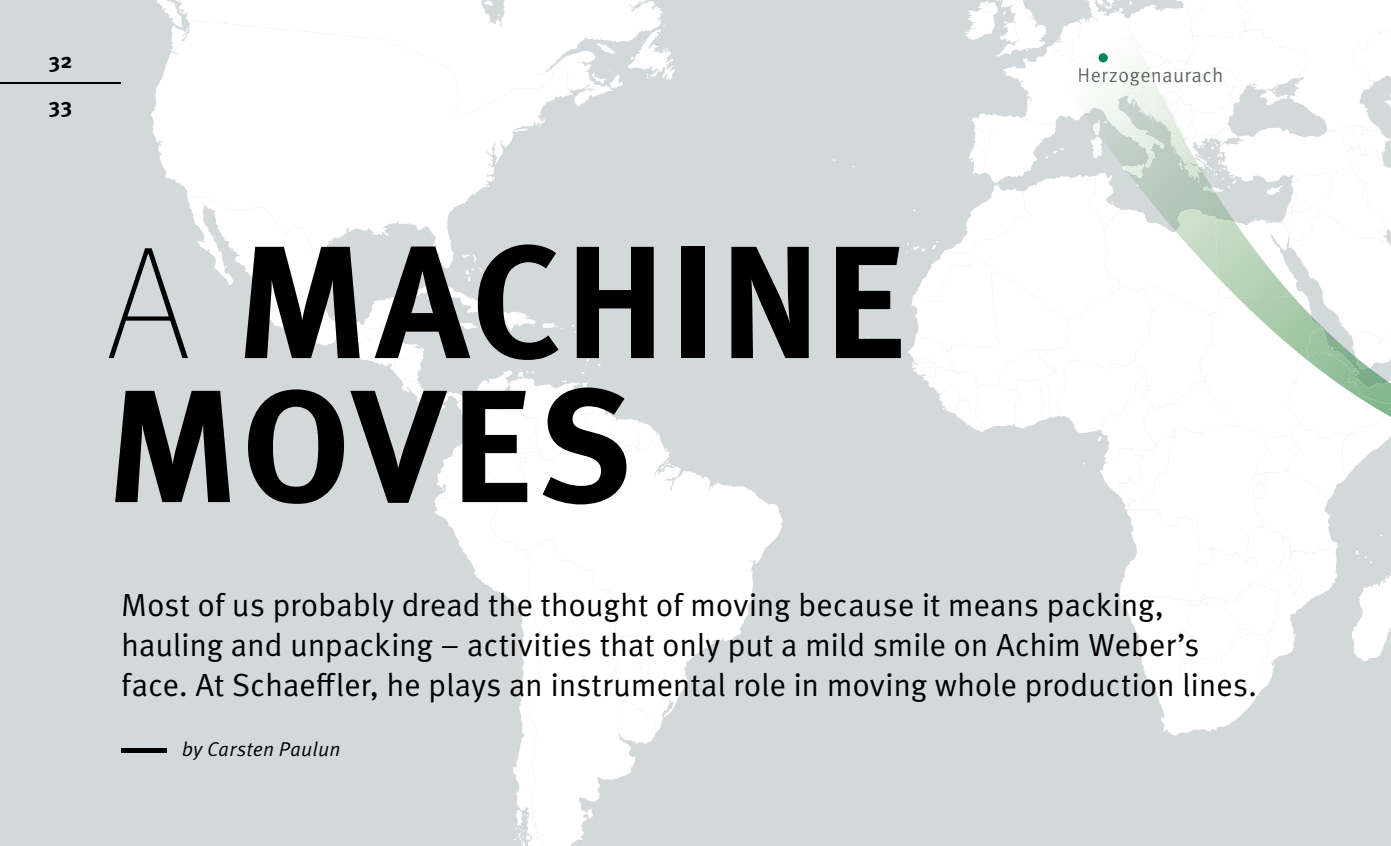
If Schaeffler is unable to find suitable equipment for its manufacturing requirements, its special engineering department comes into play.

About 1,700 specialists at 16 locations are dedicated to engineering special-purpose machines. Schaeffler typically uses its own resources whenever higher quality, efficiency and flexibility are required or a machine developed in-house can be more effectively integrated into processes and workflow. This way Schaeffler not only secures important know-how but is also able to shorten time to market for complex products such as the electric axle.

Nearly one in two production machines used at Schaeffler comes from the company's in-house special engineering department which, as a result, ranks among the world's major mechanical engineering companies.

THE AUTHOR

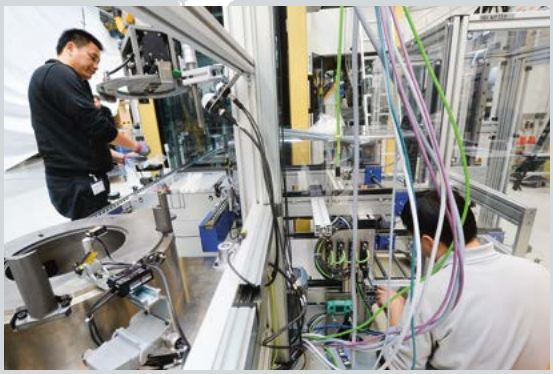
*Machines of all kinds fascinate author **Ulrich Eberl** who in the 90s was responsible for communication of future trends at Daimler and until 2015 at Siemens. In 2016, he published "Smarte Maschinen" ("Smart Machines"), a book for which he did extensive research into the future of artificial intelligence in Japan, the United States and Europe. For his personal purposes, he has a favorite machine as well: his domestic robot Nao Bluestar.*



A MACHINE MOVES

Most of us probably dread the thought of moving because it means packing, hauling and unpacking – activities that only put a mild smile on Achim Weber's face. At Schaeffler, he plays an instrumental role in moving whole production lines.

by Carsten Paulun



The production line is divided into individual segments (above left). Dismantling the line requires great care, be it protective elements or cable harnesses (above right). Teamwork (center left) makes the job and handling of the sensitive components easier. Larger elements are lifted directly onto the loading platform by a forklift truck

Achim Weber is a calm, cool and collected man. For 20 years, he's been working for automotive and industrial supplier Schaeffler. Weber is responsible for the development of manufacturing equipment in the eMobility business unit and, since recently, a specialist for moves as well. Not just because he's managed a number of personal ones before but because Schaeffler, due to the high demand in China, is now manufacturing e-axles and hybrid modules there as well – using equipment that Achim Weber and his team develop, set up and test in Herzogenaurach and subsequently dismantle, pack and ship to Asia. At Schaeffler in China, the production equipment is reassembled and put into operation. About twice a year, a production line moves this way, from one continent to another.

A major logistics feat

Moving an entire factory is a major logistics feat that requires complex planning, as illustrated by the move of the "P2 hybrid module" product line that Weber and his team are carrying out now around the turn of the year. A smooth move is indispensable to ensuring that the line in Taicang near Shanghai, about 9,000 kilometers (5592.34 miles) away from Germany, can start operating as soon as possible. Twelve employees will be producing up to 500 P2 hybrid modules per day for Chinese automobile manufacturers in the new factory. China has long discovered the emission benefits of electric mobility, so there's hardly a manufacturer that doesn't offer any vehicles in this segment. Thanks to the new production line with a length of 80 meters (262.47 feet), Schaeffler will be delivering 60,000 P2 hybrid modules to these customers per year. The major advantage of the innovative Schaeffler module: It can be integrated into both existing and newly developed powertrains (see infographic pictured right).

40,000 single parts, 17 people, 15 containers, 6 weeks in transit

However, before production can be launched, the highly complex manufacturing line has to be dismantled and carefully packed. To keep from having to individually label and pack every single bolt, every actuator and every sensor, the line is divided into the largest possible segments. Otherwise 40,000 single parts that make up the line would have to be dealt with. But even for the individual segments more than 40 shipping crates are needed. Many of them are up to six meters (19.68 feet) long, three meters (9.84 feet) wide and equally high. The individual crates are moved out of the hall on 16-ton forklifts and loaded onto the trucks waiting outside. 14 semitrailers in total haul the dismantled production line weighing 80 metric tons (88.18 short tons) to Bremerhaven. There the crates are loaded onto ships for their six-week journey.

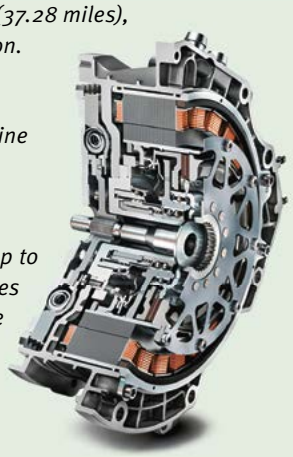
Schaeffler's know-how in worldwide demand

Considering this effort, wouldn't it be easier to just develop and build such a production line locally? Achim Weber: "The exacting quality and high safety and ergonomic standards require enormous experience." So "made in Germany" does matter, not only in China but around the globe. The same is true for training the future production workers. All of them are trained in Bühl, Germany, on the same line, by the way, that they'll be working on every day in the future.

Once the line in Taicang is up and running, Weber and his team will have finished their job – and, ultimately, saved the emissions from many miles of shipping for the benefit of the environment as in the future the P2 hybrid modules for the Chinese market will be produced close to customer sites and 90 percent of the materials used will be from the region around Taicang.

SCHAEFFLER P2 HYBRID MODULE

- *Adapts to the automobile manufacturer's requirements due to its modular design.*
- *Simple method for electrifying existing powertrains.*
- *Consumption 1.6 l/100 km (NEDC), all-electric range up to 60 km (37.28 miles), significant CO_2 reduction.*
- *Very convenient activation of the IC engine in less than 400 milliseconds.*
- *Electric motors up to 85 kW/115 hp, IC engines up to 82 kW/110 hp are possible.*



» Where necessity urges, boldness becomes prudence

Niccolò Machiavelli (1469–1527),
Italian poet, politician, philosopher

in motion

Innovations in the course of time

A LUXURY CAR **TURNED INTO A TOOL**

Necessity is the mother of invention and in the post-war years people in many places were in need of virtually everything – not only was food in scarce supply, but so were construction materials and tools. Anything people could get their hands on was put to good use. Machines were typically replaced by tedious manual work or used for purposes other than those they were originally intended for. Like this Maybach DSH ("double-six half") of which only 50 vehicles were produced in total. Built in 1935, powered by a 130-hp six-cylinder engine and selling for 25,000 Reichsmark (for comparison: the VW Beetle was to sell for 990 Reichsmark in 1938), it was one of the best and finest luxury cars in its day. It survived the war unscathed but in 1945 its owner converted it out of necessity. He replaced the rear section of the body by a saw, subsequently traveled across the country and was able to secure his and his family's livelihood with his mobile saw.

RIDING PLEA

SURE AT 50 KM/H

In the days of our great-grandfathers, 50 km/h (31 mph) on two wheels was a really wild ride. Today, we're achieving this speed even on bicycles thanks to electric assistance. Here's a comparison of three eras of an easy rider's feeling.

by Ralf Bielefeldt

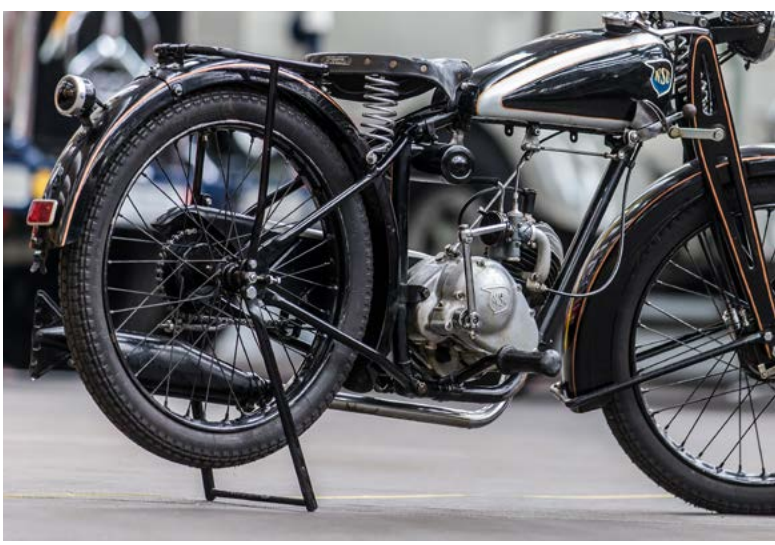
THE MOTORBIKE 1938

In the nineteen-thirties, the NSU brand enjoyed high prestige among German motorcycle riders. Models for road racing like the 501 SS clinched victories by the dozen while the 351 OT and 251 OSL won acclaim for miraculous reliability. The smallest model was the Pony 100. With its sporty gate-type tank shift, three-speed transmission and 19-inch wheels it evolved into a true "motorcycle for everyone" and caused the marque to record impressive sales figures. In 1938, NSU reported 62,619 bikes sold. The extremely lightweight two-stroke model reaches more than 70 km/h (43.5 miles) downhill with tailwind. However, the time it takes for the needle of the VDO speedometer to dance above the 50-km/h mark, seems like an eternity. Stopping, from today's perspective, is strictly a matter of courage: the foot-brake's on the left, the front-wheel brake, as usual, on the right-hand handlebar. With a strong grip you have a fair chance that the small drums will cause the wheels to stop. Simply impressive is the ease with which the cute black pony trots around corners – riding pleasure guaranteed!

NSU PONY 100

- *1-cylinder two-stroke engine*
- *97 cc*
- *2.2 kW*
- *55 km/h (34.17 mph)*
- *3 gears*
- *Drum brakes*
- *65 kg (143.3 lbs)*

The 97-cc one-cylinder leaves plenty of room below the tank. The kick-starter sits on the right, the chain runs on the left



THE MOPED 1978

While the sticker on the tank is pretty faded, this dilutes the message in no way: "International Six Days 1975–1976, Trophy World Champion Zündapp," it says inside the laurel wreath. Oh yes, in the mid-seventies, Zündapp was a proverbial big wheel. If you showed up on a C 50 Sport in front of an ice cream parlor you were king of the road (and sure not to be riding home alone). A gentle step on the nearly compression-free kick-starter on the left, and the Zündapp instantly starts. The sound is throaty and, compared with the 40 year older NSU, acceleration and dynamics mark breakthroughs in terms of performance. With respect to technology and looks, the small moped is still a smash today. The tank with chrome plating on the side continues to enjoy a similar status as a cult object as the small Coca-Cola glass bottle. The ignition pin as thin as a ballpoint pen for the plastic cockpit was the key to adolescent fame and rebelliousness back then while, today, it almost seems like a joke with its simplicity. The speedometer goes up to 80 km/h (49.7 mph), which is a bold promise – the Zündapp C 50 Sport actually achieving a little more than half of that, albeit with great aplomb.

ZÜNDAPP C 50 SPORT

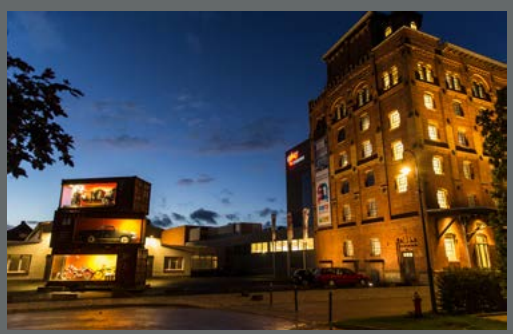
- *1-cylinder two-stroke engine*
- *49 cc*
- *2.1 kW/4.3 Nm*
- *40 km/h (24.85 mph) (legally limited)*
- *3 gears*
- *Drum brakes*
- *84 kg (185.18 lbs)*

Put on your helmet and go: Since 1976, wearing of helmets on motorized bikes has been mandatory in Germany. Due to its simplistic styling and chrome-plated tank, the slim C 50 Sport acquired cult status

GIANT QUICK-E+ 45

- *E-motor*
- *0.5 kW + pedal force / 80 Nm*
- *45 km/h (27.96 mph) (legally limited)*
- *20 gears*
- *Disc brakes*
- *23,4 kg (51.58 lbs)*

THE ELECTRIC BYCICLE 2017

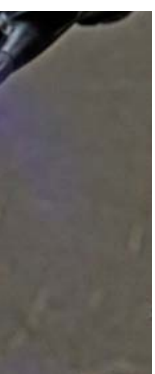


PS.SPEICHER EINBECK

PS.SPEICHER, a former granary in Einbeck, Germany, has been ranking among Europe's most fascinating automotive theme parks since 2014. *Exhibited in the Granary Cultural Heritage Foundation building in the beer-brewing city is the world's largest collection of German production motorcycles (some 1,400) as well as small and mini cars, etc. The photo production for "tomorrow" – a premiere! – took place amidst historic commercial vehicles at the PS.Depot Truck + Bus*

ps-speicher.de

Today, e-bikes and pedelecs have largely outstripped mopeds. With low noise and zero (local) exhaust emissions, electric bicycles make for sustainable tailwind. So-called S-Pedelecs such as the Giant Quick-E+ 45 provoke such a powerful storm that they actually don't belong on bicycle paths. In some countries – like Germany – legislators even insist on license plates and mandatory wearing of motorcycle helmets. Like for small motorbikes, top speed of 45 km/h is the official limit. Achieving (or even topping) it requires toiling away on the pedals in spite of the 500-watt assistance. In contrast to riding the Zündapp, you have to earn your tailwind here, but in return the Giant will reward you with the most powerful torque in the comparison of the generations. A loud horn is provided for averting dangers, while the 40-year older Zündapp still had to make do with a bicycle bell.



A digital instrument cluster, a perforated disc brake at the front, LED light and three riding modes: in terms of technology, the Giant S-Pedelec clearly sets the pace in this 50 km/h comparison

A WEALTH OF IDEAS **FOR BIKES**

Be it for motorcycles, pedelecs or bicycles – *Schaeffler offers a wide variety of products for diverse bikes and is locally present in many key bike markets around the globe with production and development sites.*

As in other markets, customer-specific innovations using state-of-the-art engineering design, calculation, testing and manufacturing technologies are one of Schaeffler's fortes in the bike sector as well.

Developments in the bike segment are focused on low-friction, compact and lightweight applications in the fields of motor/drive, transmission/gearshift and suspension which optimally convert the input energy into propulsion. High quality standards and technology know-how ensure long life and ease of maintenance of the components and assemblies.

THE AUTHOR

Ralf Bielefeldt *(model year 1966) used to speed down the roads of Hamburg's surroundings on his souped-up Peugeot TSA in the early 1980s. That sparked his unbroken fascination with bikes. Today, the father of three is a freelance writer for special-interest magazines and online portals covering anything that tacks the cheeks to the ears – on two, three or four wheels.*

LOCOMOTION **MACHINES**

In the past more than thirteen decades, the automobile – linguistically meaning “a thing moved of itself” – has undergone many development steps. It has evolved from a motion machine into a high-tech means of transportation. It has been reinvented over and over and continues having to reinvent itself. The evolution of this form of personal mobility that is spread around the world 1.3 billion times is far from having reached the end of its road. Yet the modern age has been nibbling away at the decades-long magic of the machine that has been the central element of our fascination with the automobile …

by Jörg Walz

THE FIRST OF ITS KIND

The clattering internal combustion engine is the centerpiece of the first ICE-powered automobile for which a patent is filed in 1886. Even though Bertha Benz still has to go to great lengths to buy the fuel for the vehicle from various apothecaries, Carl Benz's invention sparks a horseless form of personal mobility. But the automobile is still a carriage on the frame of which the engine is mounted. A leather belt is used to transfer the rotational energy of the one-cylinder four-stroke power-plant to the rear axle.

A1 BENZ PATENT-MOTORWAGEN

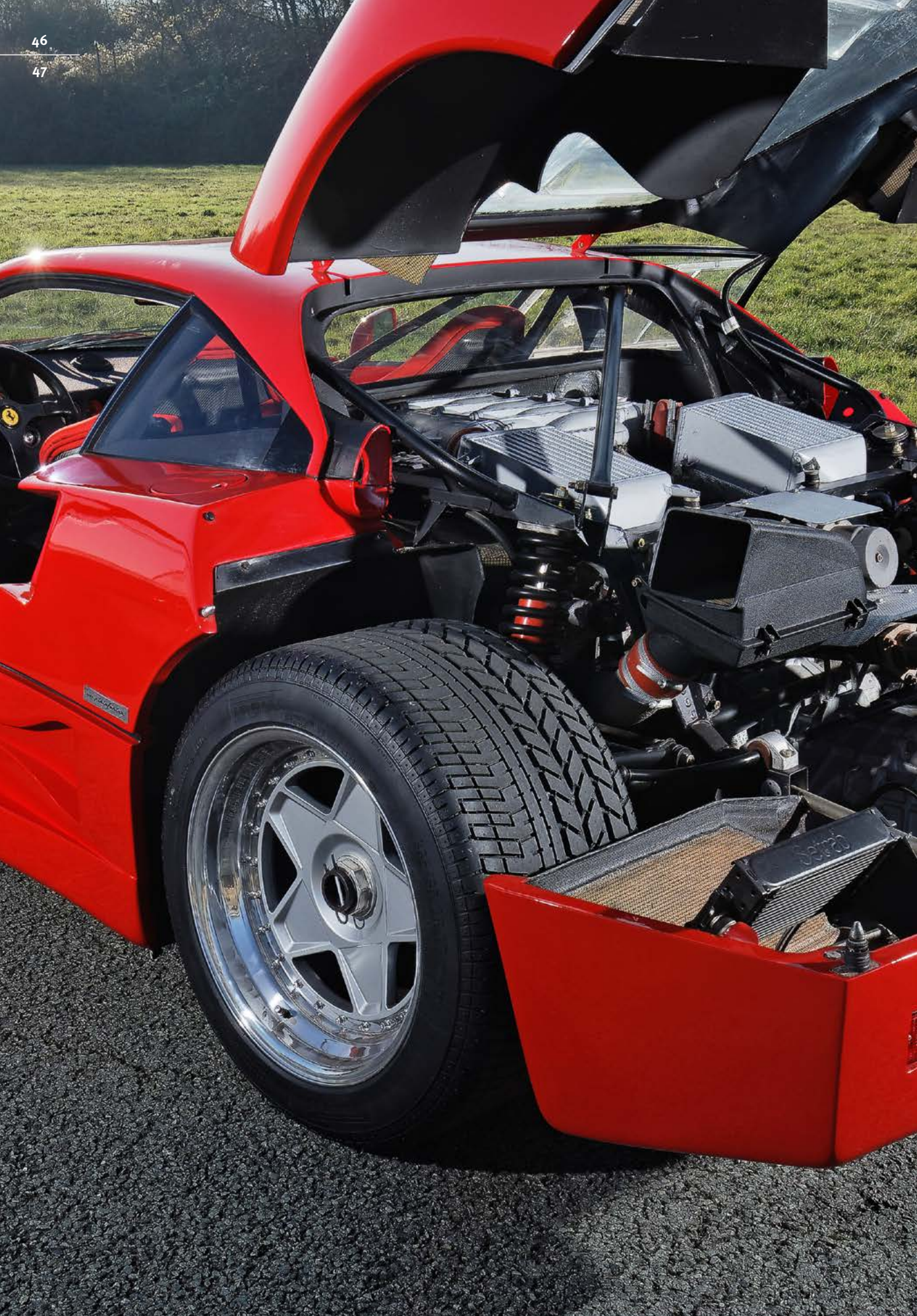
Model year	1886
Capacity	954 ccm
Cylinders	1
Bore x stroke	90 x 150 mm
HP (kW) at rpm	0.75 (0.55)/400
Torque	n. a.
Output per liter	0.79 HP/l
Installation	rear
Vmax	16 km/h
Consumption	approx. 10 l/100 km

C3 **BUGATTI ROYALE**

Model year	1931
Capacity	12,760 ccm
Cylinders	8
Bore x stroke	125 x 130 mm
HP (kW) at rpm	275 (202)/2,000
Torque	785
Output per liter	21.55 HP/l
Installation	front, longitudinally
Vmax	approx. 200 km/h
Consumption	approx. 40 l/100 km

THE PINNACLE OF ENGINEERING IN ITS DAY

The owners of the equally luxurious and sporty Bugatti proudly point out the magnificent engine sitting underneath the wing-shaped hoods, behind the characteristic radiator sporting the shape of a horseshoe. Eight cylinders with awesome displacement of 12.7 liters, arranged in line in a block and head, designed like a work of art. Straightforward work of the kind an architect could not have achieved with greater beauty and boasting precise “bird’s eye polish” that would pose a challenge to any jeweler. Bugatti’s founder, proprietor and constructor Ettore Bugatti is clearly proud of the creation – the pinnacle of engineering in its day. And proudly the engine compartment takes up two fifths of the space which the entire magnificently luxurious automobile lays claim to.



GOLDEN MEAN

"I don't sell automobiles, I sell engines." This is how Enzo Ferrari defines his purpose and, accordingly, the F40, the final automotive legacy of the "commendatore" from Maranello. Essentially, the propulsion unit has become an integral component of the automobile during the course of the decades. Unibody cars with engine compartments designed right into them replace the former bodies-on-frame. The engines and transmissions of race cars are sometimes even designed as stressed components to make the vehicles lighter and more compact. Race and performance cars are designed as mid-engine vehicles. This benefits the distribution of weight and thus driving dynamics. The F40 is a perfect example of this as well. Ferrari's showpiece from the eighties self-confidently displays its twin-turbo V8 power-plant including its transversally mounted six-speed transmission underneath a large plexiglass cover.

B4 **FERRARI F40**

Model year	1987
Capacity	2,936 ccm
Cylinders	8
Bore x stroke	82 x 69.5 mm
HP (kW) at rpm	478 (352)/7,000
Torque	575 Nm
Output per liter	164.82 HP/l
Installation	rear, longitudinally
Vmax	324 km/h
Consumption	20 l/100 km

D4 **BENTLEY CONTINENTAL GT W12**

Model year	2003
Capacity	5,998 ccm
Cylinders	12
Bore x stroke	84 x 90.2 mm
HP (kW) at rpm	575 (422)/6,000
Torque	700 Nm
Output per liter	95.83 HP/l
Installation	front, longitudinally
Vmax	318 km/h
Consumption	17.1 l/100 km

HIDDEN TECHNOLOGY

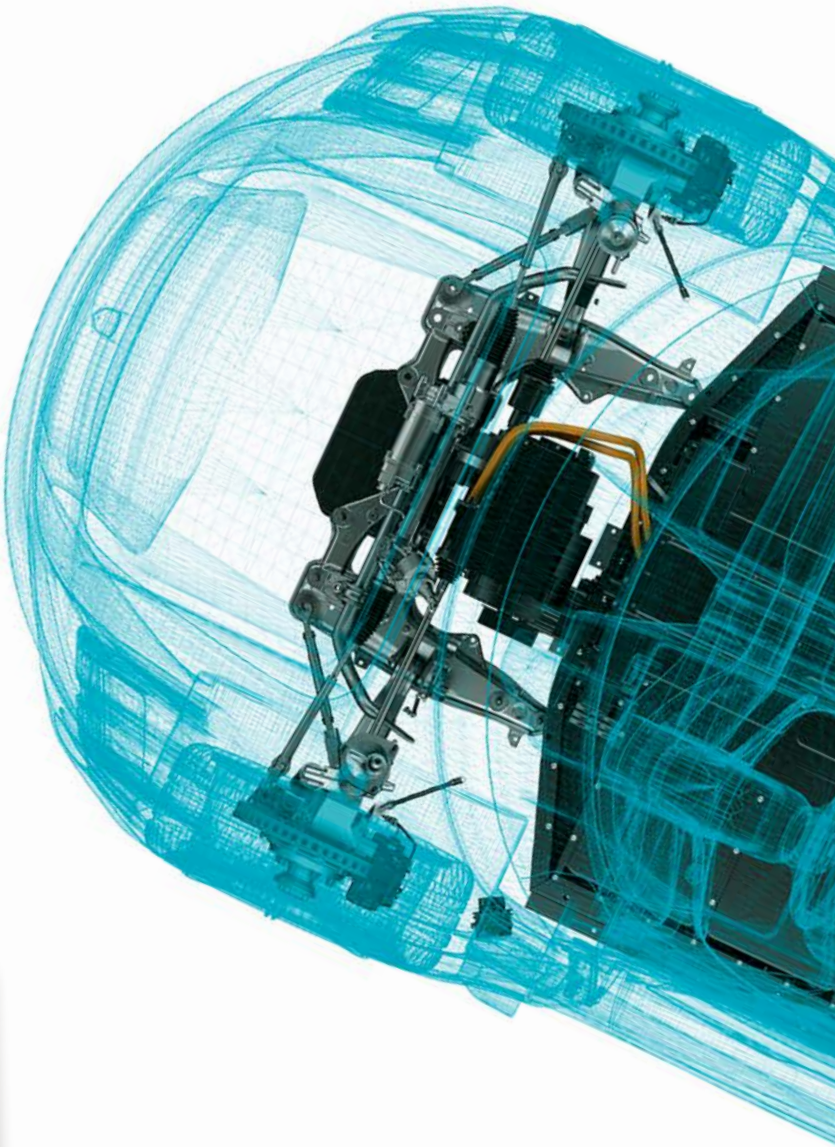
Naturally, an impressive look calls for a stretched hood. This is a design language lesson that has been learned for decades. And the 12 cylinders are another first-class prestige-relevant statement. But modern control electronics, emission control technology and the numerous lines for air conditioning and servo hydraulics make it difficult if not impossible for the engineers to provide the power-plant with the grand architectural appearance of earlier days. As a result, packaging designers come into play. Their job is to hide the engine underneath (more or less skillfully crafted) covers which in turn are intended to create an impressive look. This is no mean feat ...

BYE BYE “ENGINE BAY”

For decades, motorists were intimately familiar with the expression engine bay or engine compartment – *after all, minor underhood maintenance jobs used to be part and parcel of driving an automobile. Today’s cars, though, have become a lot more reliable, maintenance-friendly as well as being less odorous and quieter. Although drivers still occasionally open the hood to check the oil, and some may even do so out of technical interest, all they’ll see is a neatly packaged landscape of plastic covers. As a result, the “machine” that is the car’s heart increasingly vanishes from our perception and awareness and commonly used vocabulary.*

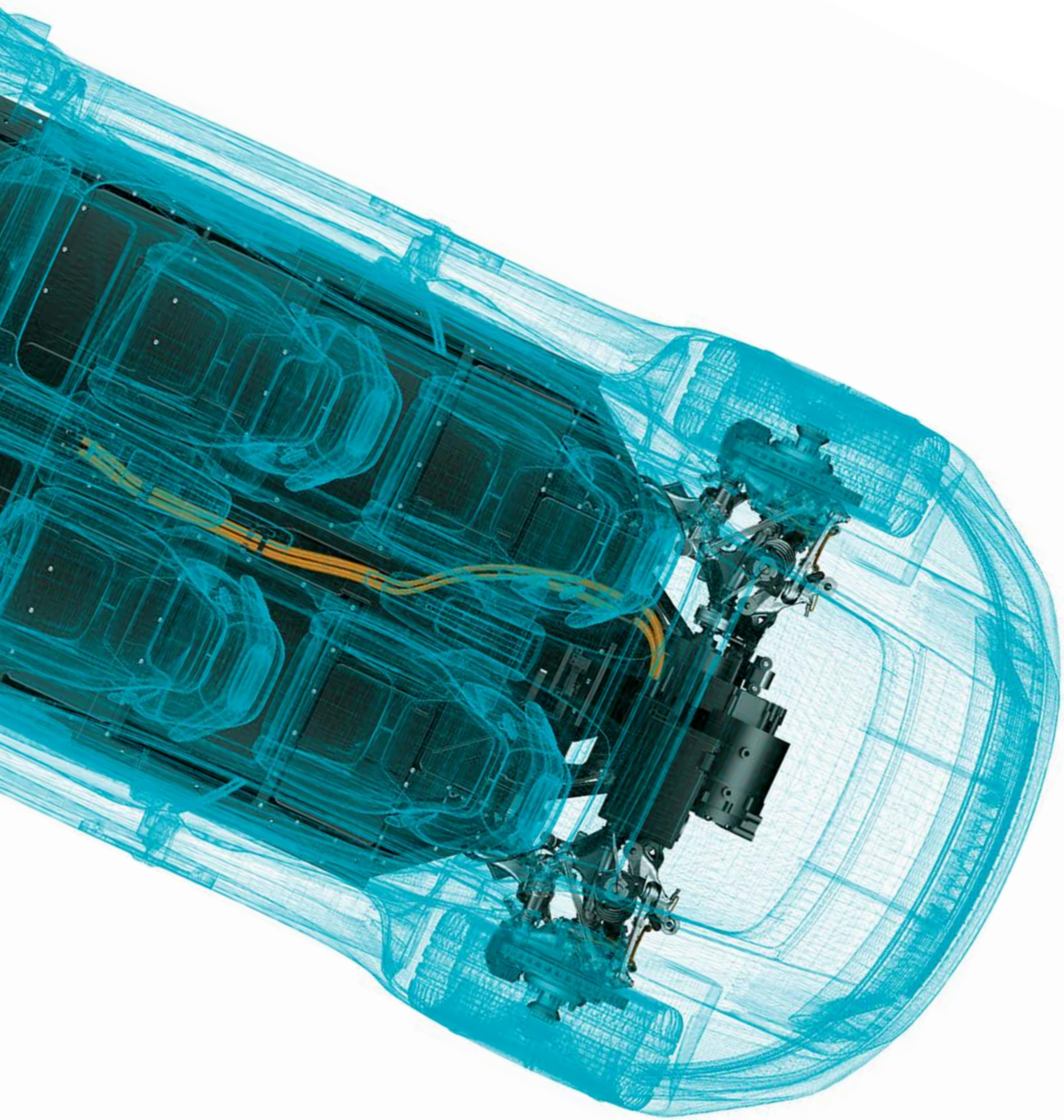
DIFFERENT PERSPECTIVES

Where's the motor? In electric vehicles whose propulsion systems formally are more reminiscent of a bucket of jam than of the familiar form of an IC powertrain – with an engine and transmission – it's difficult to create an attractive stage for the motor. The motor also requires less space, plus clearly less maintenance. That's why there are better uses for the space in the vehicle — such as room for the occupants. As a result, the motor drops out of sight and mind. Especially since the technological differences between internal and external rotors and permanently excited or asynchronous motors are a far cry from being exciting topics for conversation during happy hour or on campus like the number of overhead camshafts, cylinders, turbochargers or transmission speeds.



B3 **PORSCHE MISSION E**

Model year 2015
Motor ..... 2 x electric
System voltage ..... 800 volts
HP (kW) at rpm ..... 600 (441)/n. a.
Installation ..... front + rear
Range ..... approx. 500 km
Charging time ..... 15 minutes (80 %)
Vmax ..... ›250 km/h
Consumption ..... n. a.



THE AUTHOR

Jörg Walz *has been keeping track of the history of the automobile for decades through the eyes of a motor journalist and communicator. His own track record includes stints as a tester and writer for renowned automobile magazines, among other things. In addition, he is the author of several motor books.*

TAKING AN IDEA **TO SUCCESS**

Electricity, hydrogen, fossil or synthetic fuels? Or a mix of several energy sources? The question of what's going to power passenger cars and trucks in the future is one of the hot topics of our time. Engineers around the world are racking their brains in order to always be able to offer customers the best and most advanced technology. This report shows how complex and time-consuming such development work can be, illustrated by two pioneering examples from the Schaeffler world: the dry dual clutch and the fully variable UniAir valve control system.

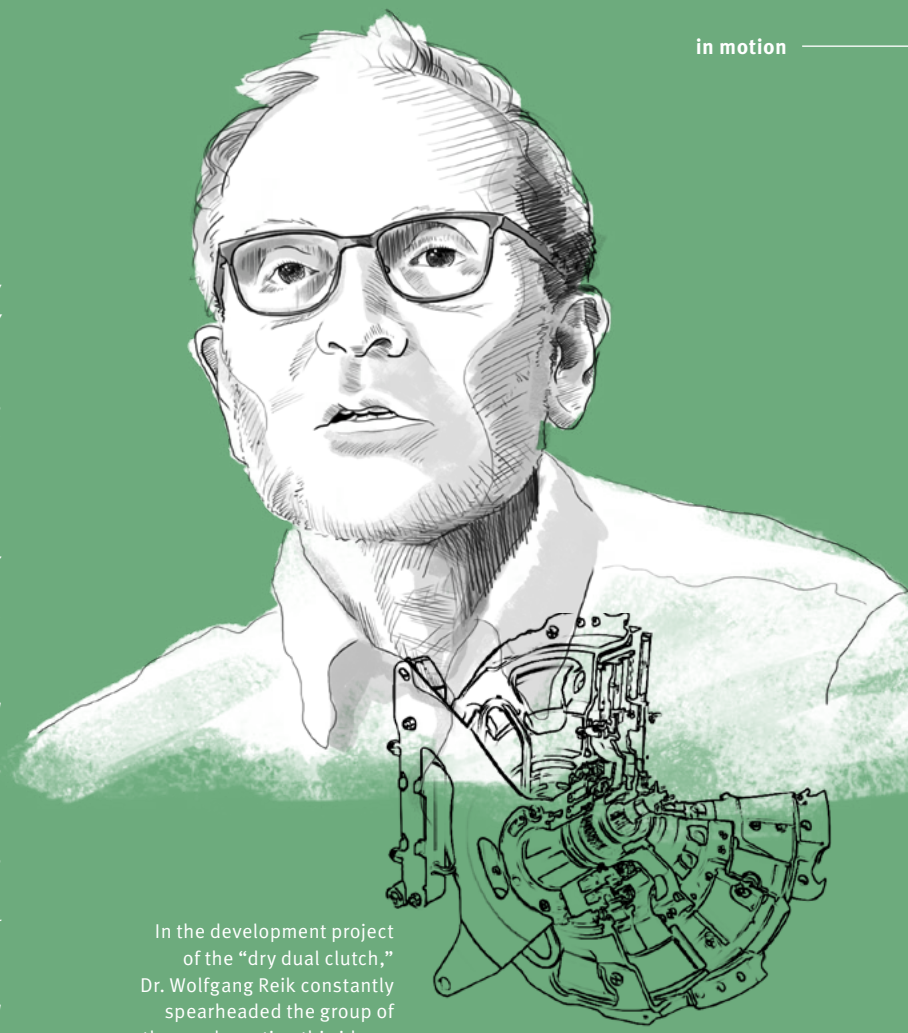
by Roland Löwisch

THE DRY DUAL CLUTCH

A technology that more than 15 million motorists are taking for granted today ultimately looks back on a ***near-100-year development history: the dual clutch transmission.*** *Up until 1931, Morgan has been installing an early version of the two-speed dual clutch transmission with two drive chains to the rear wheel into its three-wheelers. And the first patents hark back to the Frenchman Adolphe Kégresse in 1939. In the 80s, Porsche experiments with the first "wet" and pretty rough Porsche dual clutch transmissions (PDK) in racing. Audi adapts the Porsche system for use in rally racing, but deploys it only in two trial runs. At the end of 2002, VW installs the first wet dual clutch transmission (DSG) in the Golf R32. In 2008, the dry dual clutch begins to combine efficiency and comfort.*

The operating principle of the dual clutch sounds simple. *It consists of two partially automated manual transmissions which, combined, enable fully automated gear changes without interrupting traction. One of the transmissions is responsible for the even and the other one for the odd gears. In the best case, the dual clutch delivers optimized performance, fuel economy and a gain in comfort. Whereas in wet systems torque is transferred via plates running in oil, dry dual clutches deliver traction via the friction linings of the clutch plates.*

As an innovation driver, Schaeffler's LuK brand opts for the development of a dual clutch at the end of the 20th century as well. ***Dr. Wolfgang Reik (68), a physicist and former LuK chief developer, recalls the beginnings of the development project:*** *"The efficiency of the automatic torque converters was pretty poor back then. Especially in the part load range, their operation was less than perfect, so we wanted to combine the two worlds of automatic and manual transmissions – and so shifting com-*



In the development project of the "dry dual clutch," Dr. Wolfgang Reik constantly spearheaded the group of those advocating this idea – but it was a long road to travel before the goal was achieved

fort and efficiency." A roughly outlined objective had been set, but how exactly was it to be achieved? ***A tricky question which Reik and his colleagues extensively discussed too:*** *"Some of us wanted to embark on the dual clutch adventure while others tended to prefer a much simpler automated manual transmission. However, the interruption of traction with those transmissions is much harder to accept for more exclusive passenger cars." The discussion drags on for months on end – not surprisingly, considering that the decision will set an important direction and involves millions of deutschmarks in capital expenditures. Ultimately, the "or" turns into an "and" – with both systems continuing to be pursued. In 1997, marking the first step in the field of automated manual transmissions, the world's most compact automated clutch system goes into production in the Mercedes A-Class, followed three years later as a world first by the automated LuK manual easytronic transmission of the Opel Corsa.*

Meanwhile the dual clutch advocates continue to struggle with another fundamental decision: ***Should a wet or a dry version be developed?*** *Dr. Reik: "The 'dry' group used the argument of better efficiency as wet plates always involve minor drag torques. The proponents of the 'wet' solution believed that in the case of high engines torques dry dual clutches would not achieve the service life of the whole car. This was almost a religious war – after all, both sides used the right rationale to support their positions." Development partner VW finally opts for the dry version, not least because Schaeffler engineers predict up to ten percent better fuel economy compared with the wet DSG of the design back in those days and more than six percent compared with a manual transmission.*

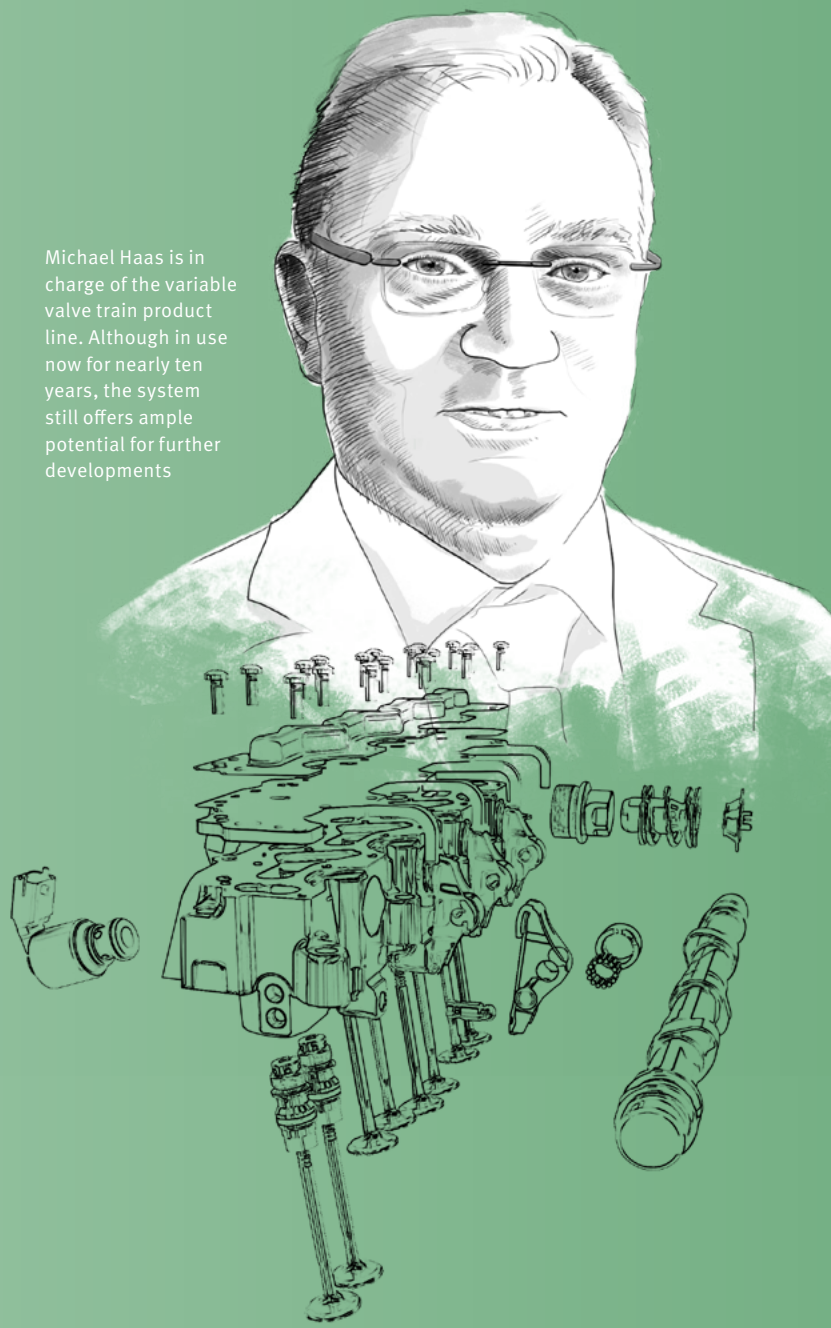
Even though the operating principle of the new dry dual clutch is similar to that of its wet cousin, a number of ***hurdles have to be overcome before the efficient shifting aid is ready for the market.*** *"For two years, we'd visit VW every week and sometimes go home with doubts in our minds due to the many issues," Dr. Reik recalls. "As soon as we'd successfully resolved a concern two new ones would emerge, so it wasn't uncommon for someone on our team to become discouraged. Fortunately, we weren't all discouraged at the same time …" Then, in 2007, VW starts installing*

> ***» Some of us wanted to embark on the dual clutch adventure while others tended to prefer a simpler solution***
>
> Dr. Wolfgang Reik,
> then chief developer at LuK

the dry dual clutch, initially in the Golf and Touran.

The meticulous and untiring development work done by Dr. Reik and his Schaeffler colleagues on the one side and VW on the other pays off. Motor journalists are full of praise for the new component. "ADAC Motorwelt," notably the magazine with Europe's largest circulation, writes: "The dry clutch now being utilized exhibits no abnormalities even when the engine is cold in winter, the shifting events are smooth and hardly perceptible. On the whole, the transmission in the Golf leaves an excellent impression. "Auto Bild" says: ***"The transmission changes gears as gently as an automatic in a luxury sedan.*** *When starting from rest, the clutch engages gingerly and a creep function assists in maneuvering. The Golf practically always operates in the optimum engine speed range across the seven speeds."*

Today, Schaeffler produces both wet and dry dual clutches, with the dry ones accounting for the larger volumes. The dry solutions tend to be utilized more for cars up to 150 kilowatts and the wet ones for the powerful models up to 500 kilowatts. ***Dr. Reik regards the dual clutch system as an "invention by and large completed."*** *For his successors in the Schaeffler research departments, though, he already sees new challenges on the horizon, for instance, hybrid cars. Reik: "If you position the electric motor there on the transmission input, you need a third clutch in order to be able to shut off the IC engine and drive in fully electric mode." So, following one and two clutches, there'll be a triple in a manner of speaking.*



Michael Haas is in charge of the variable valve train product line. Although in use now for nearly ten years, the system still offers ample potential for further developments

» There's a world of difference between inventing and industrializing

Michael Haas,
Director Variable
Valvetrain Product Line

THE FULLY VARIABLE UNIAIR VALVE CONTROL

UniAir is another typical example of Schaeffler technologies drivers arguably never get to see but that save them money, provide comfort and benefit the environment. ***It's the world's first electrohydraulic system for fully variable control of the engine valves in gasoline and diesel engines.*** *"So far, the system is exclusively utilized on the intake side of gasoline engines," says Michael Haas (56), who is in charge of the variable valve train product line at Schaeffler. "However, there are no limits to its utilization in diesel engines or on the exhaust side."*

With UniAir the engine can always operate in the optimum efficiency range. Fuel economy with UniAir in combination with downsizing improves by up to ten percent. At the same time, power output can be raised by ten percent and torque in the lower engine speed range by up to 15 percent. In addition, vehicle occupants benefit from a more comfortable ride, especially in dense traffic. ***"UniAir is not only efficient in terms of fuel economy and emissions but enhances driving pleasure as well due to its fast response,"*** *says Nicola Morelli (48), Director System Development UniAir, adding that, "UniAir responds faster to the driver's demands, particularly at lower speeds."*

UniAir technology is invented in 1999 by Centro Ricerche Fiat (CRF). However, the Italians lack the know-how for development, industrialization and manufacturing that is necessary to put the system into production, so they turn to Schaeffler to obtain it. Together the automobile manufacturer and the automotive supplier by 2009 develop the product which Schaeffler has since been manufacturing and marketing as fully variable valve control thanks to an exclusive license. Initially sold to FCA (Fiat Chrysler Automobiles), the system dubbed as "MultiAir" operates in engines of Alfa Romeo, Fiat, Chrysler and Jeep. It's the core element of the "TwinAir" two-cylinder family. "We've made the system salable," Haas agrees, "because there's a world of difference between inventing and industrializing." This is due to the many components belonging to UniAir, as well as the precision in the microscopic range. "Manufacturing requires appropriate production processes that only Schaeffler masters," says Haas. ***"We're the hydraulics specialists with the requisite precision*** *plus the capability of manufacturing the right components at the lowest possible costs." The first UniAir engine in 2009 is the Fiat four-cylinder from the Alfa Romeo MiTo 1.4, a F.I.R.E. unit (Fully Integrated Robotized Engine) that has been completely assembled by robots.*

A fully variable valve control system specifically developed for Jaguar Land Rover *has recently been introduced in the Ingenium four-cylinder engine family, combined, for the first time, with two hydraulic camshaft adjusters. As a result, for instance, the engine can be shut off with low vibrations in start-stop mode and instantly restart. Fast control of the valves with cyclical precision is another advantage. It allows spontaneous torque development without impairing efficiency due to excessive retardation in ignition timing.*

Now Schaeffler is working on making UniAir even more efficient. Conceivable for instance is a reduction of components, as well as the utilization of enhanced combustion strategies. ***"There's still ample development potential," says Haas. "We're also thinking about an integration of fully variable UniAir valve control directly in the cylinder head ..."***

In conventional valve control, the cams of the rotating intake camshaft cause the valves to open and close. The air required for combustion is controlled by the position of a throttle valve. The disadvantage of this type of valve control is that timing is optimized for a specific load condition of the engine. Even VCT variable cam adjustment cannot reflect all the continually changing driving conditions, especially not at the frequently required pace. As a result, the engine does not run efficiently in all ranges. By contrast, Schaeffler's fully variable UniAir valve control always optimally adjusts to changing power requirements.

THE AUTHOR

Roland Löwisch, *a freelance motor journalist from Hamburg, is always curious about the latest technology developments in the field of cars and engines. For his research he delved into the special topics of wet and dry dual clutches, and fully variable valve control.*

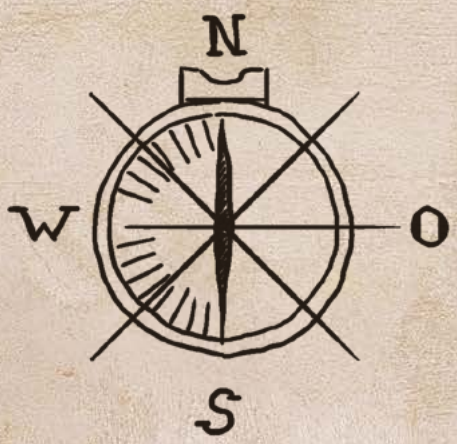
GAME CHA

Twelve machines that have decisively driven the development of the world.

by Dr. Christian Heinrich

AROUND 1000

COMPASS



A magnetized needle, movably suspended: It's hard to imagine a simpler machine – if the term machine is even appropriate in this case – yet the compass is one of humanity's greatest inventions. To whom this invention can be attributed is still being debated today. Apparently, its origins are in China, dating back to around the year 1000 when the compass there, however, is utilized less for navigation but rather for planning and selecting the location of houses to create harmony and balance in accordance with the principles of feng shui. In Europe, the compass is mentioned for the first time in 1269 – laying the groundwork there for the age of discoveries.

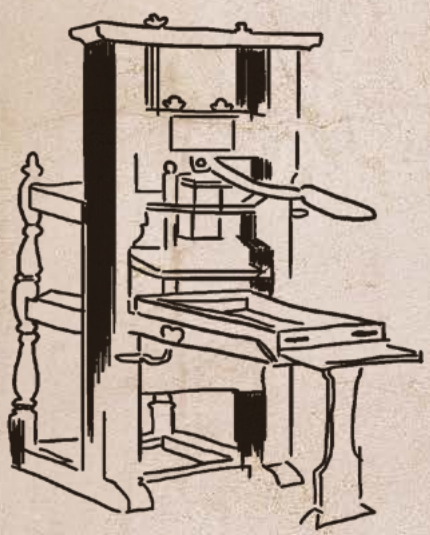
WHY IT CHANGED THE WORLD

- *Navigation in the pre-compass age was unreliable*
- *Foundation for surveying the world: Only the compass made it possible to create reliable land and sea maps*
- *Discovery of new countries and continents*
- *Expansion of global trade due to the emergence of fixed trade routes*
- *Navigating today: GPS instead of compass*

AROUND 1450

PRINTING PRESS

In Mainz, Germany, around 1400, a boy named Johannes Gutenberg is born as the son of a merchant. Presumably even at a young age, he sets a goal for himself: the ability to reproduce written works. Some 50 years later, he succeeds in printing the Bible for the first time. Decisive for this feat is Gutenberg's hand mold that enables him to cast type individually, faster and more precisely, as well as the printing press and improved ink.



WHY IT CHANGED THE WORLD

- *Simple reproduction of text and images*
- *Without the printing press, humanity would not have culturally and intellectually evolved into present-day civilization*
- *Democratization of education and language*
- *Higher educational level*
- *Fast and precise exchange of knowledge*
- *Beginning of mass communications*

NGERS

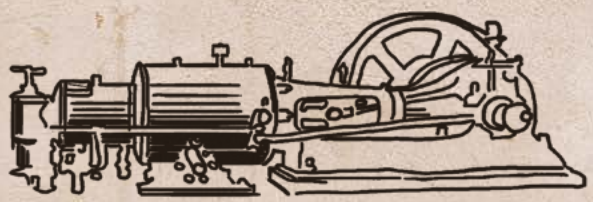
1765

STEAM ENGINE

What would a world be like in which everything – from transportation to everyday work to production – largely depended on the muscle power of humans and animals and, at best, on locally harnessable forces of nature such as hydropower and wind? There'd be no cars and no trains, and nearly everything would have to be made by hand. This is what the world was like up until around 1765. It's the year in which the Scottish inventor James Watt achieves a crucial further development of steam pumps already in use in mining at the time by adding components such as a condenser which, as a result, saves three quarters of the required fuel. The steam engine that's attributed to him accordingly is not only able to perform work that previously had to be largely done by humans or animals. By means of the sheer power it delivers it opens up completely new possibilities as well.

WHY IT CHANGED THE WORLD

- *Engine of mobility: Trains and steamships changed society, the economy and everyday life*
- *Initiator of the industrial revolution leading to enormous population growth, urbanization and major progress in technology and science*
- *Factories produced goods as efficiently as never before*
- *A new upper class of factory owners emerges*



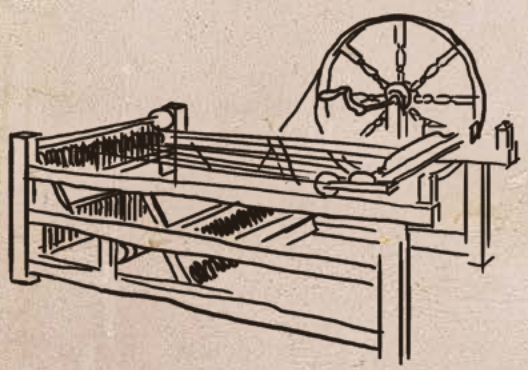
1786

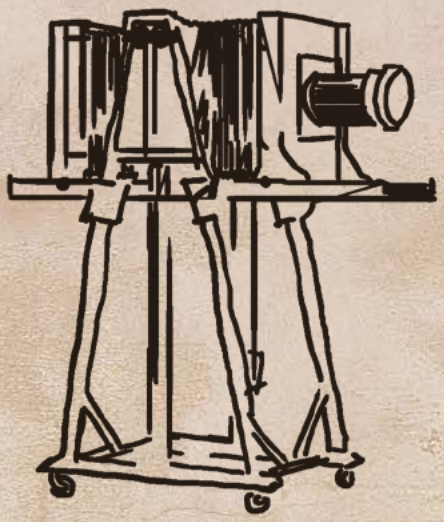
POWER LOOM

Clothes are of vital importance for every human being in many respects, protection against cold and the elements being merely the most fundamental aspect. So it's not surprising that humans since time immemorial have been trying to simplify the weaving of clothes or to even automate it. Simple predecessors of the loom using stones as weights have existed for several thousand years, but only the power loom designed by the Englishman Edmund Cartwright achieves a real breakthrough. In 1786, Cartwright files a patent for his loom that operates strictly on steam power. It marks the beginning of a new form of manufacturing.

WHY IT CHANGED THE WORLD

- *Significant increase in productivity*
- *First mass production using machines*
- *Besides the steam engine, the power loom marks a crucial milestone of the industrial revolution*
- *Factories displace craft production*
- *Low-cost production of large volumes of consistent quality*
- *Today, more than 60 million people are working in the textile industry*





1826

CAMERA

For the first time in human history, the Frenchman Nicéphore Nièpce manages to permanently capture a moment on a photograph. He uses the "camera obscura" principle that is already known at the time. Nièpce solves the previously existing problem of the resulting pictures not being light-resistant, and therefore not permanent, by changing the exposure surface, now using asphalt which is extremely hard and durable. This way, on November 22, 1826, Nicéphore Nièpce succeeds in creating the first permanent picture. It shows the view from his workshop. Pictures of people and animals, however, are still near-impossible in those days due to the long exposure time of several hours.

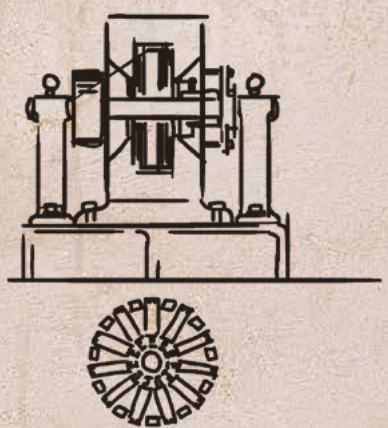
WHY IT CHANGED THE WORLD

- *Documentation and conservation of reality*
- *The photograph gives artists the liberty of greater abstraction*
- *Precursor to moving images*
- *Today, 1.2 billion pictures are taken per year*
- *Basis for social media such as Snapchat or Instagram*
- *Today, image editing programs make it possible to manipulate photographs resulting in lower credibility*

1867

DYNAMO

People have long been familiar with the power of electricity by the time of the 1867 World Exposition in Paris. Telegraphy, for instance, is already transmitting messages across several miles via power cables. The demand for electricity, though, keeps growing while the possibility to produce sufficient amounts of it is still lacking. Although the magnetic force of electric spools is being utilized, it takes batteries to operate them – an inefficient method. The dynamo which Werner von Siemens presents at the World Exposition is designed so that the magnetic field amplifies itself due to the electricity generated. Consequently, the dynamo machine only has to be connected briefly to an external electric power source when it's used for the first time.



WHY IT CHANGED THE WORLD

- *The dynamo is the first electricity generator that was truly and comprehensively fit for practical use*
- *Enabled the triumph of electricity which has since moved into every area of life*
- *Electrical light sources provide independence from daylight*
- *21 trillion kWh per year are consumed today*

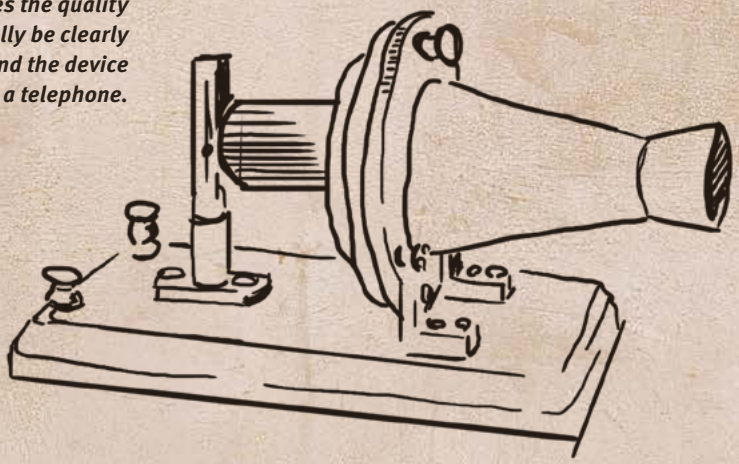
1876

TELEPHONE

The invention of the telephone cannot be credited to a single individual but to several people. A central figure is the mathematician and physics teacher Philipp Reis who in his barn in 1861 constructs a "sausage casing" telephone. The skin of a sausage stretched across a wooden auricle emulates the human eardrum and the oscillations are captured by means of electric current interruptions. But only when the speech therapist and teacher of the deaf Alexander Graham Bell in 1876 no longer interrupts the electric circuit but makes it oscillate in the rhythm of the sound waves the quality is such that the transmission can actually be clearly understood on the other end of the line and the device can be called a telephone.

WHY IT CHANGED THE WORLD

- *Direct communications across large distances*
- *Location independence due to cell and smartphones enables new level of communications: simultaneous freedom and connection*
- *Prerequisite for globalization*
- *Average users reach for their smartphone 1,500 times per week*



1891

AIRCRAFT

How do birds fly? They have wings and flap them. The German Otto Lilienthal takes a closer look and discovers the principle of lift and propulsion. Based on this, he develops airfoils and ultimately a glider that carries a man. From 1891 to 1896 Lilienthal in numerous successful test flights personally demonstrates that the dream of flying has come true for humans. Building on this feat, the American Wright brothers in 1903 manage to take off and land in a powered aircraft.

WHY IT CHANGED THE WORLD

- *People and goods can be hauled across longer distances faster, enormously expanding their scope of activities*
- *Aircraft have globalized humanity*
- *Flying internationalizes tourism*
- *More than 100,000 aircraft daily are in the air around the globe*
- *First step toward conquering space*

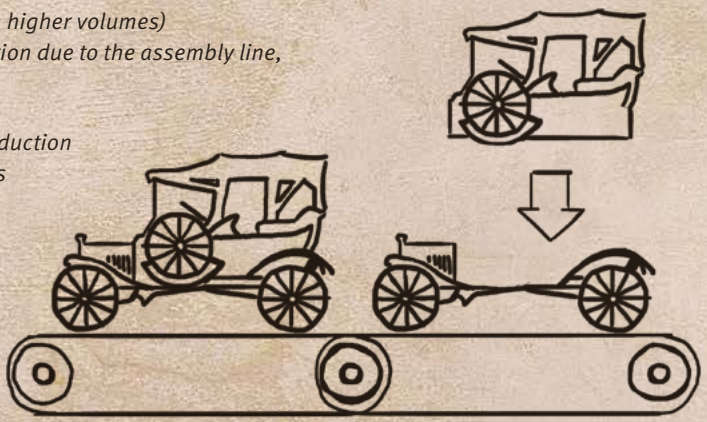
1913

ASSEMBLY LINE

His cars are still traveling on our roads today. The name of U.S. automaker Henry Ford stands for the breakthrough of the assembly line. On October 7, 1913, Ford starts testing the operation of an initial makeshift line for the production of the so-called Model T. The introduction of this step doesn't materialize out of thin air. Ford draws on the previous experiences of other industries, such as the Chicago stockyards where beef and pork is cut and packed in a kind of continuous production line. But only the adoption of this production concept by the automotive industry and full automation there turns the assembly line into a symbol of a new age.

WHY IT CHANGED THE WORLD

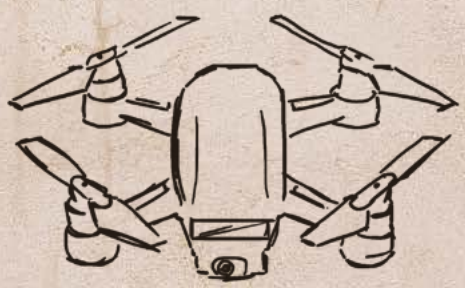
- *Increase of productivity (faster and cheaper with higher volumes)*
- *Automobiles become means of mass transportation due to the assembly line, 15 million units built of Ford's Model T alone*
- *Method reaches its peak in the 1950s and 1960s*
- *Due to the disadvantages of assembly lines (production method is rigid and inflexible, if a process step is not performed fast enough the entire system stalls) manufacturing operations frequently use modular concepts with manufacturing cells today*



SINCE 1914

DRONE

The first radio-controlled aircraft emerge as far back as during the First World War. They're able to fly on a pre-determined route and drop torpedoes at a specified location. In World War II, unmanned aerial vehicles are deployed on a larger scale, followed by decades in which they're primarily used for reconnaissance flights. However, the revolutionary potential of drones has only begun to be tapped in recent years.

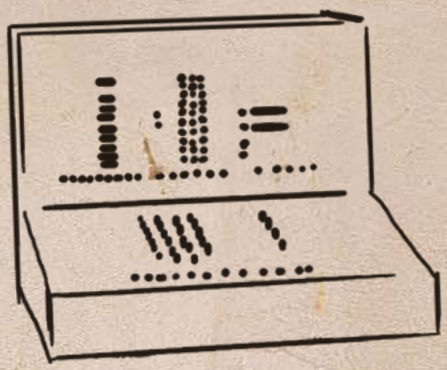


WHY IT CHANGED THE WORLD

- *Highly agile: Drones take off, fly and land like helicopters instead of like airplanes*
- *Usable for diverse applications in logistics, transportation and manufacturing*
- *Easy to operate*
- *Makes remote locations accessible*
- *Nearly 3.8 million drones were sold in 2017*
- *Autonomous drones can shift urban transportation into the airspace*
- *U.S. start-up Matternet has a long-range vision of covering all areas of land around the globe with a transportation network of drones*

1941

COMPUTER



"War is the father of all things," says Heraclitus. This dictum seems to particularly apply to computers. The first computers emerge during the days of the Second World War, frequently with the intention to calculate ballistic trajectories and to decode enemy communications. One of the first designers of a computer is the German engineer Konrad Zuse who in May 1941 builds the Z3. In the following years, other computers are designed in Germany, the United States and the United Kingdom. These computers are behemoths of several meters in length, the so-called ENIAC computer, for instance, built in the United States in 1946, is 17 meters (55.77 feet) long and more than ten meters (32.8 feet) high.

WHY IT CHANGED THE WORLD

- *Enormous acceleration of technology development*
- *Low-cost mass production makes high tech accessible for large parts of the population*
- *Computers have advanced into 95 percent of all areas of life*
- *20 million units: The C64 is the most frequently sold computer of all time*
- *The internet connects people around the globe and revolutionizes data and information exchange*
- *Enables digital networking in Industry 4.0 ("smart factory") operations*

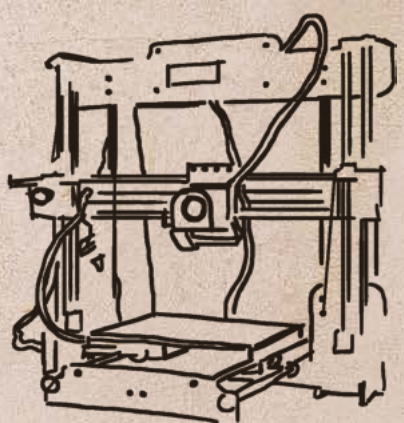
1986

3D PRINTER

In 1986, the American Charles Hull files a patent for the first 3D printer. Just like people print text on paper at home using laser printers, a 3D printer prints small three-dimensional objects. Initially, the technology was mainly used for prototyping purposes, but today specific contract manufacturing is increasingly using 3D printing technology too. 3D printers are gradually moving into private homes as well, albeit their use being frequently limited to gimmicks such as printing playing pieces or tokens specifically designed on a computer. The revolution, however, is already appearing on the horizon.

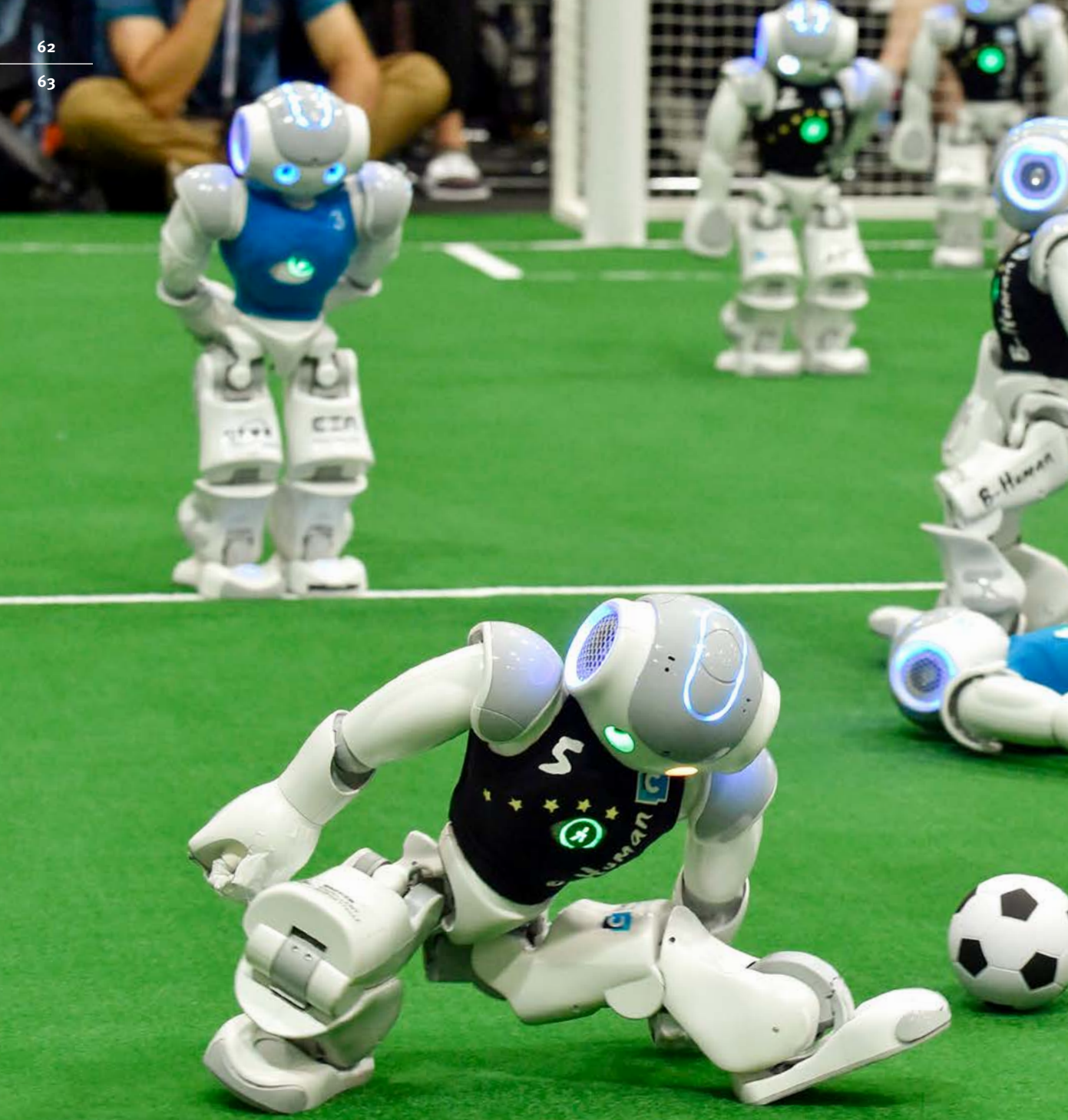
WHY IT CHANGED THE WORLD

- *Miniaturized factory: The printer can even be standing in a living room*
- *Privilege of producers with factories is disappearing – and thus their market power*
- *Products are tailor-made and customized to suit individual needs*
- *Parts can be manufactured fast and on the spot*
- *Production sites become flexible*
- *Reduction of transportation and shipping requirements*



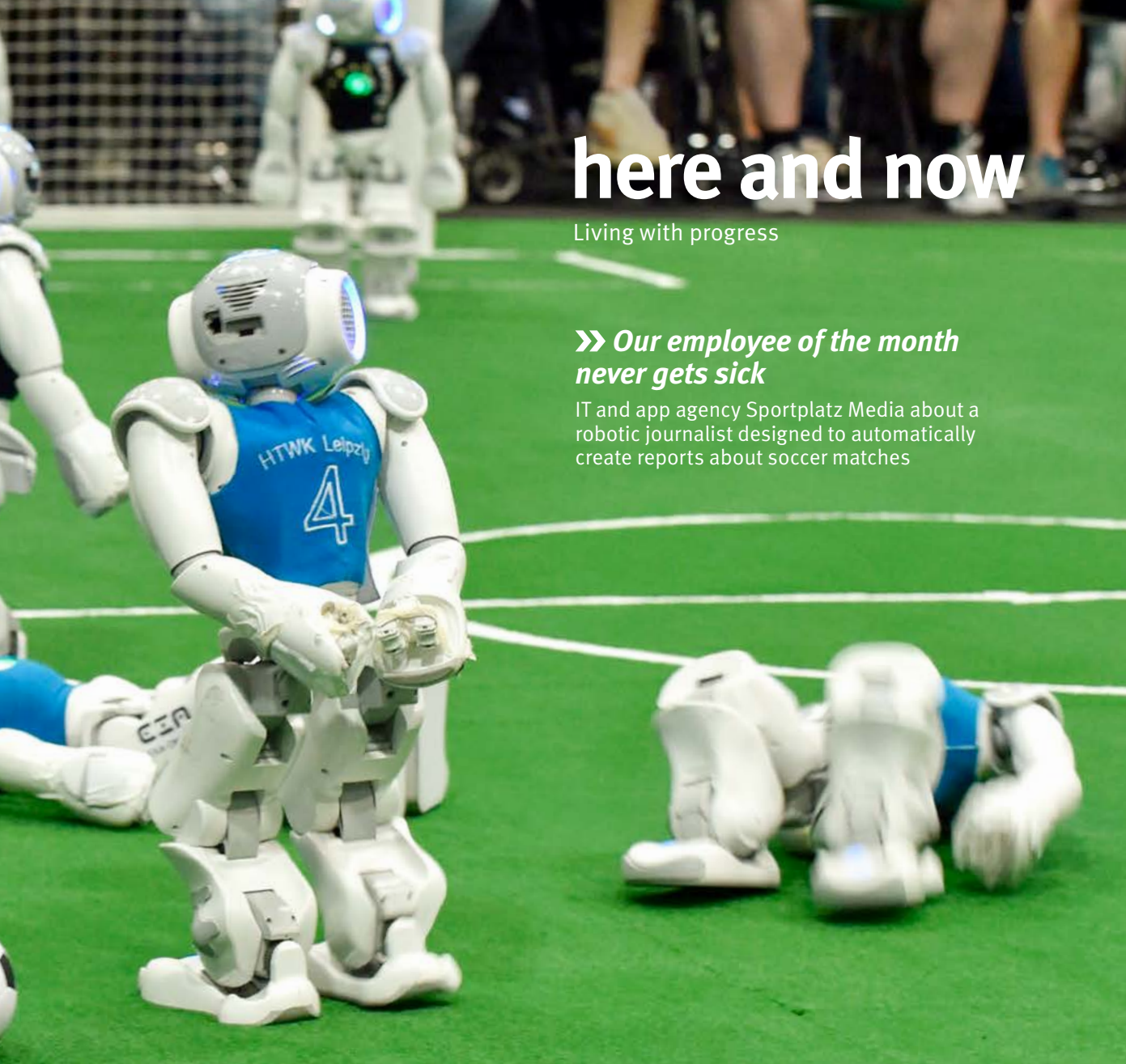
THE AUTHOR

Christian Heinrich *is a freelance journalist writing for "taz," "Zeit" and others. He's eager to see what machines are going to change the world next and expects that more than likely it'll be robots with artificial intelligence. The movies have already captured a number of scenarios of what this revolution might look like. The ones the author is particularly fond of are "Her" and "Blade Runner."*



MACHINE **KICK**

Robots in sports – now while that might make you think of a tennis ball throwing machine or a greenkeeper's mowing robot, technology has advanced far beyond such devices. In robotic soccer (pictured), for instance, two teams consisting of five digital kickers, about 60 centimeters (24 inches) tall, are pitted against each other. Thanks to sophisticated programming and two cameras installed in their heads, they act completely autonomously, in other words without external remote control. Passing, running, dribbling, shooting, falling down, getting up again and goalkeeper saves – everything just like with their counterparts of flesh and blood. By the way: The "RoboCup" project, an international initiative to promote research in the fields of artificial intelligence and robotics, aims to develop a team of humanoid robotic soccer players by 2050 that will beat the German men's national team.



here and now

Living with progress

›› *Our employee of the month never gets sick*

IT and app agency Sportplatz Media about a robotic journalist designed to automatically create reports about soccer matches

ARTIFICIAL INTELLIGENCE IN SPORTS – MILESTONES

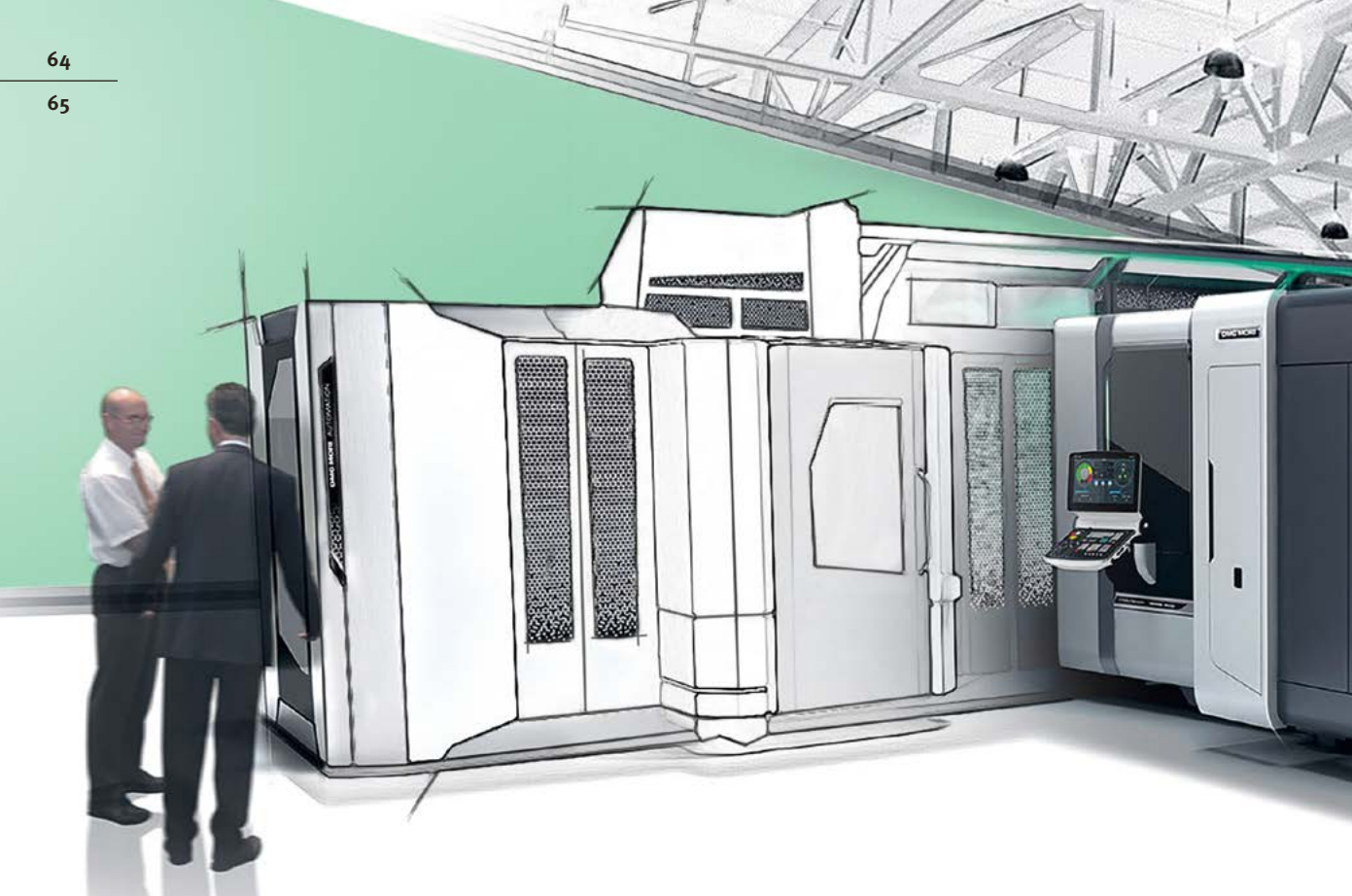
1769 The first **chess robot** moves the pieces as if by an invisible hand. Decades later, the machine's cover is blown: It was operated by a human.

1897 British mathematician Charles Hinton invents the first **baseball pitching machine.** It is operated with gunpowder.

2016 The **autonomous electric Robocar racer** does initial demo laps in the Formula E electric racing series.

2017 The highlight of the **robotic battles** that have been popular since the beginning of the millennium: the Japan vs. USA competition with behemoths controlled by humans.

2020 For greater objectivity: In the Olympic Games in Tokyo, a robot is supposed to evaluate the athletes in **rhythmic gymnastics.**



NEW **BEAUTY**

Factories are acquiring chic. Mechanical engineers have long begun to give their machines attractive shapes. The art lies in harmonizing what seem to be opposites: emotion and technology, form and function.

by Christel Trimborn

There's an adage all of us are familiar with: You eat with your eyes first. In other words, food that is presented with high visual appeal is particularly appetizing. In fact, even conventionally cooked peas, beans and company may actually taste better when the vegetables are stylishly arranged on a plate. The same applies to cheerfully decorated classrooms in which learning is fun, to aesthetically pleasing medical device technology that patients are not afraid of or to ultralight tools that allow even occasional do-it-yourselfers to achieve respectable work results. That inspiring surroundings or user-friendly everyday products are able to enhance people's comfort and motivation to purchase or perform is common knowledge. After all, thousands of companies and designers enter their products in prestigious international design competitions such as the "Universal Design Award," the "iF Design Award" or the "Red Dot Award." Based on their professional expertise, the members of their judging teams are tasked to confirm the high level of quality and innovation and thus the market value of a wide variety of products – from wrist watches to dental chairs. But what about industrial and machine tool design? Will work on elegantly designed printing or measuring machines,

IDEALS

stylish presses or visually appealing CNC milling equipment actually be more efficient, less prone to defects and perhaps even more enjoyable?

People-centric approach

There's hardly another industry in which function used to dictate form as rigorously as mechanical engineering. As well as ease of use and maintenance, robustness was of paramount importance, while visual appeal seemed to be a subordinate consideration. This changed a few years ago. One of the people attesting to this trend change is Swiss industrial designer Dominic Schindler. Together with his team he specializes in innovation strategies for sophisticated goods and complex systems, having completed more than 3,000 projects to date – from winches to spindle heads – for his international clients. Always in the back of Schindler's mind are the people that operate the equipment, in line with the mission statement of his agency that's based on Lake Constance and near Zurich: "We transform visions into working realities while always putting people at the center of our solutions." That's why for him – besides the classic criteria of ease of use and maintenance and the increasingly important efficiency of workflow – the emotions and experiences involved in operating industrial machines rank among the primary criteria to be considered in the development and design of a product, which he refers to as "experience design." In Schindler's view, aside from aesthetic appeal, the user's experience plays a much greater role in the design of new or enhanced machines. The less stress and effort a machine involves, the easier and more intuitive its operation, the greater the operator's comfort, the higher the attractiveness and value of the machine, he says.

Hand in hand

The demands made on modern industrial machines and machine tools are growing continually. While equipment – frequently loaded with high tech – is expected to deliver increasingly higher speed, precision and efficiency, it's not supposed to put excessive demands on its

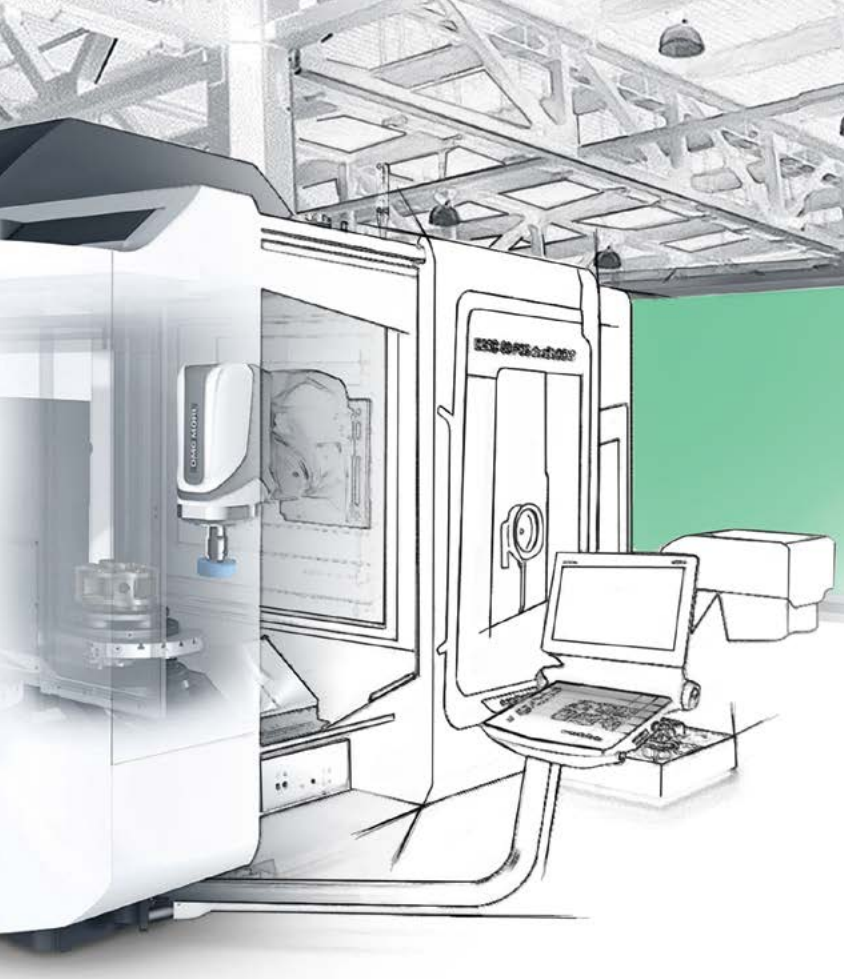
> ***Today, designers and engineers are increasingly working hand in hand – they meet on a level playing field and both are equally involved in the development of a product***
>
> Björn Steinhoff,
> Design Center North-Rhine Westphalia

operators. To meet these more and more complex expectations without losing sight of people, close collaboration between developers and designers is a key requirement. "Today, designers and engineers are increasingly working hand in hand – they meet on a level playing field and both are equally involved in the development of a product," says Björn Steinhoff, Head of Communications & Public Relations at the Essen Design Center North Rhine-Westphalia that organizes the Red Dot Award. Sounds logical: While the engineers contribute their often highly specialized technical knowledge, designers tend to think in aesthetically pleasing or solutions-oriented categories. In the best case, the combination of rational and emotional input results in synergistic effects and successful new products or tools. Industrial designer Dominic Schindler, though, even takes all this a step further. In an interview with the Swiss trade magazine "Maschinenmarkt," he said that just interviewing users about their processes was by no means sufficient. Instead, he explained, it was necessary to accompany them on their daily routines – or, as a designer, to personally step into the shoes of a machine operator to find out what was really needed. In the dawning age of Industry 4.0 (aka smart factories), marked by integrated, self-controlling processes, it's safe to assume that designers, engineers and users will have to work together a lot closer and intensify their exchange. The harmonization of the diverse demands made on products, machines and systems in terms of design, use and services requires more interdisciplinary thinking than ever before.

The middle of the 19th century when consumer goods start to be mass produced in industrialized societies, marks the beginning of the **history of product design** and prototyping. One of the first stars of the scene was German furniture designer Michael Thonet.

Best of the best

The judges of the international design competitions, as well, are intimately familiar with the complexity of evaluating what "good design" actually is. Consequently, only products that combine perfection in form with maximum functionality qualify for the highest-level recognition to be bestowed on entrants by the jury of the Red Dot Award, according to the competition's officials. "Ease of use and maintenance, ergonomics and specific styling in terms of form and color are all factors that are associated with an industrial machine being well-designed," says Björn Steinhoff. The question is what effects can be produced by design that has been well-conceived in every detail and carefully tailored to the needs of the users. "All of these factors significantly help increase productivity. Working on a well-designed, ergonomic machine is clearly more enjoyable, so employee motivation is enhanced as well." In addition, there's another positive side effect being observed, according to Steinhoff. Employees are said to handle well-designed, operator-friendly machines with



The production machines shown in this article are from Schaeffler's partner DMG Mori. The global leader in cutting machine tools has been setting standards in the field of design for many years. The design of the milling and turning machines and machine tools optimizes the interaction between the operator and the machine on the one hand and between the machine and superordinate networks on the other. DMG Mori and Schaeffler are working together on developments for Industry 4.0, among other things

greater care, making sure that they're left in good condition after work.

Not completely new

A look at the history of industrial design reveals that the type of modern designer emerged as far back as in the twenties of the past century – on both sides of the Atlantic and in two markedly different forms. In Europe, it was the artists of the Bauhaus movement and the members of the school of classical modern style whose work was primarily constructivist and experimental while activities in the United States were already of a more commercial nature. Here it was the automotive industry that created the first job market for industrial designers. In General Motors' "Art and Color" department their mission was to increase new car sales by periodically restyling GM's models. "The 'machine, component and equipment engineering' category has been part of the 'Red Dot Award: Product Design' from the very beginning – in other words since the mid-1950s," says marketing expert Björn Steinhoff. "This means that some manufacturers recognized the value of good design even back in those days. During the 1990s, this awareness intensified and today it's an essential component of the capital goods sector." Consequently, with styling having become a central element here as well, designers and developers have been working hand in hand earlier and more intensively – for perfect harmony of form and function.

10 PROPOSITIONS ABOUT GOOD PRODUCT DESIGN BY ICONIC DESIGNER DIETER RAMS

- *Good design is innovative.*
- *Good design makes a product useful.*
- *Good design is aesthetic.*
- *Good design makes a product understandable.*
- *Good design is unobtrusive.*
- *Good design is honest.*
- *Good design is made-to-last.*
- *Good design is consistent in every detail.*
- *Good design is environmentally friendly.*
- *Good design is as little design as possible.*

THE AUTHOR

*When it comes to the design of everyday objects **Christel Trimborn** who almost became a fashion designer (but dropped out after the 4th semester) shows no mercy. Whenever a product's veneer shines brighter than its practical functionalities, it won't find her favor. Still, things that are fascinatingly beautiful yet totally useless can spark her enthusiasm – as long as she doesn't have to use them.*

LORD OF THE **SKIES**

Aviation, today, would be unthinkable without them. Only modern turbofan engines – with high-tech components such as specialty bearing systems and other precision components from Schaeffler – provide the necessary thrust allowing us to grow together globally, thanks to heavy airliners.

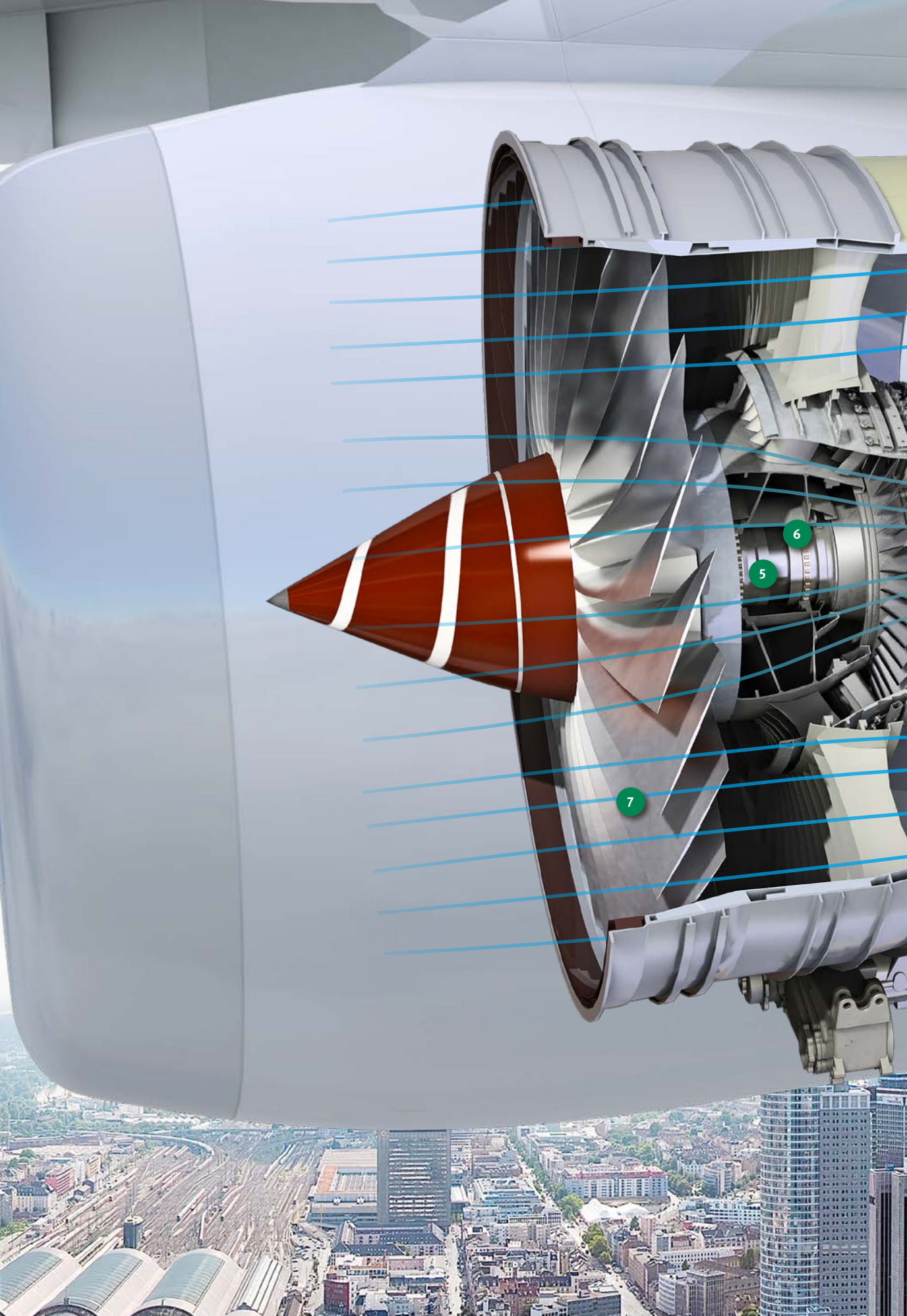
by Carsten Paulun

PAGE FOLDS OUT ▶


T STRAPPING ZONE
WLL 32000kg
RED ROOF

HIGH **PRESSURES** – HIGH **MATERIAL** REQUIREMENTS

Actually, the technology behind a jet engine is quite simple. A compressor 1 compresses the air sucked in at the front of the engine, followed by the injection of fuel and ignition in the combustion chamber 2. Due to the combustion process, the air-fuel mixture expands explosively and is pushed rearward by new air sucked in and compressed at the front. The volume of the air after combustion is much larger than that of the air flowing in at the front. For this amount of exhaust gas to leave the engine, it must be clearly faster than the air flowing in. The resulting exhaust jet 3 generates thrust and exits the engine at the rear. In addition, the exhaust jet drives the turbine blades 4 connected to the compressor 1 at the front of the engine via a shaft 5. In order to increase the pressure to the 45-fold input pressure, modern jet engines have between eight and 14 sequential pressure stages. The high exhaust temperatures of up to 2,200 °C (3,992 °F) and the loads acting on the shafts pose particular challenges. Engineers have resolved the temperature issue by using special materials and cooling techniques directly on the rotor blades. For the shafts, Schaeffler has developed bearings and integrated shaft components 6 welded together by electron-beam welding. To enhance the fuel efficiency of jet engines, engineers have split the air jet entering at the front. More than 80 percent of the air, via the first pressure stage, the fan 7, bypasses the combustion chamber 2. Like a huge blower, this fan accelerates the bypass air which exits the rear of the engine together with the hot exhaust jet and produces the majority of the engine's thrust. This results in fuel savings of 10 to 15 percent.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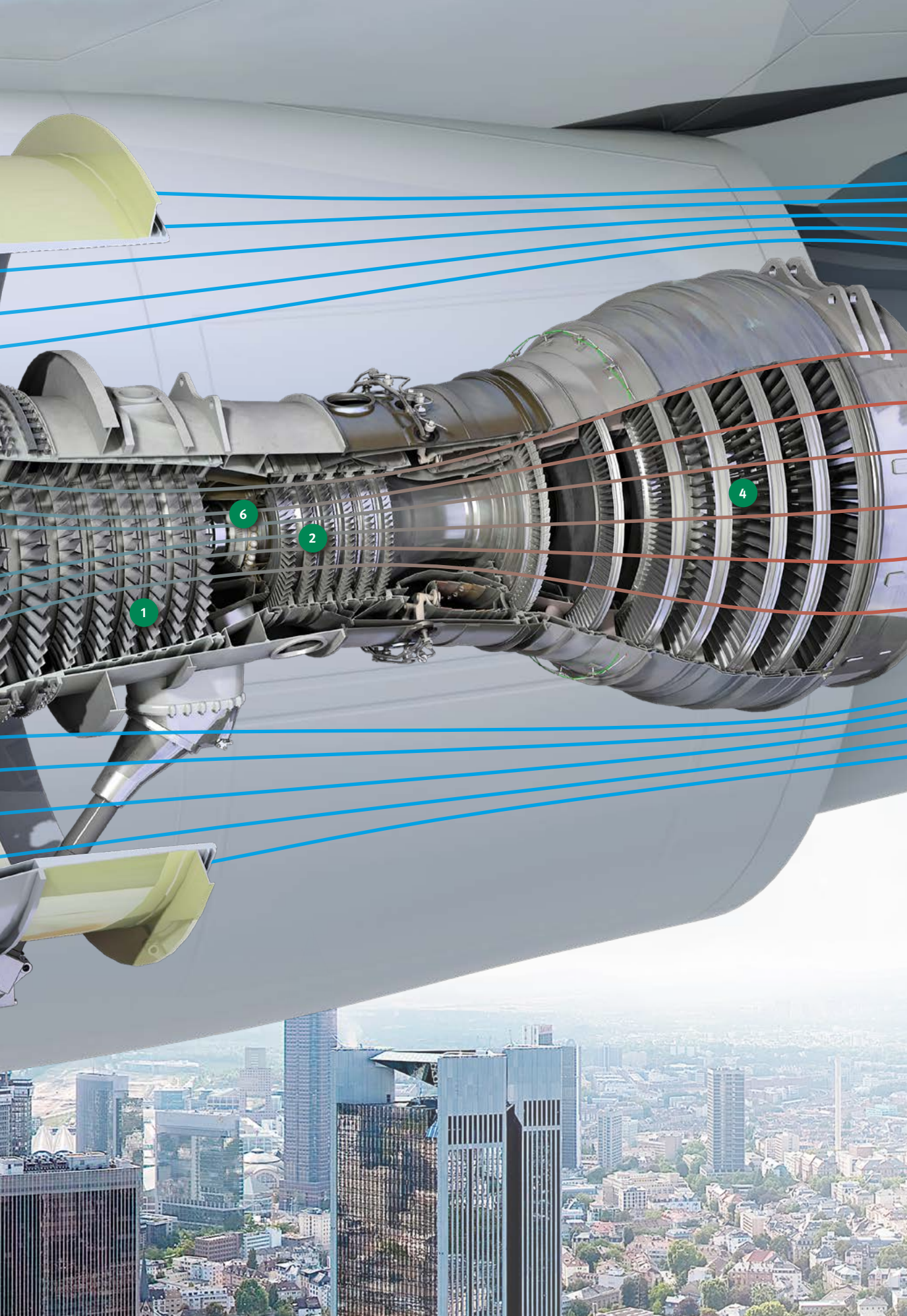
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ELECTRIC MOBILITY ALSO IN THE AIR?

Airbus, Rolls-Royce and Siemens are testing hybrid-electric jet propulsion

If it were up to aircraft manufacturers Airbus and Boeing – YES! Both already have electrically powered prototypes in the air. The research is focused on three versions:

— ***Hybrid propulsion.*** *An electric motor and an IC engine complement each other like in automobiles. Three examples:*

Electric wheel motors for taxiing. The jet engines are only turned on before take-off and turned off again after landing.

As in the case of a range extender, a kerosene-fueled turbine generates the electricity to recharge the batteries of the electric turbines when the plane is airborne.

An electric motor and conventional jet engine provide propulsion in parallel operation.

— ***Fuel cell.*** *As in a fuel cell car, hydrogen and oxygen react and produce electricity. Advantage: Hydrogen can be put into fuel tanks in a similar way as kerosene, batteries are not needed.*

— ***All-electric propulsion.*** *The jet engine is replaced by an electric version. Problem: currently insufficient battery capacity.*

Dr. Dirk Uwe Sauer from RWTH Aachen University: "Flying in a large passenger aircraft powered strictly by electricity based on batteries will still remain a dream for a long time."

STEELY FARMHANDS

Machine hall vs. mini vehicle fleet – a visit to two highly diverse agricultural operations in Brazil.

by Philipp Lichterbeck

At first glance, the game-changing machine looks like a huge, voracious insect: a tracked vehicle at the front of which four slightly angled screw conveyors form a metallic mouth. Towering above it is an awe-inspiring boom. Sitting in the middle is the operator's cabin, behind which is a tall conveyor arm. The unusual sight turns out to be a sugar cane cutting machine. It's parked in the machine hall of Antônio Cury, owner of the Estiva agricultural operation. The 62-year-old comments about the harvester: "It marked the beginning of a new age in Brazil."

3,000 hectares, four million-euro sales

Fazenda Estiva is located near the small town of Ituverava in the Brazilian state of São Paulo. Ituverava is the center of a region dominated by agriculture. The town is surrounded by rolling hills with fertile red soil. The climate is sub-tropically warm. "These are ideal conditions for large-scale cultivation of various crops," says Antônio Cury. It's not for nothing that the region is called "Brazil's California."

Recent decades have seen an amazing transformation here. While up until the late 1980s cotton was still being planted around Ituverava, the farmers subsequently began to specialize in corn and soy beans. Around the turn of the millennium, a sugar cane boom began, continuing to this day, driven by the demand for bio fuel. Today, the fields with the bright-green sugar cane stalks extend as far as the eye can see. The risks entailed by such monocultures are known around the globe: soil degradation and a fast proliferation of pests.

Antônio Cury is one of the major farmers in Ituverava. His "fazenda" covers 3,000 hectares (7,413 acres) of land and he employs 40 people. Cury harvests 230,000 metric tons (253,000 short tons) of sugar cane per year which he sells to three factories that convert them into sugar and ethanol, and produce electricity from incinerating the bagasse. His annual sales volume, expressed in euros, varies between 3.2 and four million.

Large-scale operations such as Cury's have helped turn Brazil into the world's major sugar cane producer. The country today harvests as much as its six closest competitors on the world market combined. This is a trend that characterizes Brazilian agriculture in general. Be it coffee, soy beans, corn, oranges or beef: Brazil ranks among the world's major producers. This wouldn't be possible without the use of specialized machines. In the sugar cane sector, the country has practically seen a technological revolution.

BRAZIL'S AGRICULTURAL POWER

Brazil has become one of the top three in the global ranking of agricultural nations. *The country currently has a five-percent share in the global trade in agricultural raw materials. Agricultural Minister Blairo Maggi, who is one of the world's major soy bean farmers himself, is aiming for an increase to ten percent. Brazil is the leading exporter of sugar, orange juice and coffee, and in the top rankings in terms of soy bean, beef, chicken meat and pulp exports as well. For Brazil's national budget, agricultural exports are indispensable. More than 40 percent of the country's exports are of an agrarian nature. This transformation is all the more remarkable as Brazil as late as in the 1970s was still importing food. Productivity per hectare (2.47 acres) back then was 1.4 metric tons (1.54 short tons). Today, it's 4.5 metric tons (4.96 short tons). This increase is attributable to the use of agricultural chemicals and growing mechanization. Within a few decades, Brazil's traditional, hardly mechanized agriculture was transformed into an ultra-modern industry. Factors with a favorable effect on mechanization are the climate, improved access to capital for the farmers and fertile land enabling the utilization of machines. Some 20 percent of Brazil's area is used for breeding cattle and eight percent for growing crops. The OECD-FAO Agricultural Outlook predicts that by 2024 Brazil will be the world's largest agricultural exporter.*

95-percent mechanization

"I was a pioneer," says Antônio Cury. "I was the first in Ituverava to grow sugar cane. Over the years, I increased my yield by 20 percent." This success, he says, is owed to mechanization. Modern machines deliver speed and precision.

Cury's machinery line-up consists of 40 vehicles including a new twelve-ton tractor (13.2 short tons) with GPS and 225 horsepower which he uses to pull heavy plows. His most recent acquisition though is a spraying vehicle equipped with an onboard computer that applies pesticides in previously programmed quantities with sectional precision in a field. Ground clearance of 1.35 meters (4.4 feet), spray arms with a span of 24 meters (78.7 feet), an insulated driver cabin preventing ingress of pesticides and the high speed of 50 km/h (31 mph) are other characteristics of the machine that costs about 200,000 dollars. "This vehicle performs the work of ten conventional tractors," Cury enthuses – and now it's clear why operations like his are referred to as Precision Farming.

» *Mechanization is a game changer*

Antônio Cury,
Agricultural entrepreneur

The fleet of the Brazilian large-scale agricultural operation of Fazenda Estiva is made up of 40 vehicles. The spraying vehicle depicted here is the most modern and important tool. Thanks to its high-tech equipment, it performs the work of ten tractors

Computers have also conquered the cockpits of modern agricultural machines

The stars, though, says Cury, are the sugar cane cutting machines: “They’ve been game changers.” Only a few years earlier, sugar cane was being cut in Brazil by seasonal workers using machetes. Before cutting the plants, the fields were set on fire to rid the stalks of the leaves. These days are over. In 2014, 95-percent mechanization of the sugar cane harvest was achieved in Brazil.

What this looks like can be watched a few kilometers away from Cury’s fazenda. There one of the harvesting machines literally cuts its way through a field at a speed of 20 km/h (12.4 mph). With a forward arm it cuts the leaves off the stalks which it then severs slightly above the ground and then picks up. Inside the machine, the stalks are cut into pieces before being ejected into a truck traveling alongside the machine. Cury himself owns only one of these harvesting machines. It’s common practice, he says, to rent them from the sugar cane factories, which is cheaper and easier.

However, Cury points out when we leave, that the best machines are useless if it doesn’t rain. Unfortunately, he continues to explain, dry spells have been increasing in recent years. Experts assume that the absence of precipitation has something to do with the cutting of the rainforest in the Amazon region 2,000 kilometers (1,250 miles) further north, as less forest leads to less cloud formation. The Amazon rainforest is cut for huge fields of soy beans and cattle pastures. It’s the downside of industrialized farming operations like those of Antônio Cury.

Contrasts: 344 hectares, 170,000 euros in sale

600 kilometers (373 miles) south-east of Ituverava farmers are struggling with dry spells as well. At Fazenda St. Rita, a foreman is just in the process of hitching a plow to one of the farm’s two tractors. A small field is to be prepared for sowing corn – although there hasn’t been enough rain yet, says the fazenda’s manager, Amauri Almeida. Fazenda St. Rita is located in a narrow high valley in the mountainous region of the state of Rio de Janeiro. On some 90 hectares (222 acres) Almeida, assisted by ten employees, grows corn, coffee and vegetables: beans, tomatoes, zucchini and eggplant. On another 254 hectares (628 acres) they keep about 400 cattle. In addition, the fazenda includes a small chicken farm.

Although Almeida is not the owner of Fazenda St. Rita – who lives four hours away in the metropolis of Rio de Janeiro – he has been its manager for 27 years. Once a week he has the farm’s produce hauled to a central market in the valley on an old truck. In total, the fazenda generates sales of 170,000, expressed in euros.

Like in the old days

Fazenda St. Rita fundamentally differs from Fazenda Estiva in Ituverava, not only in terms of statistics. It represents the other side of the Brazilian agricultural model. While Precision Farming takes place there with computer-controlled machines on huge mono-culturally planted areas, farming here is almost like it used to be in the old days. Almeida’s employees harvest most of the vegetables by hand, even corn is picked manually. “We’re small but proud of producing food for the population,” says

» *If I run out of co-workers, I'll need suitable machines*

Amauri Almeida,
Small farmer

The 75-hp tractor is small farmer Almeida's "universal workhorse." He uses it for plowing, sowing, application of pesticides and trips to the market

Almeida. There's certainly truth in this. While the production by the large-scale operations is primarily intended for export, 70 percent of the food consumed by Brazilians is produced by small to mid-sized farms such as Almeida's.

The small farms achieve this exclusively due to their large numbers. 4.4 million of them are registered in Brazil, employing 14 million people. They can hardly afford machines. It's been four years that Almeida has made his most recent major acquisition: a tractor with 75 horsepower for 29,000 euros (converted from pesos). Up until that time, the farm was using a single tractor built in 1982. The new machine, explains Almeida, was a compromise between performance and weight because if the tractor were too heavy it would compact the soil. The machine is used for all kinds of purposes: for plowing, for sowing, for application of pesticides, but also for pulling trailers with vegetable boxes. "It's our universal workhorse," says Almeida.

Besides the dry spells, the 54-year-old describes the uneven terrain as the greatest challenge. That's why he'd like to have an additional small tractor allowing him to drive down the steep slopes between the vegetable fields and coffee plantations. But he hasn't found one yet on the market. "We're a small farm," he says, "but we'd like to grow." In the future, though, exactly that will more than likely only be achievable with suitable machines. For a simple reason: Almeida is running out of workers. The average age of his ten employees is 45 years and their sons and daughters would rather look for jobs in the city than get their hands dirty in the fields.

Almeida cannot understand that. He's been working at Fazenda St. Rita for 27 years, not having taken a single vacation during this time. "It's nothing I miss," he says. "I find fulfillment in my work. And if I run out of co-workers, then I'll just need suitable machines."

THE AUTHOR

Latin America had been a subject of ***Philipp Lichterbeck's*** *academic and journalistic work for nearly 20 years when in 2012 he decided to open a new chapter in the book of his life. From Berlin, where he had been working for the "Tagesspiegel" daily paper for a long time, he moved to Rio de Janeiro. Since then, he has been reporting from the "Magnificent City" about Brazil and the rest of Latin America for German-language media. In addition, Lichterbeck is an author of travel guides and has published a book with background reports about Haiti and the Dominican Republic.*

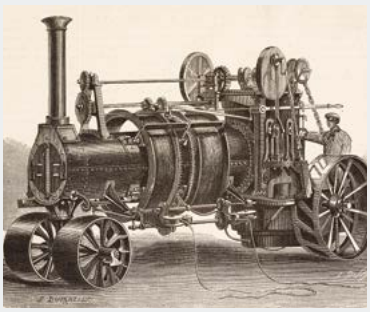
Plows have been used for work in the fields for 6,500 years. The picture shows a German farmer around 1949

THE **PLOW**

The plow is one of the oldest agricultural tools still in use today. *Tools similar to a plow were even used by the very first crop farmers to loosen the soil. Through the ages, the positive effects of plowing have been the supply of oxygen to the soil, plowing in weeds and harvest residues and the destruction of the tunnels and nests of field mice and other pests. Apparently as far back as in the Neolithic Age, the first farmers would plow furrows across their fields using very simple tools that consisted of nothing more than sharpened wooden sticks. The oldest discovery of a plow in Europe was made in today's Switzerland, the tool's age dating to the middle of the 5th century B.C. Whereas the early farmers would still pull their plows themselves, draft animals were used later. The utilization of tractors only started in the 20th century. Accordingly, plows became larger and heavier.*

THE **MECHANIZATION** OF AGRICULTURE

The utilization of machines in agriculture was a consequence of industrialization. *In Europe and the United States, it began at the end of the 19th century and not only changed the rural economy but social structures as well. Mechanization was one of the triggers of "superfluous" farm help migrating to the cities. The first agricultural machines included tow trucks and tractors. In addition, agricultural tractors changed the livestock of the farmers who needed fewer draft animals, especially horses and oxen. Technological progress was also accelerated by the fact that it was no longer possible to cultivate the huge fields in the Midwestern United States without machines. The United States was also the country in which the first combines were used. One of the first tractor models in Europe was the Lanz Bulldog in the 1920s. A tractor, though, would remain unaffordable for many farmers for a long time. Their utilization only increased after the Second World War.*



A steam-powered agricultural machine from 1864. It did not tow the plow but pulled it toward the machine itself using cable drums around the water tank

SMART **FARMING**

How can the world population of nearly 10 billion anticipated by 2050 be fed? The Food and Agriculture Organization (FAO) of the United Nations has calculated that agricultural production would have to increase by 70 percent to achieve this. *But will this be possible without destroying our planet's ecological balance – particularly since most of the land fit for cultivation is already being used? The FAO sees increasing the yield per hectare as the only possibility. This could be achieved by mechanization, the utilization of agricultural chemicals and new plant varieties. A supplementary answer is: Smart Farming. It means that a farmer keeps an eye on various factors – the weather, moisture and mineral content of the soil, weed and pest infestation – and, based on these factors, is able to calculate the ideal application (timing, quantity, location) of fertilizers, water and pesticides using computer models. The GPS-controlled agricultural machines introduced at the beginning of the millennium were a step in this direction. The tracking system, for instance, prevents the machine from "overlooking" a section of the field or working on it twice. The machines by now are interconnected and able to autonomously work in concert.*

The cockpit of a modern agricultural machine (pictured here is a Fendt tractor) is loaded with high-tech. The vehicles can also operate autonomously and interact with others

THE SUBTLE **DIFFERENCE**

Are men interested in machines and women are not? Before this question provokes a public outcry, it's worth taking a look at a few statistics and the changes that are currently taking place. And, most importantly, to keep calm!

by Wiebke Brauer

More than 5,600 neuroscientific studies in the field of gender difference research have been published since the early 90s – according to an analysis by a working group of the University of Cambridge. A huge number which also proves that the gender discussion is in full swing and an extremely sensitive subject with a decades-long history. A recent example illustrates the point. In the United States, a man was fired in 2017 for having written a memo in which he claimed that there were genetic differences between men and women which manifested themselves in different inclinations. The fact that he was fired for this was met with astonishment in many quarters, particularly since in publications by U.S. psychologist and best-selling author Dr. Gregory L. Jantz we can read that "scientists have discovered approximately 100 gender differences in the brain." So, are these findings alone a reason for differences between the things that make women and men tick? Not necessarily. Numerous studies have emphasized that it's not just the hardware (brain) that matters, but also its programming (by the social environment).

Gender-neutral early education has become an important topic. Is this the reason the online shop of toy giant Toys'R'us can be searched by all kinds of criteria except gender-specific ones? But, on the other hand, why is there a market for special surprise eggs for girls? Wherever you look, the gender discussion is a battle on many fronts and quite a few people even feel that the playpen is the front line: toy excavators on one side and glittery Barbies on the other.

A man and a woman in front of a vending machine

That there are differences between males and females when it comes to dealing with technology has also been demonstrated in an investigation by German

research scientist Uta Brandes. Brandes, a professor of gender and design in Cologne, performed research into the behavior of people standing in front of ticket vending machines. She found out that men in front of the machines are less afraid of failure, preferring the trial and error method, while women spend more time thinking before pushing a button. But what do these and other investigations prove? How were they conducted? Do the findings represent tendencies, and what conclusions can be drawn from the outcomes? Plus, the question, again, is whether the respective behavior is a consequence of gender-stereotypical socialization experiences or biologically induced. So, we have a sneaking suspicion that studies often raise more questions than provide answers. Remarkably, researchers seem to have a greater interest in manifesting differences between men and women whereas the demonstration of similarities seems to be an attractive proposition to only a few. This minority includes neuroscientist Dr. Lise Eliot who doesn't think much of the pop psychology statement "Men are from Mars, Women are from Venus" – the title of a top-selling gender book from the 1990s. If there should be any difference at all, it might be that "Men are from North Dakota and women from South Dakota," she says. Accordingly, women could absolutely develop a strong interest in technology – provided that they're exposed to respective social conditioning in early childhood. So, girls, go for that toy excavator if you want to become engineers.

User affinity or true technology interest?

Before turning to our next topic, interest in technology, we need to ask how interest should be precisely defined in this context. Does serious interest start with the urge to dismantle a toaster or does just the thrill of using it qualify, too? And what do we mean by technology or, say machines, in the first place? According to Wikipedia, "A machine uses power to apply forces and control movement to perform an intended action." Claiming that the machine in its early days obviated the need for the physical strength of men and that men subsequently created a new, effective masculine identity for themselves – an identity combining the myth of being a creator, possessing untiring vigor and the glory of an inventive spirit – would be a step far into the realm of feminism. Or as author Georg Seeßlen once wrote: "Man merges with his machine into a new, powerful being, whereas Woman is liberated by her machine." Machines that liberate women? Now that immediately evokes memories of a blatantly chauvinistic advertising slogan used by a German household appliance brand that, for no less than 50 years, claimed to "know what women want," namely fridges, washers and dryers.

It's true that these technical devices are mainly operated by women. In Germany, for instance, still twice as often as they are by men. But notably, even "taz," a left-liberal German daily, in 2016 praised domestic appliances for their favorable effects on emancipation: "Automatic spin-drying, if you will, expanded the slogan of the '1968' women's movement, 'The personal is political,' by a technical aspect. Vacuum cleaners, irons and washing machines do not seem to be symbols of oppression but of liberation." The same article quotes an opinion poll conducted by the German TNS-Emnid Institute in which 44 percent of the respondents saw the washing machine as one of the most important inventions of all. South Korean economist Chang Ha-joon even lauds washers as "more revolutionary than the internet." So when creating an empirically supported connecting link between washing machines, technology and women, it's possible to come to the conclusion that

88 %

of all **patents filed** in the IT sector between 1980 and 2010 are based on developments by all-male teams. All-female teams filed 2 % of such patents.

Source: National Center for Women & Information Technology 2016

14 %

of all executives in **Silicon Valley** are women.

Source: Studie Fenwick & West 2016

females have absolutely no problem handling pioneering machines – but maybe women just celebrate the fact that they've successfully mastered the operation of a piece of equipment with less fanfare.

Share of women varies from country to country

Still, a look at the number of women in so-called MINT professions, in other words jobs in the fields of math, IT, natural science and technology (engineering), might suggest that women don't have a strong natural inclination to work in these fields. In Germany, the percentage of males is 70 versus 30 percent women. The situation in Poland and Spain is similar with a third of all budding engineers being females. By contrast, in Italy and Canada – at least in some natural science subjects – more than half of the college students are women, according to a report by McKinsey. India and Australia, as well, report a 50-percent rate of females among the graduates of a given year having majored in some fields of technology and natural science. So: "all clear" on the global gender front? Not quite: In Japan, for instance, only one in five graduates in a MINT subject is female, so there's still room for improvement. The differences in these statistics reveal that interest in technology does have something to do with socio-cultural conditioning.

Corinna Schittenhelm, Chief Human Resources Officer at Schaeffler, has internal comparative figures from the Greater China and European regions that underpin this proposition: "In Greater China, at 25 percent primarily at the managerial level, we have a high share of women compared to only eight percent in Europe. At specialist level, Greater China with a share of 33 percent is clearly ahead of other regions as well." On a global scale, the share is 21 percent at Schaeffler. However, there are signs of these percentages changing at Schaeffler as well. A look at trainee positions shows that the share of women there is 30 percent. Chief HR Officer Schittenhelm is hoping for as many female job starters as possible to climb up the career ladder. Her goal in this respect has been clearly stated: "Schaeffler wants to increase the share of women in leadership roles."

A figure from the United States illustrates that women in leadership roles have a pulling effect on other females. A current survey by the "FundersClub" has revealed that U.S. technology start-ups founded by women have twice as many female employees as peer companies with all-male entrepreneurs.

One thing, though, should always be borne in mind in the light of such statistics: An equal balance or – why not? – an even larger percentage of women than men in technical professions will not emerge overnight on the global job market. Even if 90 percent of all newly hired engineers were females, it would take years to arrive at an equal balance due to the current clear majority of men, and firing established men just for the sake of proportional representation would carry the concept of equal opportunity to an absurd extreme.

Electronic gadgets as gender-neutral status symbols

More appropriate today might be a look at the extent to which machines are moving in the direction of electronics in the age of digitalization and the resulting implications for the gender issue in technical professions. Obviously, a lot has happened in terms of attribution due to the invention of the iPhone. Technology no longer stands strictly for skill or force but rather for mental power and communicative strengths – in other words traits the possession of which both men and women like to claim. And – in totally gender-neutral ways as well – the smartphone has evolved into a status symbol at the forefront of gadgets, resulting in the creation of new technical affinities. So it's perfectly possible that the smartphone as a unisex showcase technology will have a disruptive effect on the gender dispute as well.

THE AUTHOR

*Even as a child **Wiebke Brauer** who hails from Hamburg enjoyed taking her toy cars apart and has been fascinated by machines ever since. However, in spite of her fascination with technology, ticket vending machines drive her to despair.*

FOUR **PIONEERS**

The interest of girls in technology is strongest between the age of eleven and 16, then dropping rapidly, according to a Microsoft study. One reason is the lack of female role models although they exist in all parts of the world.

THE AUTODIDACT

Aya Jaff is regarded as Germany's digital revolutionary. Born in Iraq, the 21-year-old taught herself to program and co-developed the online stock market game "Tradity." Today, she is studying economics and sinology in Nuremberg, writing a book about stock market fundamentals and says things like: "I love programming languages!" In 2016, she was the ***only German scholarship student at Draper University in Silicon Valley,*** *presented a concept for a German hyperloop system to the judging panel there and received an offer by Dirk Ahlborn, founder of Hyperloop Transportation Technologies, to work for him as a freelancer. She chose to finish working on her degree first – it will be interesting to see what happens after that.*

ayajaff.strikingly.com

THE FIGHTER

Sheryl Sandberg may be the ***most important symbol of female success in Silicon Valley.*** *For five years, she served as chief of staff to the U.S. Secretary of the Treasury in the Clinton administration, in 2001, she became vice president of global online sales and operations at Google Inc. and since 2008 has been Facebook's chief operating officer. In 2013, she released "Lean In: Women, Work, and the Will to Lead." Many women have been regarding the bestseller as their personal career bible. Since the unexpected death of her husband two years ago, Sandberg has been raising her two children alone. Her book "Option B" was released in 2017. In it she writes that she had to rethink feminism and that the quest for equal opportunities would have to put a much stronger focus on single mothers.*

THE TEACHER

Linda Liukas from Finland is fighting for more women to take an interest in computers *and founded "Rails Girls," an initiative enabling women to learn how to program. Now, free computer courses for women and girls are conducted around the globe from Cracow to New Zealand. She says: "Programming code is the language of the 21st century." In addition, the 31-year-old wrote "Hello Ruby: Adventures in Coding." She raised 380,000 dollars for the project, the largest amount of crowd funding to have ever been achieved for a children's book – the illustrations in the book, by the way, were created by Liukas as well.*

helloruby.com ***railsgirls.com***

THE FACTORY WORKER

Zhou Qunfei is the world's youngest self-made billionaire. The 47-year-old Chinese comes from a poor family, left school at the age of 16 and went on to work on the assembly line of a watch glass manufacturer. ***At the age of 22, she started her first company.*** *Today, her Lens Technology group produces cell phone touchscreens supplied to companies such as Apple and Samsung. Lens Technology employs 90,000 people and Zhou Qunfei's assets are estimated to amount to 11 billion dollars. She's known for occasionally reminding her senior managers to sit up straight in meetings. China is said to be a country that has more female self-made billionaires than any other, the reason being the promotion of equal opportunities by the communist party under Mao Zedong.*

» To create a new standard, it takes something that's not just a little bit different; it takes something that's really new and really captures people's imagination

Bill Gates

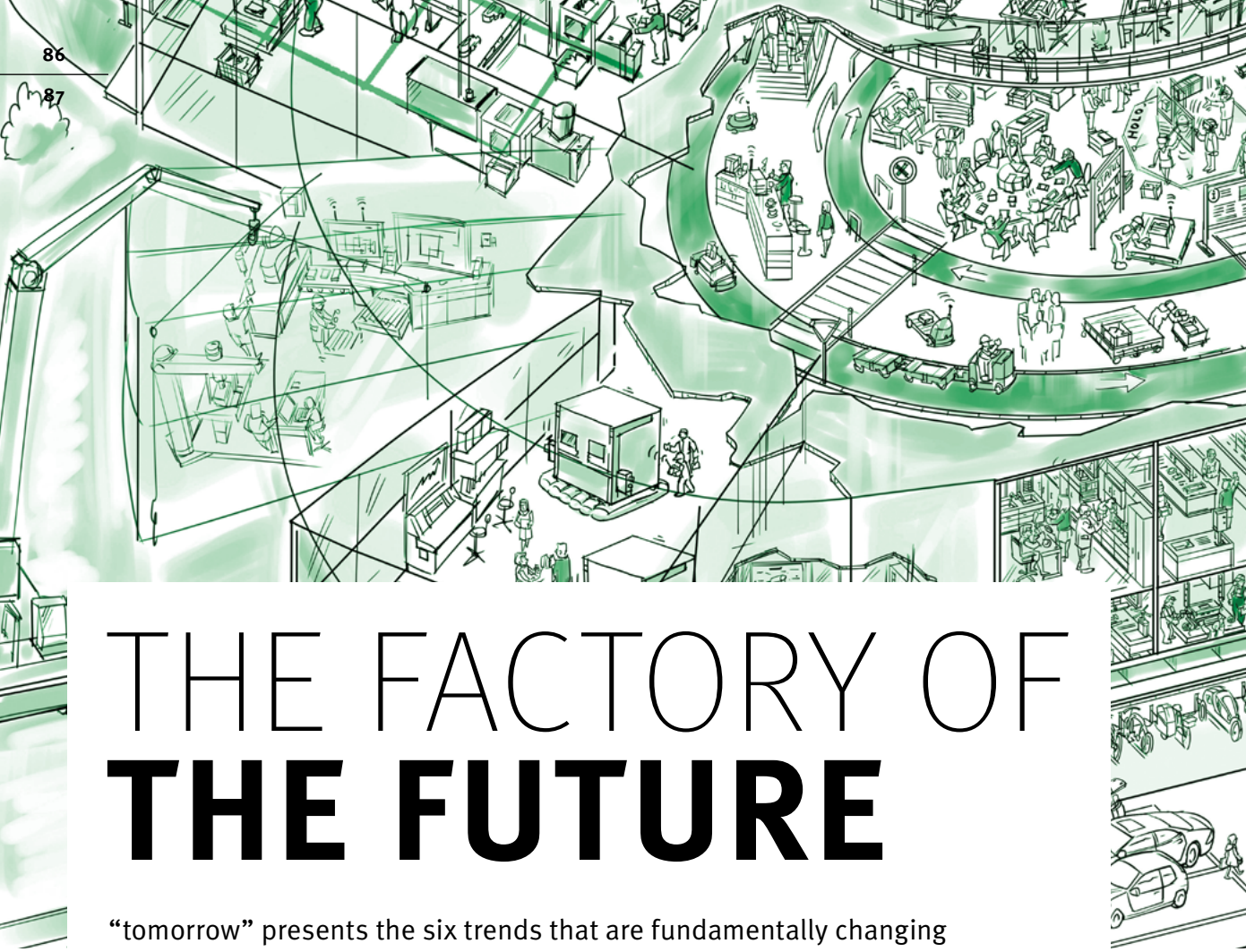
outlook

Technology for tomorrow

SMART **CITIES**

A test lab for technologies of the future: Bill Gates is investing 80 million U.S. dollars to purchase land for the planned smart city of Belmont for up to 200,000 people in the Arizona desert. In Asia, as well, big high-tech cities are on the drawing board featuring transportation concepts without privately owned passenger cars, with underground systems for deliveries and garbage disposal – all powered by the Sun and wind. In Masdar (UAE), small pods carry people to their desired destinations via a tunnel system. Neom in the tri-border area of Saudi Arabia, Jordan and Egypt is to become a new Silicon Valley with a 500-billion dollar investment. Machines and people will become neighbors there with robots performing a major portion of the jobs in administration and services.

MAP OF **AUTOMATED CITIES**



THE FACTORY OF **THE FUTURE**

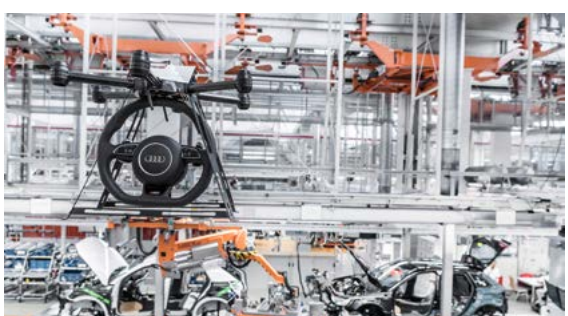
"tomorrow" presents the six trends that are fundamentally changing the manufacturing interaction of humans and machines.

by Dr. Christian Heinrich

HUMANS AND ROBOTS WORK HAND IN HAND

In a small factory hall of the "Future Work Lab" at Fraunhofer Institute for Industrial Engineering IAO in Stuttgart, Germany, ***a robot does more than just lend a helping hand to a human worker.*** *The "Stuttgart Exo-Jacket" is a so-called exoskeleton, a type of jacket that assists a factory worker in leg and arm movements, thereby helping the human to exert less energy, and facilitates movements that strain the muscles. The exoskeleton made of carbon is just one of several developments in which* ***machines and robots do not replace humans but make them stronger and enhance their capabilities****. Another example that can be seen at the Future Work Lab in Stuttgart is a smart worktable that completely adjusts to the human operator by automatically adjusting the height of the tabletop and using light cones to point out the next step in the workflow. And then there's also a type of flying servant,* ***a drone that delivers the required parts*** *to the factory workers. In all of these innovations, safety plays an important role as well. Mobile manufacturing assistants such as drones or grippers are equipped with cameras and sensors in order to be able to detect humans and get out of their way. In addition, the machines are supposed to be able to interpret human behavior based on the information they've gathered. A body lying on the floor, for instance, indicates an emergency that requires medical attention – so the machine calls for help: robots, our new congenial colleagues.*

In Audi's Smart Factory research project, the use of drones is being tested as well



AN ARCHITECTURE THAT DOESN'T SEPARATE BUT UNITES

Schaeffler's new production site in Xiangtan, China, to be launched in 2019 is configured like a butterfly. *The central building and adjacent material warehouse form the torso connected to which are the wings: four manufacturing halls, two on either side. All workers enter the factory through the central building and proceed across a type of backbone into one of the two wings. The central building and the backbone – both also referred to by Schaeffler's designers as the campus – are* ***intended as places for people to meet and communicate.*** *Be it a manager on the way to the office or a factory worker on the way to the assembly line – all of them will walk on the same paths for a while and can engage in an exchange. While this may sound like nothing unusual it's still a far cry from reality in many of today's factories. This exchange-promoting architecture, though, is just one of the aspects in which Schaeffler's production site in Xiangtan sets new architectural standards. Included in the concept design of the campus was* ***a feng shui consultant in order to incorporate the local culture right from the beginning.*** *The main entrance, for instance, opens toward the south so the energy of the Lian Shui river can be absorbed. In addition, the factory was constructed so that the employees are able to look outside from practically anywhere in the factory –* ***a considerable enhancement of workplace quality.*** *Sometimes future simply means – more daylight.*

APPROX. 2 **new factories** are planned to be built by Schaeffler per year, modeled after the "factory for tomorrow."

> ***We had plenty of specifications. Perhaps the most important one was bringing people together***
>
> Andreas Fuchs, Head of Programming at Henn, the architectural firm that has planned Schaeffler's first "factory for tomorrow"

Sets new standards: the architecture of Schaeffler's production site in Xiangtan that promotes exchange and is flooded with light due to ample use of glass

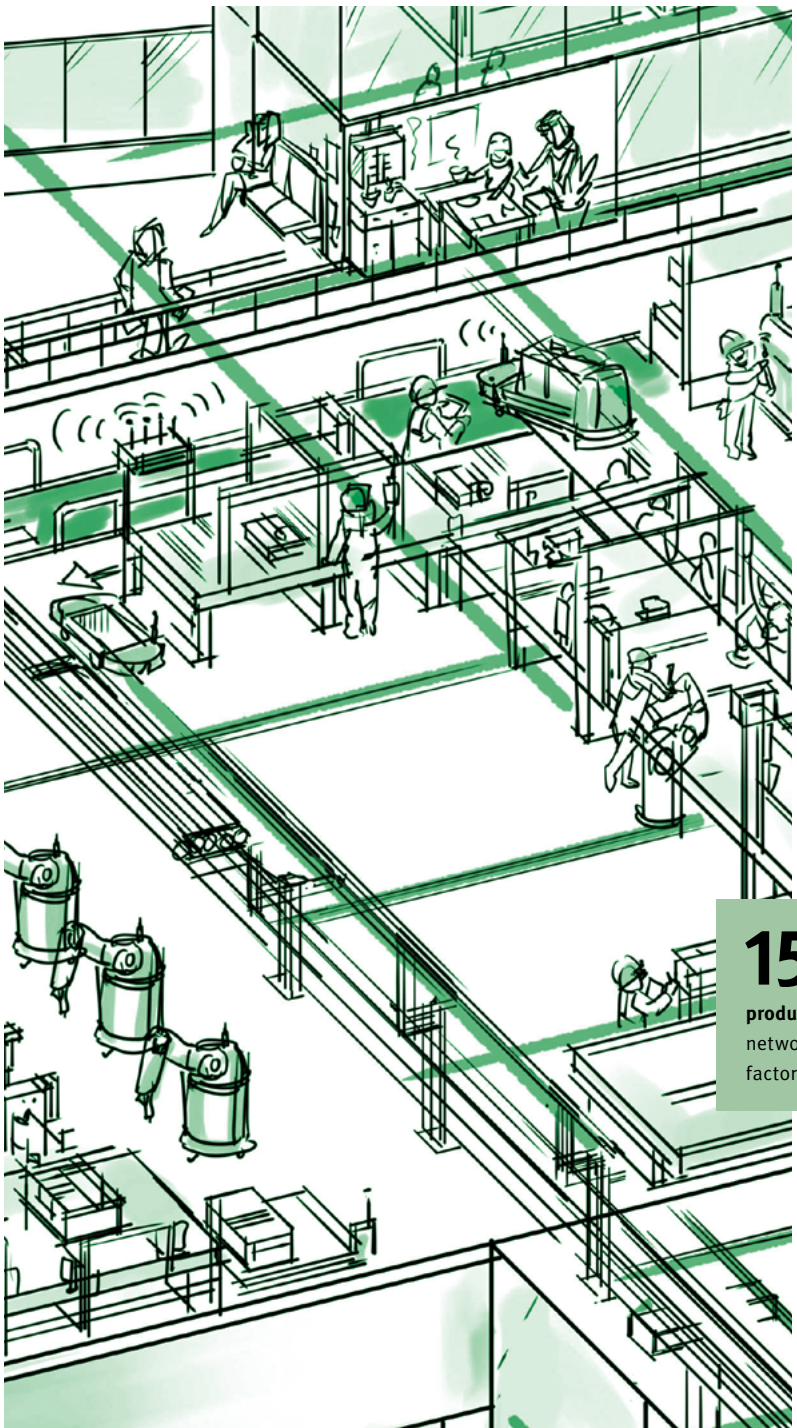
MORE THAN JUST THREE-DIMENSIONAL: AUGMENTED REALITY IN PLANNING, ASSEMBLY AND MAINTENANCE

What would it be like to walk around a production machine or a finished component to take a close look at it before it even exists? The concept of augmented reality (AR) makes exactly this possible. Smart AR glasses ***literally expand the horizons of both engineering designers and factory workers.*** *They project additional information and objects directly into the wearer's field of view – precisely where and when needed or desired. For the engineering designer, for instance, this means being able to realistically check if all the components in a visualized project can be assembled and what the final product looks like in detail. In a manner of speaking, it's* ***like taking a look into the future*** *that can predict and thus prevent a number of failures and bad designs. AR glasses can be of major help to factory workers as well by enabling design data shown in the display to be compared with the real-world image captured by a camera in the AR glasses to detect variations. The symbiosis of the virtual and real world is a gain for everyone. And if the tactile senses should be required after all, 3D printing technology enables rapid prototyping.*

> ***» Augmented reality and autonomous robots will merge with each other***
>
> Science fiction author Bruce Sterling in tech magazine "Wired"

SMART NETWORKING OF MACHINES AND COMPONENTS

They used to be silent servants without eyes and ears. ***Today, production machines, not least due to digitalization, are increasingly evolving into responsive and extremely alert partners.*** *Cameras scan their surroundings and, for example, prevent work accidents, microphones record noise and detect trouble, other sensors such as laser measure gaps, volumes, surface shapes or temperatures. The data exchange between machines enables them to capture working worlds on all-new levels. Both the machines themselves and central computers continuously improve their ability to correctly interpret data –* ***the key to success being smart software.*** *To drive this progress, Schaeffler not only cooperates with universities and research facilities such as Fraunhofer Institute. Recently,* ***Schaeffler also fully acquired autinity systems GmbH.*** *The IT firm specializes in machine data acquisition and interpretation. Time for the smart factory to move in? Actually, most of it has already arrived!*



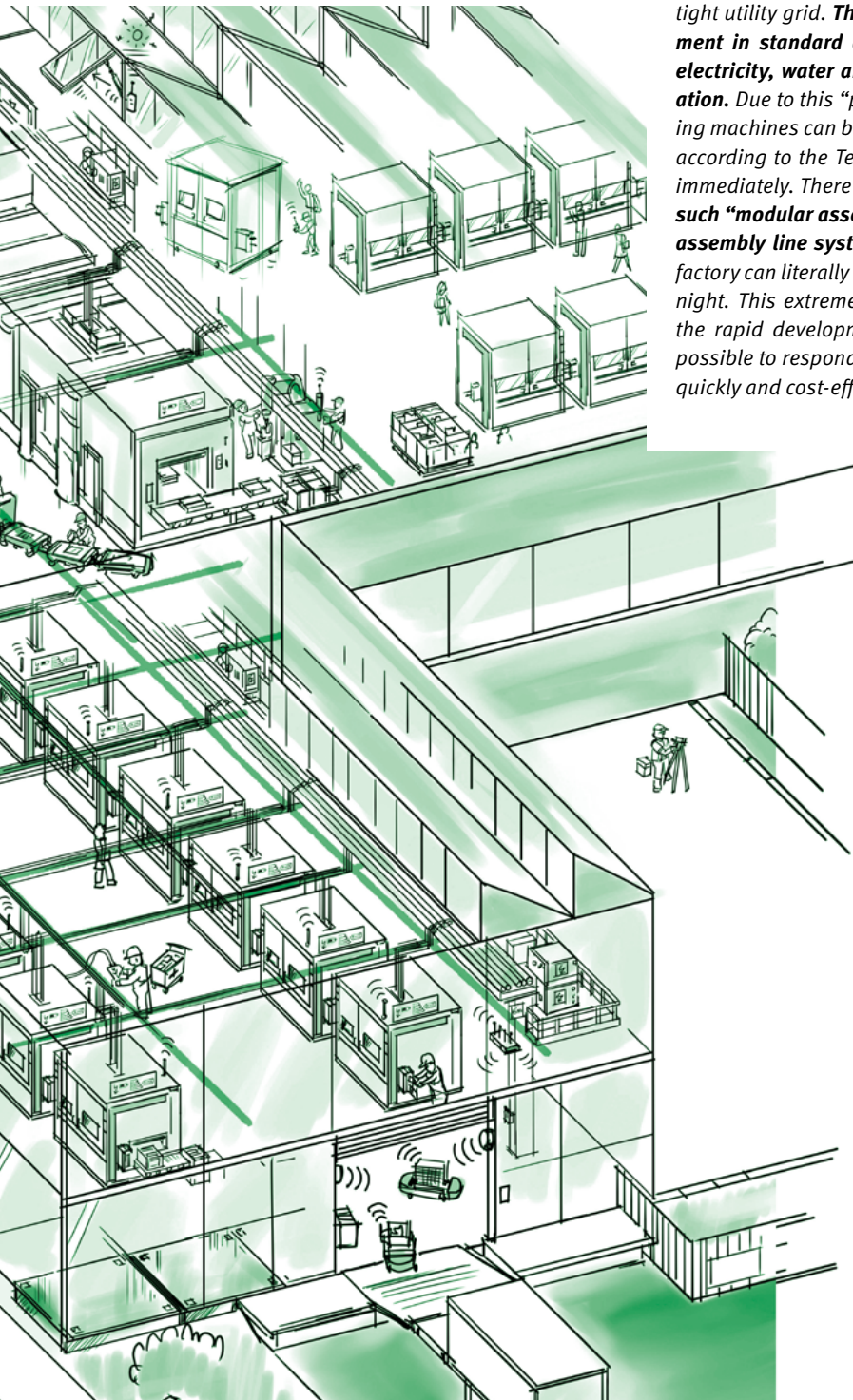
Networked machines in a smart factory ensure autonomous and fully automated end-to-end manufacturing material flow

15–20 %

productivity increases due to networked machines in smart factories are anticipated by experts.

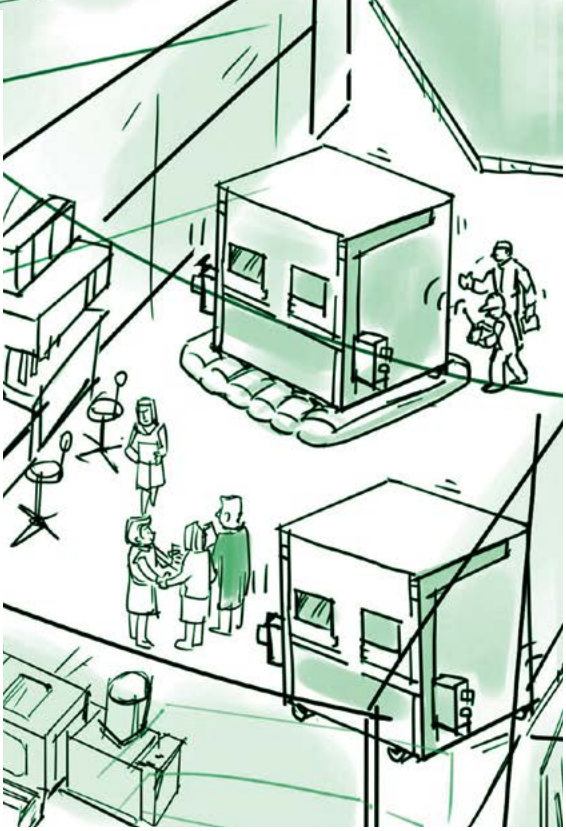
PRODUCTION PROCESSES TO BE ADJUSTED OVERNIGHT

Progress means speed. This also applies to manufacturing in particular. ***Production cycles keep getting shorter, and so does the life span of technological developments****. A manufacturing line that, once set up, will produce the same things for years or even decades – is history. That's why factories today and in the future have to be as flexible as possible. Starting in 2019, the new Schaeffler production site in Xiangtan will show what this looks like in real life. The large factory halls there will be provided with a tight utility grid.* ***This way modular manufacturing equipment in standard dimensions can be connected to the electricity, water and data network and taken into operation.*** *Due to this "plug and produce" concept, even existing machines can be shifted and fit into new environments according to the Tetris principle – production could start immediately. There are many indications that in the future* ***such "modular assembly" will displace the long and rigid assembly line system.*** *Flexibility even goes so far that a factory can literally be switched to a different product overnight. This extreme adaptability not only accommodates the rapid development of technology but also makes it possible to respond to economic trends and requirements quickly and cost-efficiently.*



» A standardized utility grid makes it possible for us to connect machines to the grid with greater speed and ease

Stephan Böhnlein,
Manager Corporate Factory Planning at Schaeffler



BIG DATA: THE SELF-LEARNING FACTORY

It's about the needle in the haystack. And about why we're going to increasingly find it in the future. And about what autonomous learning processes of factories have to do with all this. The haystack in this case is big data (see "Smart networking of machines and components"). ***But if you take a very close look at the huge volume of data generated in a digital factory you'll actually find the famous needles*** *with pinpoint accuracy. In this case, it's important correlations and information that can improve manufacturing operations. High-performance computers can already achieve this today. They analyze huge data volumes, recognize contexts and correlations and are able to predict events that can be prepared for. A few examples: Due to sensors and RFID tags, the material inventory is always in the computer. Over time, the computer learns how much is actually being consumed –* ***as a result allowing material to be ordered with increasingly greater accuracy.*** *Machine failures due to wear will soon be history too. Thanks to an accumulation of sensor data and information,* ***maintenance schedules can be optimized and parts exchanged before they fail.*** *The factory of the future will also be able to autonomously detect malfunctions in the production process by automatically matching machine parameters stored in the memory in the case of abnormalities with the actual values at the time of manufacturing.* ***In such cases, the factory of the future displays a trait humans sometimes lack: It learns from its mistakes.***

How, what and why? The YouTube clip about the Schaeffler factory of tomorrow provides answers

ROBOTS AT SEA

All hands, abandon ship! Autonomous vessels are supposed to sail the seas in the future – powered by electricity where possible. Here's a glimpse of the seafaring world of tomorrow.

by Alexander von Wegner

Quietly buried deep down in the history books, there's a piece of initial proof: a battery-powered tourist boat traversed the Spree river in Berlin as far back as in 1886. The boat was fittingly named Electra. Electric boats have been cruising on Lake Königssee in Bavaria for nearly a century as well. And a hybrid boat sails from the airport to downtown Venice in Italy – thanks to diesel power, it plows through the waves in the open sea at 30 km/h (18.6 mph), while in the Venetian lagoon the electric motor provides sufficient propulsion for 6 to 7 km/h (3.7 to 4.3 mph).

These uses of marine technology have several things in common. Relatively short routes result in frequent returns to the pier for recharging and the regular service of an entire fleet combined with low deadweight and payload have been paving the way for electrified propulsion in these cases: but what about ferries, freighters and other types of vessels?

Trailblazers on the hybrid wave

As far back as in the 1990s a diesel-electric hybrid boat was used as a supply vessel for oil platforms in the North Sea. Unlike the parallel hybrid powertrain typically used in automobiles, it was a series hybrid with several diesel generators producing the power for the electric motors driving the ship's propellers. In spite of the low efficiency of such serial drives, the solution may pay off in specific applications. One or several of the generators can be shut off, depending on the energy demand of the ship. In that case, the necessary generators will operate at optimum efficiency and are disengaged from the propellers. Consequently, in the event of frequent changes in propulsion power demand, the savings outweigh the lower efficiency. Solutions like these cut fuel consumption by up to 35 percent, compared with all-diesel powered systems.

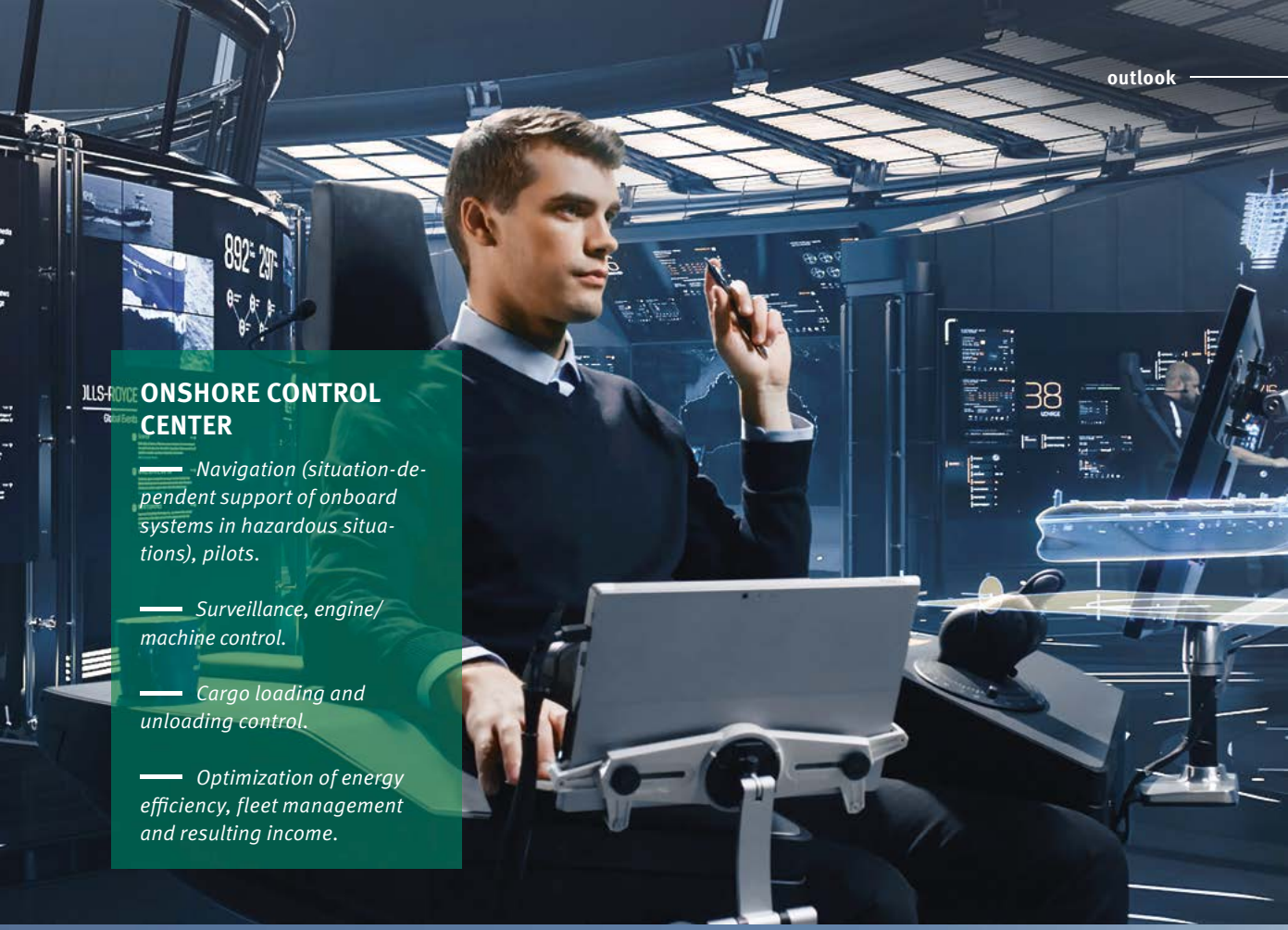
Another advantage of hybrid solutions is that they reduce the amount of air pollutants in port cities when the ships put to sea on electric power. Ferry operator Scandlines is already providing hybrid ferry service on several Baltic Sea routes. Its competitor Color Line is planning to launch service with the world's largest hybrid ship in 2019.

All-electric solutions are coming closer as well. In 2015, the first fully electric car-carrying and passenger ferry crossed a fjord in Norway powered by batteries. The "Ampere" built by the Fjellstrand shipyard needs 20 minutes for a six-kilometer (3.7-mile) distance in the Sognefjord. The two electric motors of the propulsion train supplied by Siemens each deliver 450 kilowatts of power output. The lithium-ion batteries tipping the scales at no less than ten metric tons (11 short tons) provide 1,000 kilowatt hours of energy – enough for several trips. During loading and unloading of passengers and cargo the batteries can directly be recharged. Plus, not a single gram of carbon dioxide is emitted as the electricity in this part of Norway is generated strictly from hydropower.

With respect to container ships, Norway is about to perform a pioneering feat as well. Yara, a global producer of fertilizer, and the Kongsberg shipping company

NEW APPROACH TOWARDS ENERGY

The solar sails on this ship concept are designed to convert the power *of the wind and Sun into energy for propulsion and power supply. In interaction with other technologies, Eco Marine Power, the company offering the system, intends to save up to 40 % fuel.*



ONSHORE CONTROL CENTER

— *Navigation (situation-dependent support of onboard systems in hazardous situations), pilots.*

— *Surveillance, engine/machine control.*

— *Cargo loading and unloading control.*

— *Optimization of energy efficiency, fleet management and resulting income.*

ON BOARD

— *Automated driving up to and including mooring maneuvers.*

— *Condition monitoring with self-diagnostics, remote maintenance and maintenance robots.*

— *Automated condition reports.*

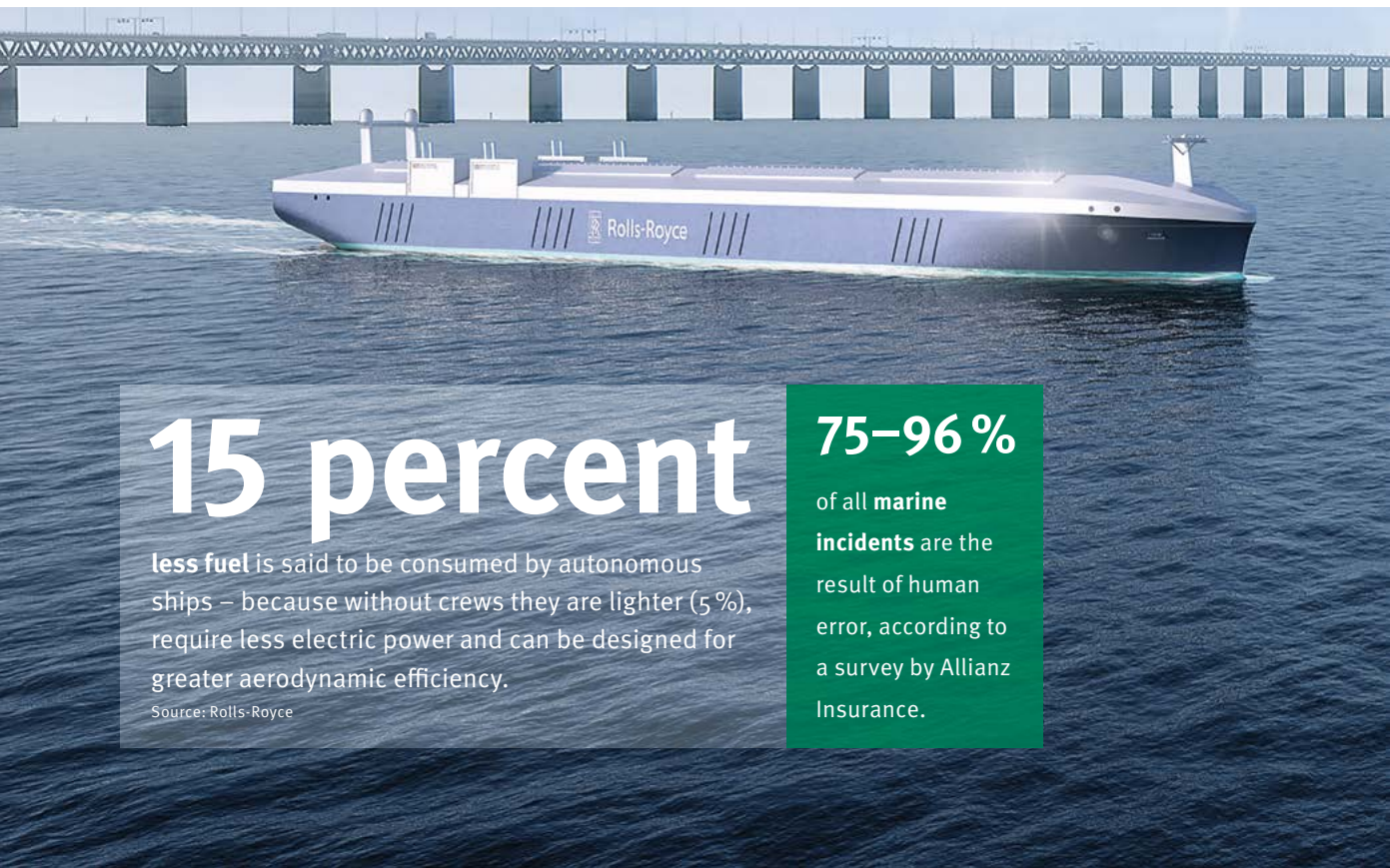
have formed a partnership to launch an all-electric ship as early as next year, its route covering three ports. This will remove about 40,000 truck trips per year from the region between Yara's plant in Porsgrunn and the ports in Brevik and Larvik. The more than 70-meter (229.7-foot) long container ship is said to achieve a maximum speed of 18.5 km/h (11.5 mph), designed for a cargo capacity of 120 TEU (TEU = 20-foot standard container) and use batteries for 3.5 to 4 megawatt hours of energy. The innovative container ship is planned to initially operate as a manned vessel starting in 2018, moving to remote operation in 2019, and expected to be capable of performing fully autonomous operation from 2020. The vessel will sail within 12 nautical miles from the coast. Three control centers are planned to handle all aspects of operation such as emergency and exception handling, condition and operational monitoring, decision support, surveillance of the ship and its surroundings and all other aspects of safety.

Autonomy provides new opportunities

Aiming for autonomous operation by 2020, the Norwegian partnership has set its sights on the same year as Rolls-Royce, the engineering company focused on power and propulsion systems having targeted the end of the decade as far back as in 2014. Without people on board there are many aspects that can be omitted in the ship's design, according to Esa Jokioinen, who leads the Blue Ocean Team at Rolls-Royce Marine. Be it due to the omission of crew's quarters or even the entire bridge, shipbuilding engineers enjoy greater latitude in terms of cost, weight and layout. By contrast, connectivity requirements will increase. Redundant systems and functions must be planned for as well, while permanent monitoring in real time helps cut service and maintenance costs. Here modular sensor bearings from Schaeffler are able to acquire data such as speeds, forces and temperatures. Condition monitoring systems such as FAG SmartCheck can diagnose the condition of rolling bearings and machine components.

At the same time, the ample stream of data opens up new economic dimensions to ship owners: fleets can be optimized and the planning of route and cargo combinations improved, plus new services will emerge. There will be new pooling opportunities and alliances, new forms of leasing, new online marketplaces for cargo logistics services, etc.

Whether all of these benefits will suffice to refinance the complex systems required for self-driving ships remains to be seen. Skeptics have their doubts. In an article published on the maritime-executive.com internet platform, the author, Captain George Quick, notes that crewing costs only account for about six



15 percent

less fuel is said to be consumed by autonomous ships – because without crews they are lighter (5 %), require less electric power and can be designed for greater aerodynamic efficiency.

Source: Rolls-Royce

75–96 %

of all **marine incidents** are the result of human error, according to a survey by Allianz Insurance.

SCHAEFFLER ON THE WORLD'S OCEANS

Schaeffler offers an extensive portfolio of bearings for marine applications. These are some examples:

For pipe-laying vessels such as the "Seven Navica," Schaeffler supplies heavy roller bearings for the huge reels on which the pipes are wound.

For cranes used on barges, Schaeffler's portfolio includes axial or radial self-aligning roller bearings. The bearings have to absorb the high weight of the superstructures, plus the load to be lifted, while withstanding enormous tilting forces.

For the "Pieter Schelte" construction vessel, Schaeffler has made the largest delivery to date of maintenance-free heavy-duty Elges spherical plain bearings. 240 bearings with outer diameters ranging from 400 to 1.060 mm (15.75 to 41.73 inches) have been installed in the topsides lift system for oil platforms. With a length of 382 meters (1253.28 feet), a width of 123.75 meters (406 feet) and 403.342 gross tonnage (GT), the floating giant that has been named "Pioneering Spirit" since 2015 is the world's largest ship built to date.

For marine propulsion systems and transmissions, Schaeffer's expertise is in demand as well. Self-aligning roller bearings used on giant cruise ships like the "Celebrity Solstice" have to absorb enormous thrust and weight forces and are designed for loads of up to 430 metric tons (474 short tons).

Together with ABB Schaeffler has modified its UniAir fully variable valve control system from the automotive sector for use in large engines with a minimum cylinder output of 400 kW being used in marine technology as well as in machine and stationary applications.

percent of the overall cost of running a ship. This is a fact that would not exactly speak in favor of automation. On the other hand, more than three quarters of all marine accidents are attributable to human error (see info box). The financial consequences of such incidents can be enormous which, in turn, would speak for "computerized captains."

Non-stop at sea

Maersk Line, the world's largest container shipping company, can imagine using robot ships from 2030 on. Business simulation games of the logistics group even involve unmanned ships sailing the seas non-stop without ever making port calls, being loaded and unloaded at sea by drones.

At any rate, Esa Jokioinen anticipates an exciting future, predicting that some of the aforementioned new services "will support existing market players and some will be disruptive – allowing a new player to enter the market and take over large shares of the business in the same way as Uber, Spotify and Airbnb have done in other industry sectors." Obviously, all this will also entail the need for extensive risk management because ships must still be controllable in the event of piracy, system failures, storms or monster waves. Nature will continue to be unpredictable in spite of automation.

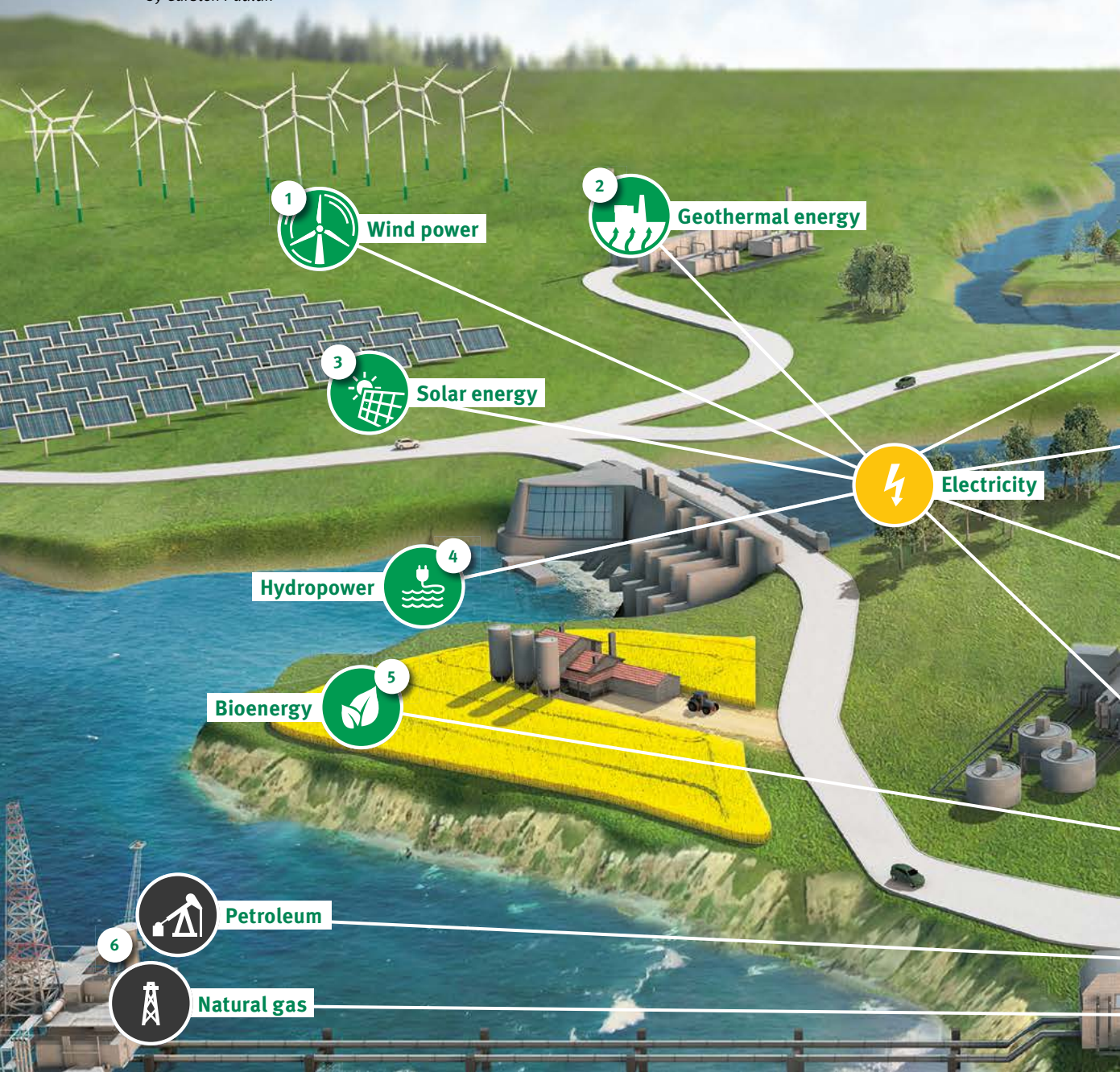
THE AUTHOR

*Dealing with the subject of maritime navigation clearly surpassed **Alexander von Wegner's** personal experience as a captain. The author's boating skills, if any, are limited to rowing on Hamburg's Alster river.*

NO MACHINE RUNS WITHOUT **ENERGY**

Sustainability of the production, storage and utilization of energy is the key to reducing harmful emissions and environmentally responsible management of resources. The Schaeffler technology group takes a holistically-visionary look at the correlations and interactions of this energy chain and aligns the group's strategies accordingly.

by Carsten Paulun



ENERGY PRODUCTION

A sustainable energy chain begins with renewable production of the required primary energy. Various forms of renewable energy are available to us today: wind and hydropower, geothermal energy, bioenergy and solar power. Schaeffler technology is utilized in all sectors.

1 WIND POWER

Our ancestors used wind as a source of energy more than 4,000 years ago, *both for locomotion in the form of sailboats and to power windmills. Wind turbines generating electricity have been used since the end of the 19th century. Specialty bearings for the rotor shaft, rotor blade adjustment and wind tracking for the nacelle and in the transmission and the generator play a major part in the efficiency of these giants that today are up to 200 meters tall. Schaeffler, the market leader in transmission bearings, has all the required rolling bearings in its portfolio. These bearings may have to withstand a weight force of more than 500 metric tons (551 short tons), operate with low rolling resistance and, above all, deliver reliable performance.*

2 GEOTHERMAL ENERGY

Our planet generates heat within its core. *The first three kilometers of the Earth's surface contain enough energy to supply the current world population for 100,000 years. As in the case of electricity generation from wind and hydropower, geothermal energy production uses a renewable source to drive a generator. Typically, this is steam from the Earth's hot strata.*

3 SOLAR ENERGY

The Sun is our largest and most important supplier of energy. *The fusion of hydrogen into helium nuclei in the Sun's core is the source of this energy. Theoretically, the Sun would only have to shine for one hour to cover the energy requirement of all humans for one year. We just have to make better use of this energy, like in the Noor power plant in Morocco where bearings from Schaeffler enable precise tracking of the adjustable mirrors.*

4 HYDROPOWER

We wouldn't be able to live without water. *65 percent of our body consists of water. It is also our most important source of renewable energy today. Be it from tidal, marine current, pumped storage or wave power plants – electricity can be generated just from the energy of flowing water. Low-friction and reliable bearing support for shafts, axles and the adjustable blades of turbines is essential to efficient operation.*

5 BIOENERGY

Renewable raw materials such as wood as well as agricultural raw materials and residual organic matter *contain chemically bound energy. Following the conversion of these materials, we use them as electricity, heat or in the form of fuels.*

6 FOSSIL FUELS

In spite of intensified utilization of renewable energy, fossil fuels such as ***oil, gas and coal*** *will continue to play a role in the energy and mobility sectors in the years ahead.*

» It is about a fundamental transformation of our economy, covering all sectors – industrial production, mobility, energy production, thermal insulation, energy efficiency

Angela Merkel, Federal Chancellor, pictured here with Schaeffler CEO Klaus Rosenfeld (center) and Automotive CEO Matthias Zink at the Schaeffler booth at IAA 2017

ENERGY STORAGE

Renewably produced energy in most cases requires intermediate storage before powering a machine. This particularly applies to electricity being generated at times when it cannot be used. Storing larger amounts of it for longer periods of time is only possible by indirect methods requiring a conversion into another form of energy. Schaeffler is pursuing a strategic expansion of expertise in this field.

1 STATIONARY ENERGY STORAGE

We are currently using three technologies to store electricity. *The most commonly known form is electrochemical storage based on the principle of the galvanic cell in batteries. Electrochemical methods include electrolysis as well. The second possibility is mechanical storage in gas pressure, pumped-storage and mass storage systems or flywheels. The third approach pursues thermal storage in water, salt, concrete, rock, ice or storage-optimized substances. The decisive criteria for the utilization of a particular form of storage are its efficiency, storage capacity, the duration of the storage or extraction process, the repetition frequency of the storage process and, for mobile uses, the weight of the storage device, plus relative and absolute costs in relation to the energy production and sales price.*

2 BATTERY

Super-silent and without exhaust emissions: Electric mobility sounds attractive, *especially if the electricity, as shown in our examples, is generated completely from renewable sources. For vehicles to be able to use this electricity they have to be able to store it. There is no battery available yet that is able to compete with fossil fuel in terms of space requirement, weight and energy density. Today's technology allows about 350 watt hours to be stored in a lithium-ion battery that weighs one kilogram (2.2 lbs.) One liter (0.26 gallons) of gasoline contains about 11,000 watt hours of energy. Experts at Schaeffler expect the capacity of batteries to more than triple by 2030 due to the use of new materials.*

3 HYDROGEN

Two thirds of the Earth's surface are covered by water, a compound of hydrogen and oxygen *that packs a punch: One kilogram (1.1 lb.) of hydrogen contains 33 kWh of energy – nearly three times as much as gasoline. In nature, though, hydrogen is almost exclusively found in chemically bound forms such as in water or in various gases like methane. A lot of energy is required to extract it from those bonds in complex electrolysis processes. The idea now is to generate hydrogen using a surplus in renewable energy, to store it and to subsequently convert it, for instance in fuel cells, into electricity or heat.*

» Electricity from renewable energies is not available around the clock. We need efficient means of storage to store energy and feed it back into the grid as needed

Prof. Tim Hosenfeldt,
Senior Vice President Corporate Innovation

4 SYNTHETIC FUEL

In relation to their volume, liquid fuels have the highest energy density of all fuels. *But they involve the issue of emissions. Exactly this is to be resolved by synthetic fuels. Unlike their natural relatives, synthetic fuels are not produced from petroleum but from other gases or biomass, using biological or chemical processes assisted by electricity from renewable sources. In addition, CO_2 is used as a raw material, in roughly the same amount as the one being released again in the subsequent combustion process. That's why this fuel is regarded as being CO_2-neutral. Other emissions such as nitrogen compounds are drastically reduced as well.*

5 BIOFUEL

Using renewable electricity, biomass can be directly converted into liquid fuel in a CO_2-neutral process. *Many parameters of biofuels are similar to those of gasoline or diesel, which means that they can be transported and stored just as easily. With just minor technical modifications, internal combustion engines can use this type of fuel without any problems.*

6 GASOLINE/DIESEL

The most commonly used fuels are gasoline and diesel. ***They're produced from petroleum in a petrochemical process*** *and, compared to their volume, have a high energy density which makes them particularly attractive for mobile applications. Their chemical energy is converted into propulsion energy by combustion.*

7 CNG/LPG

The ***gaseous form of petroleum is called natural gas*** *and available as CNG (compressed natural gas). Whereas CNG contains between 75 and 98 percent methane and is used for heating, electricity generation and propulsion, LPG (liquefied petroleum gas) consists of the gases propane and butane. They're liquefied and used in IC engines like gasoline.*

ENERGY UTILIZATION

Our energy hunger keeps growing around the globe. More and more machines are making life easier for us and more and more people populate our planet. Even if we continually intensify our efforts of producing renewable energies we have to utilize them as efficiently as possible. Therefore, Schaeffler has already put a large number of sustainable innovations into production – in both electric mobility and conventional IC engine technology. Under the banner of "Mobility for tomorrow," the global player is additionally working on visionary new drive concepts such as space-saving electric wheel hub motors.

1 ELECTRIFIED POWERTRAINS

There's no "one-fits-all" solution for the automotive future. ***Be it IC engines or electric motors, batteries or fuel cells or combinations of these elements – the engineers at Schaeffler are working on all possible types of powertrains.*** *In the field of electric mobility alone, Schaeffler will be investing half a billion euros and hire 1,200 new employees by 2020. In spite of all the optimization work done so far and further improvements expected in the field of IC engines, without electrification/hybridization, experts don't think it will be feasible to push mid-size or larger vehicle classes "below the future CO_2 emissions limit of 95 g/km," according to Professor Peter Gutzmer, Schaeffler's Chief Technology Officer. That's why Schaeffler has been driving the development of an extensive modular hybridization kit including the Gen 3 hybrid module with an integrated torque converter.*

2 FUEL CELL

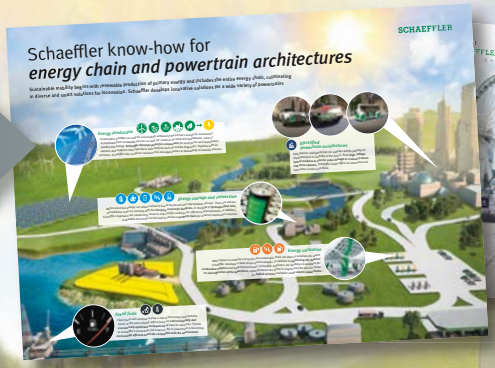
It's hard to believe but the functional principle of the fuel cell has been known since 1838. *In a nutshell: It converts the chemical reaction energy of a continuously supplied fuel and an oxidant into electricity and heat. However, the fuel cell did not become widely used because back in those days concerns about emissions were non-existent. The development continued only when astronautics and the military in the early 1950s were looking for compact and powerful energy sources. From a technological perspective, the hydrogen-air fuel cell in particular is deemed to have been fully developed. Its major advantage is that its only local emissions are water. In addition, fuel cells operate practically without any noise emissions and in combination with electric motors achieve clearly higher maximum efficiency (up to 60 percent) than gasoline or diesel engines (38 to 45 percent). Schaeffler engineers are conducting research into materials that will further enhance the performance of fuel cells.*

» Global reduction of emissions can only be achieved in a skillful interaction of the entire energy chain

Prof. Peter Gutzmer,
Chief Technology Officer Schaeffler

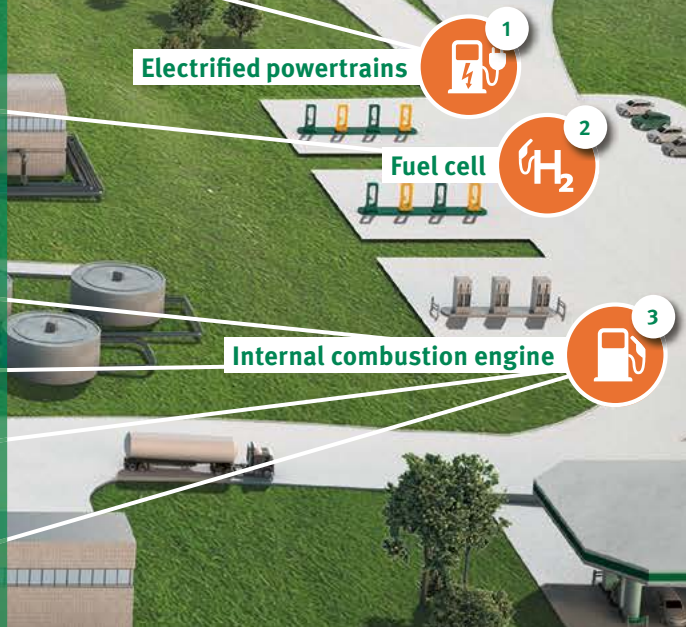
STORY POSTER

THE ENERGY CHAIN AT A GLANCE



3 INTERNAL COMBUSTION ENGINE

Even though electric mobility is making major strides, there'll be no way around the IC engine in the coming years – *and why should there? After all, the potential of the IC engine is far from having been fully tapped. "We estimate the remaining efficiency enhancement potential at the current state of production engines to be 20 percent for gasoline and 10 percent for diesel engines," says Schaeffler's Chief Technology Officer Prof. Peter Gutzmer. Schaeffler has developed a range of effective products to achieve further reductions of fuel consumption, recuperation being the only aspect that cannot be used with an IC engine alone. This is where mild-hybrid concepts using electric motors come in, a combination in which the IC engine will live on. If synthetically produced fuels are used in them as well then even the operation of existing IC engines can become CO_2 neutral.*



MIDGETS WITH POTENTIAL

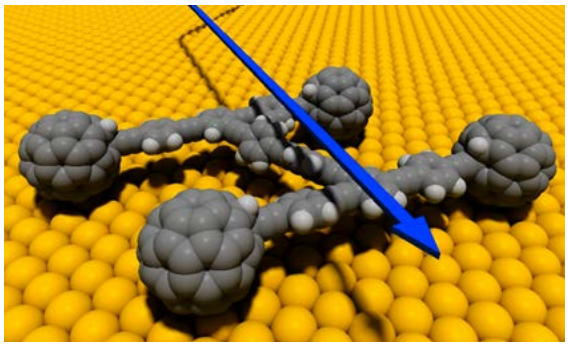
The Nobel Prize in chemistry last year was awarded for the fundamentals of building complex nanomachines. Following initial steps in the early eighties, this new field of research has since seen rapid development – opening up fascinating possibilities in sensor technology, manufacturing and medicine.

by Denis Dilba

Submarines, robots, windmills, cars, elevators and motors – as a non-expert you need a certain amount of imagination to detect the various and sundry things that scientists in the discipline of molecular nanotechnology see in the tiny molecules under a scanning tunneling microscope. In the future, for example, such artificial nanomachines are supposed to navigate through the bloodstream, diagnose diseases and deliver drugs directly to the place where they're needed. They could track down environmental toxins and directly neutralize them or put together chemicals just like their big robotic cousins assemble cars on a production line. In spite of such prospects, the imagination of the scientists who are building the first nanomachines today probably describes only a fraction of the possibilities resulting from this comparatively young field of research.

At the level of electric motors in 1830

"I also believe that there'll be a lot more to come," says Leonhard Grill, who leads the "Single-Molecule Chemistry" working group at the Institute of Chemistry at Karl Franzens University of Graz, Austria. "But until then, there are so many steps still to be made that today we can't estimate what exactly it's going to be. We're just at the beginning." The Nobel Prize Committee that awarded the Nobel Prize in chemistry last year to the three



Such a small, two-nanometer race car is driven by current pulses from an electron microscope

scientists Jean-Pierre Sauvage, James Fraser Stoddart and Bernard Lucas Feringa for the development of the fundamentals to build nanomachines compares the current state of their development roughly with that of electric motors in 1830. At that time, the motors were able to spin the first wheels or cranks, but not much more than that. Nobody back then had any inkling of how revolutionary this technology was to become.

The work of the nanomachine pioneers had similarly rudimentary beginnings. In the early eighties, the Frenchman Jean-Pierre Sauvage finds a way to link ring-shaped molecules together to form a chain. With that, the chemist from the University of Strasbourg creates the first possibility to transfer mechanical forces from one movable nanocomponent to another. The Scot Sir J. Fraser Stoddard, today a research scientist at Northwestern University in Evanston near Chicago, in the early nineties manages to thread a molecular ring onto a thin molecular axle and demonstrates that the ring is able to move along the axle. And the third scientist in the Nobel Prize trio, Bernard Feringa, a chemist at the University of Groningen, crowns this young field of research shortly before the turn of the millennium with the first molecular motor. Its molecular rotor blade continuously spins in the same direction when exposed to irradiation with light.

Nano race track as an incubator

The Dutchman is also the scientist to create the first nanocar in 2011. The molecular construct including the chassis and wheels has a size of two nanometers (i.e. two millionths of a millimeter or 0.0000000787 inches) and is driven by pulses of current from an electron microscope. The chemist and his team thus prove that it's possible to use modules of atoms and molecules to design machines that function in similar ways as those in the macroscopic world. The work of Leonhard Grill, among other things, includes such nanocars as well. Together with American professor James Tour from Rice University in Houston the scientist from Graz wins the world's first nanocar race at the end of April 2017 in which, similar to Feringa's race cars, the molecular vehicles have to be moved along a specified track by electrical impulses from a scanning tunneling microscope.

"The nanocar race was more of a PR gimmick – albeit one that was great fun, not least because we won," says Grill. Essentially, the object of such races is to learn more about the interaction between the surface and the molecule, in other words to optimize the nanocar's grip, in a manner of speaking. Grill and Tour have since developed an even more flexible light drive for a nanomachine. This "fuel," says Grill, offers several advantages: "With it we can remotely activate the machines and also move an extremely large number of molecules at the same time – in the future, possibly for systematic transportation of atoms or molecules."

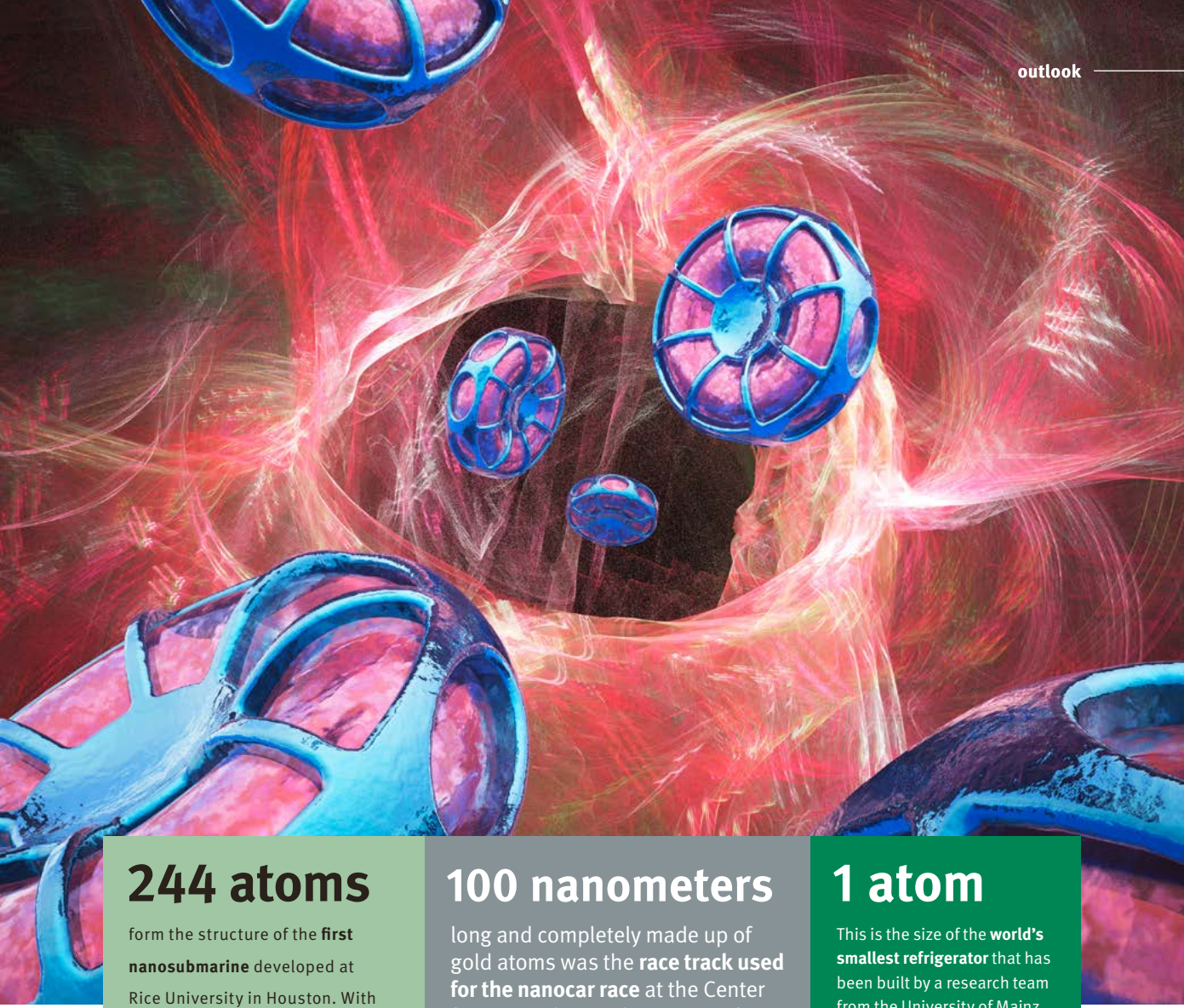
Nanomachines attacking malignancies in the body

This is a feat scientist X. Chris Le from the University of Alberta has just achieved for a special case. He attached artificial enzymes to a nanoparticle of gold in order to channel them into a cancer cell. The pathogenic cell produces a chemical substance which in turn activates a switch that has been incorporated in the artificial enzymes. Subsequently, the artificial enzymes begin to split certain molecules. At the moment, this is still only a principle, but it shows the direction of this research, as in the future it might be possible to activate drugs inside pathogenic cells.

James Tour is working on a version that uses an even more forceful approach when healing the cell is not the object. His latest molecular motor starts rotating at incredible speed under UV light. The more than two million revolutions per second suffice to drill through cell walls. The plasma will run out of the cell through the hole and cause the cell to die. In tests, Tour's nanodrills

» *We're just at the beginning*

Leonhard Grill, Leading expert at the University of Graz, about the current state of nanotechnology



244 atoms

form the structure of the **first nanosubmarine** developed at Rice University in Houston. With its light-driven motor it achieves speeds of two centimeters (0.78 inches) per second, a record for nanomachines.

100 nanometers

long and completely made up of gold atoms was the **race track used for the nanocar race** at the Center for Materials Development and Structural Investigations (CEMES) in Toulouse. The molecular race cars had a maximum of 36 hours to complete the distance.

1 atom

This is the size of the **world's smallest refrigerator** that has been built by a research team from the University of Mainz. The calcium atom trapped in a special magnetic field converts thermal energy into mechanical work and might be used to cool nanosystems.

have destroyed prostate cancer cells within the period of three minutes. However, at the moment, the method only works in in vitro experiments. Particularly the question of how future nanodrills and other molecular machines can be systematically steered to where they're needed is one of those yet to be answered. As UV light is absorbed by the human skin it's not of much use inside the body.

That's why Nobel Prize winner Feringa is starting to get impatient. He feels that his colleagues should now intensify their efforts of thinking about how the nanomachines known today can be put to use – so that imagination will actually turn into reality.

THE AUTHOR

*Mini submarines and other nanomachines that fight diseases in our bodies are much closer to reality than **Denis Dilba** thought prior to his research for this article. We're going to hear a lot from this fascinating realm of the midgets in the future, the writer ("Financial Times Deutschland," "New Scientist," heise.de) specializing in technology topics is convinced.*

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** Design of the PWG planetary screw drive. The spindle and planetary gears are produced in a chipless process. In the diameter range from 5 to 25 mm (0.19 to 0.98 inches) the PWG achieves the highest power density among Schaeffler's spindle drives and can even replace hydraulic drives.*

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