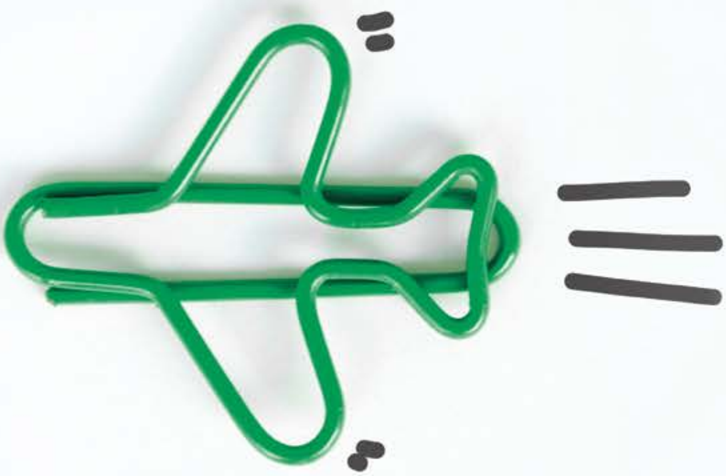
tomorrow

Experiencing technology with Schaeffler



The path to success

How good ideas turn into
game-changing inventions

Issue 2/2020 · Innovation

SCHAEFFLER

In|no|va|ti|on; - [in′ə vā′shən]

Innovation is commonly defined as the “carrying out of new combinations” that include “the introduction of new goods, … new methods of production, … the opening of new markets, … the conquest of new sources of supply … and the carrying out of a new organization of any industry.” […] In economics, management science, and other fields of practice and analysis, innovation is generally considered to be the result of a process that brings together various novel ideas in such a way that they affect society. […]

Source: Wikipedia contributors. (2020, November 12). Innovation.
In Wikipedia, The Free Encyclopedia. Retrieved 13:41, November 17, 2020,
from https://en.wikipedia.org/w/index.php?title=Innovation&oldid=988354740

Dear reader,

The focus topic of this issue of “tomorrow” addresses the main component of the Schaeffler Group’s DNA: innovation. Schaeffler has been at the forefront of the German Patent Office’s applications ranking for years. In 2019, with 2,385 patent applications filed, we claimed the runner-up’s spot once again: a result we’re very proud of. We’re set to cement our innovation leadership, and more: we’re set to extend it. In the Schaeffler Group’s recently launched “Roadmap 2025,” Innovation is one of three strategic priorities alongside Agility and Efficiency.

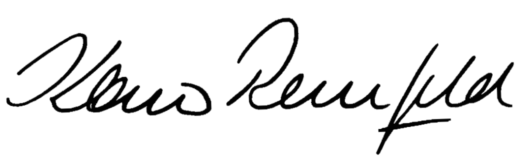
While reading this issue of “tomorrow,” which I cordially invite you to do at this point, it will become clear that innovation is more than just a good idea. Innovation is a process in which an idea merely marks the first step. The next one is to continue developing the idea into something that’s tangible and can be experienced. This development process may take years and setbacks are not uncommon. In fact, they’re part of the process and – provided that the right conclusions are drawn from them – may well be of value. However, the act of creating something new only turns into a breakthrough when users adopt the outcome as a meaningful improvement. Starting on page 32, you’ll find some examples of failed ideas. They also show that in many cases it wasn’t the idea itself that was flawed, but that other factors prevented its breakthrough. As mentioned earlier, innovation is a process involving many steps and challenges.

Innovation is of vital importance to a technology group with global operations like Schaeffler. That’s why we conduct research and development at more than 20 locations worldwide. In our SHARE projects, we work together with renowned universities in various areas and on several continents. A promising focus field of our R&D activities is hydrogen, which plays an important part on our path toward a carbon-neutral society. More on this starting on page 56.

Innovation leads to technological and social progress and we are the source from which it springs. Therefore, the objective of modern education must be to energize this source. Just imparting knowledge is no longer enough, because knowledge can now be accessed online anywhere anytime. Today and tomorrow, educators are challenged to inspire curiosity and a zest for learning in their students, to open their minds to new views and to encourage self-determined action. This is another topic covered in this issue of “tomorrow.”

Obviously, innovation provides new impetus to sports as well – from chess to soccer to sailing. At Schaeffler, we use our motorsport commitment as a high-speed innovation lab – now, by the way, complemented by the digital version on simulators. More on this topic starting on page 22.

Following a pandemic year that has been challenging to all of us, I wish you innovative energy aplenty for 2021. Stay healthy and stay optimistic.



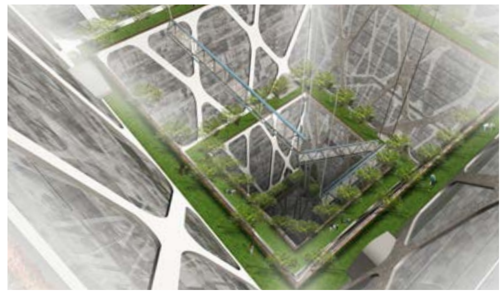
Klaus Rosenfeld
Chief Executive Officer

Global

A glimpse of the world

In motion

Innovations in the course of time



Here and now

Living with progress

Outlook

Technology for tomorrow

Global

A glimpse of the world

Innovation reloaded

Hurricanes are devastating forces of nature and unstoppable. Really? No, says OceanTherm, a Norwegian start-up that has launched a novelty which has actually been around for a while. Underwater bubbles that have been used for 50 years to keep fjords ice-free are supposed to stop future tropical cyclones. The idea is that, unlike in the cool Norwegian Sea, the bubbles in hurricane regions are supposed to cause cold instead of warm water to rise. It's a technology from the category of climate engineering, in other words, human interventions with weather phenomena. Hurricanes (aka cyclones or typhoons) are formed above ocean surfaces with water temperatures above 26.5 °C (79.7 °F). Even if this limit should not be sustainable, every degree gained in the process will mitigate the momentum of the storm by as much as 20 km/h (12.4 mph). To create an effective curtain of bubbles, an extensive pipeline system conveying compressed air must be created at a depth of more than 100 meters, either permanently installed or as a mobile solution using some 20 ships as a floating base. The startup is still in the process of looking for research and, above all, funding partners. The costs of the mobile solution are estimated to amount to some 270 million dollars per year. However, this investment would likely pay off if this type of climate engineering proved viable, because just in the United States, the expected damage caused by hurricane winds amounts to around 54 billion dollars per year, according to estimates by the U.S. Congressional Budget Office.

» ***You learn to know a pilot in a storm***

Lucius Annaeus Seneca, Roman philosopher

305 km/h (175 mph)

was the speed at which hurricane **Camille** swept across the Gulf of Mexico in 1969. A record! Only hurricane Allen reached the same speed off the coast of Texas in 1980.

45 kilometers (28 miles)

is the average **diameter of the eye** of a hurricane around which the storm rages. The entire vortex system is larger with potential diameters of more than 1,600 kilometers (1,000 miles).

3 names,

one meaning: the storms referred to as **hurricanes** in North and Central America are called **cyclones** in the Indian Ocean and the South Pacific region, and **typhoons** in South East Asia.

81 billion $

was the **damage caused by hurricane Katrina** that struck the southern United States in 2005 – making it the costliest tropical cyclone in history to date.

28 days

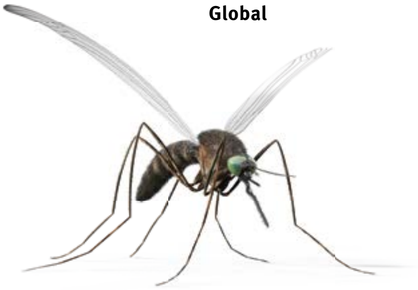
has been the **longest duration of a hurricane** on record. The storm swept across the Atlantic for nearly one month.

360°
Innovation

Facts, figures, oddities – a 360-degree view of the focus topic of this issue of “tomorrow.”

African Sunrise

The World Economic Forum has identified **five startup hot spots aside from Silicon Valley** as particularly fertile breeding grounds of innovation. Ranked in fourth place behind Singapore, Israel and South Korea is **Kenya, a surprise candidate,** but for good reason: Startups there can draw on a large pool of young talent from numerous universities. The fact that they’re native speakers of English is an additional benefit. Reliable internet, plus an excellent online payment structure built around the M-Pesa service cause many mobile app-based business models to prosper. In addition, the government with its “Enterprise Kenya” initiative assists entrepreneurs in growing and scaling their ideas. Kenya is also regarded as an attractive market for early 5G deployment.



OX5034

is the name of a **genetically modified mosquito** of which 750 million are planned to be released in the Florida Keys in 2021 and 2022. The blood-suckers have been modified to produce female offspring that will die in the larval stage **in order to decimate the population of the insects carrying diseases such as Zika and yellow fever.** Will this type of bioengineering on which hundreds of scientists around the globe have been working for ten years be a beneficial innovation or genetic Russian roulette? Critics warn that the project is a "Jurassic Park experiment" because potential long-term consequences have not been adequately investigated.

Words to remember

» They always say time changes things, but you actually have to change them yourself

U.S. pop art icon Andy Warhol

» The best way to have a good idea is to have a lot of ideas

Nobel Prize in Chemistry winner Linus Pauling

» Failure is an option here. If things are not failing, you are not innovating enough

Tesla CEO Elon Musk

» I love those who yearn for the impossible

Universal genius
Johann Wolfgang von Goethe

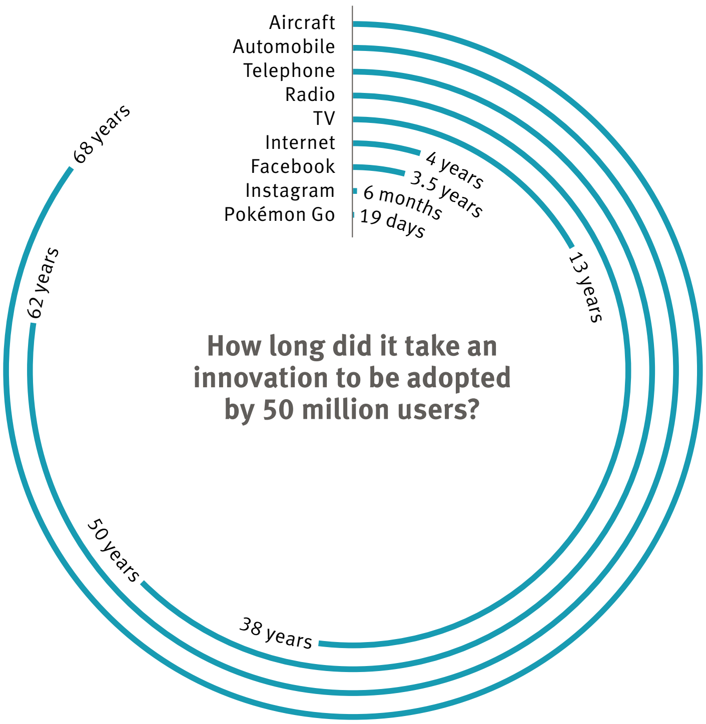
» At first, innovations are massively overrated, but in the long run, they're massively underrated

Former Area VP of Microsoft Germany Achim Berg

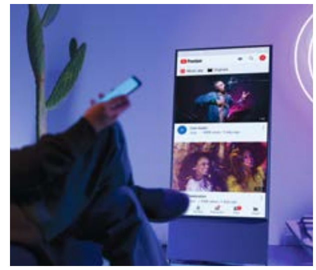
Sun catchers

Roughly a third of the worldwide energy consumption, and counting, is used for buildings. So, any idea that helps curb this trend is welcome. Engineers are pinning great hopes on **semiconductor solar cells with perovskite crystal coatings.** The coated areas in the nanometer range of thickness are so flat and transparent that they can be placed between the panes of double-glazed windows, where they work in two ways: When the sun shines, the perovskite crystals rearrange themselves, first into chains, then into plates and finally into cubes. Each new shape progressively tints the glass and reduces solar irradiation. This automatic tinting effect takes place within just a few seconds. **But the real kicker comes when the panes are dark and the window turns into a solar cell producing electric power.** That's when the crystal palaces of modern big cities will become solar power stations. At the moment, this is still pie in the sky, but scientists at the National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy are planning to build an initial prototype by fall of 2021. The German Fraunhofer Institute is investigating this technology as well.

Leaving the niche



Source: “Tech for Life” by Lars Thinggaard and Jim Hagemann Snabe

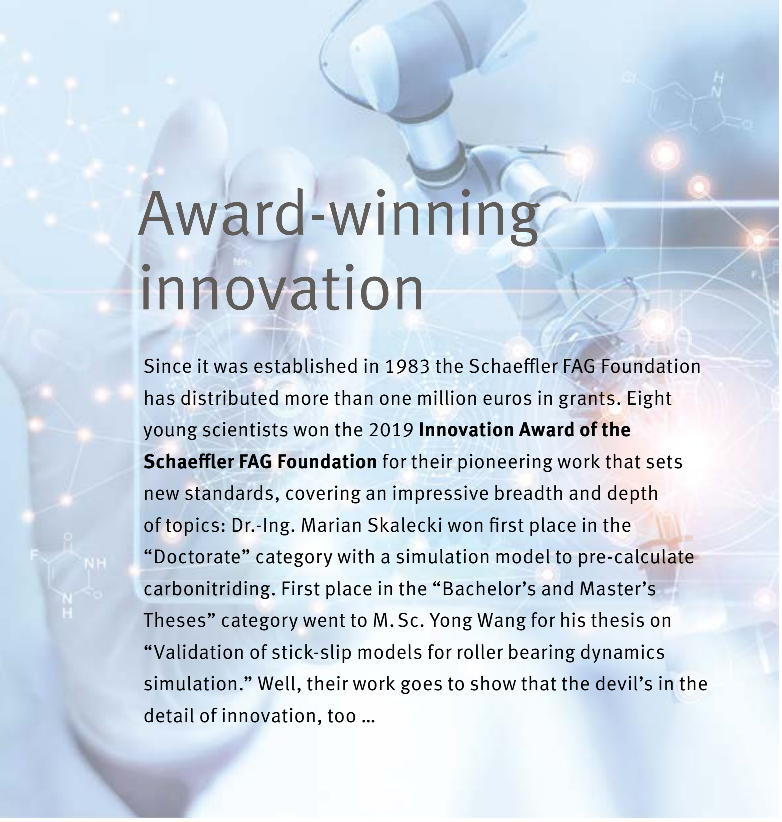


Are you watching vertically?

Arguably having been the most important invention of the 21st century, smartphones have changed our lives a lot – including our viewing habits. Hardly anyone holds a smartphone display horizontally to watch a video. **Will movie theaters and TV be following this trend?** With a ten-million-dollar budget, Russian filmmaker Timur Bekmambetov produced a vertical movie that’s planned to be shown by the Quibi streaming service, a kind of Netflix for vertical movies, and others. Samsung has hopped on the vertical bandwagon, too, by presenting a TV with a screen that can be rotated to a vertical view (pictured).

OPTIME from Schaeffler wins Innovation Award

The condition monitoring solution **OPTIME** developed by Schaeffler **is the winner of the 2020 Industry 4.0 Innovation Award.** The prize is presented by VDE-Verlag in collaboration with ZVEI (Central Association of Electrical Engineering and the Electronics Industry) and the Standardization Council Industry 4.0. OPTIME is a simple, cost-efficient and scalable tool for condition monitoring of entire plants and production equipment. The monitoring system is focused on electric motors, pumps, units and fans, in other words, drive systems and units being used in very large numbers and often hardly or just manually being condition-monitored due to a lack of economically and technically feasible solutions. Rauli Hantikainen, Senior Vice President Strategic Business Field Industry 4.0, is delighted about the accolade: “Our Schaeffler teams and development partners have displayed a strong sense of commitment in aligning the OPTIME concept with the needs and specific working world of our customers. We’re very proud of having been recognized now for OPTIME with the Industry 4.0 Innovation Award. The award motivates us to continue developing solutions for our customers with a pioneering spirit and innovative prowess.”



Award-winning innovation

Since it was established in 1983 the Schaeffler FAG Foundation has distributed more than one million euros in grants. Eight young scientists won the 2019 **Innovation Award of the Schaeffler FAG Foundation** for their pioneering work that sets new standards, covering an impressive breadth and depth of topics: Dr.-Ing. Marian Skalecki won first place in the "Doctorate" category with a simulation model to pre-calculate carbonitriding. First place in the "Bachelor's and Master's Theses" category went to M. Sc. Yong Wang for his thesis on "Validation of stick-slip models for roller bearing dynamics simulation." Well, their work goes to show that the devil's in the detail of innovation, too …

The internet as a supplier of ideas

Coming up with ideas for innovations can be difficult … or simply brilliant – when you don't look for them yourself but have someone else do so. That's what Vivere from Hamburg does. The international team around Sebastian Johnston **analyzes search queries on Google or Amazon by means of intelligent algorithms** and creates ad-hoc and in-house products from them. Everything happens at Vivere, from laboratory research to prototyping to mass production, from packaging design to marketing and sales. 55 proprietary brands and 700 products have been created in this way, for instance an anti-snoring spray and a nail polish that prevents fingernail biting.

Meals on 4 wheels and with 5G

Fast food fans watch out, your dreams have come true – at least in Shanghai. In the Chinese metropolis, Kentucky Fried Chicken uses **self-driving food trucks** – a perfect move in times of social distancing. The vehicles developed by Neolix reach a speed of **50 km/h (31 mi) with a range of up to 100 kilometers (62 mi), use 5G technology, and their batteries can be changed within 30 seconds.** Orders are placed on a roof-mounted screen and paid for by smartphone, and the chicken parts are deposited "fresh" behind a door. Even though Pizza Hut is the next fast-food giant to have expressed an interest in it, there are clearly healthier uses for the trucks than "meals on wheels." During the pandemic, for instance, the autonomous vehicles are used for contactless deliveries of medications to hospitals and have even helped with cleaning the streets.

Always follow the sun

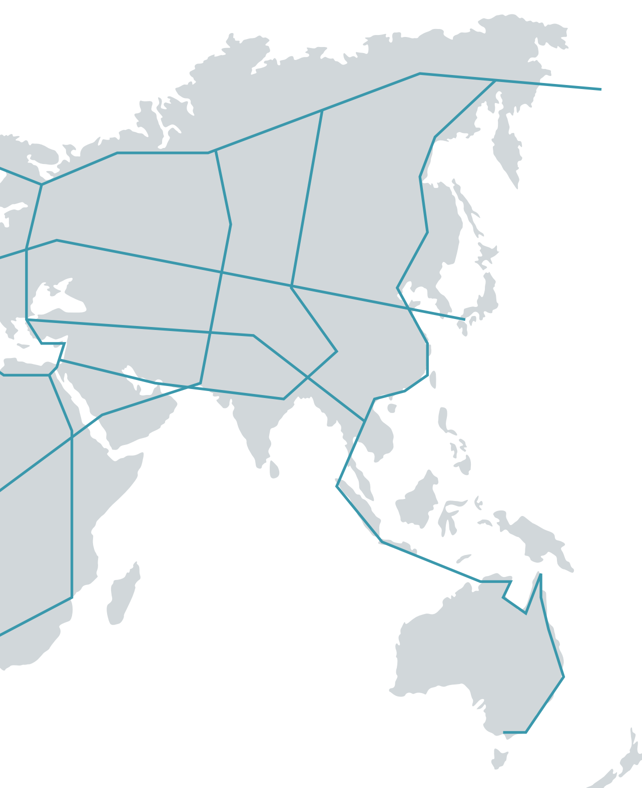
Sun, wind and water can supply sufficient energy to cover the worldwide demand. An efficient global power grid is an important key of innovation to achieving this goal.

By Dr. Lorenz Steinke

The hope that increasing use of renewable energies and the related geographic proximity between their sources and consumers would diminish the importance of power grids was short-lived. Today we know that this has not happened. Although photovoltaics, solar, wind and, above all, hydropower are by now contributing about one fourth to worldwide electricity production, they're not leading to grid independence. Regional self-sufficiency remains a utopian idea even in the 21st century. The opposite is true: Only a connection with many other producers results in the requisite supply security delivered by the small-scale roof-top power plant or the wind turbine on a village field.

Proximity to the consumer is not always an advantage either: For instance, photovoltaic cells in tropical regions harvest more than twice as much energy from sunlight as comparable systems in more moderate climatic zones north of the 40th parallel, where the hunger for electricity in cities like New York, Berlin, Moscow and London is greater than elsewhere. In interaction with prices for modules and inverters, which have been in constant decline now for years, solar parks in sunny regions are becoming increasingly attractive. Such a solar park is currently developing in the desert state of Dubai, where the production costs for one kilowatt hour from solar energy are supposed to drop to a mere 1.5 cents, which is a fraction of what electricity from conventional power plants costs. Consequently, there'd be plenty of good reasons for creating global power transmission lines so that electric snowmobiles in the icy conditions of the Russian port city of Murmansk could be operated with CO_2-saving solar power from the desert city of Manamah in the future.

This is how the global mega power grid of the Chinese GEIDCO project is planned to span the globe



High-loss power transmission

If it weren't for Q=I*L*R/Delta U, the formula that causes electric utilities and operators of transmission grids headaches worldwide. The formula expresses how electric current on its way through copper and aluminum suffers a voltage loss on every meter or yard it travels, while dissipating energy – usually in the form of heat – to the environment. To reduce these so-called transmission losses, the cross sections of the lines must be enlarged or the current stepped up.

Today, the so-called transport level of the synchronous grid of Continental Europe (formerly known as the UCTE grid) operates with 380 kV alternating current. Russia and Canada even transmit electric current at levels of up to 750 kV, with one to six percent of the transmitted energy being lost per one hundred kilometers (62 miles). The loss, for instance, increases when the line bundles heat up to 80 degrees centigrade (176° Fahrenheit) under load or emit their typical crackling noise via so-called corona discharges on hot summer days. The electrical energy lost by buried-cable transmission on the way to the consumer amounts to yet another fourth.

AC vs. DC

That's why direct current has been seeing a revival for some time now by means of so-called high-voltage direct current (HVDC) transmission lines, for instance in the case of connections to offshore wind farms or point-to-point connections across long distances. That's where 3-phase AC technology reaches technical limits, because its lines act like large electric capacitors. The line losses of direct current are up to ten times smaller, but the transformer and circuitry technology at the end points is clearly more complex. HVDC lines through the Skagerrak, for instance, have been reliably connecting the North-European synchronous NORDEL grid with the synchronous grid of Continental Europe since 1977.

In spite of such connections the European synchronous grids are far from being a highly efficient "supergrid" although respective initial concepts were developed even before the turn of the millennium. In such a supergrid, huge amounts of electricity could be hauled across longer distances – or imported, for instance from North African countries with plenty of wind and sunshine.

An agile and efficient distribution of large power packages from renewable energies across national borders or continents would also alleviate fears of capacity bottlenecks due to so-called "dark doldrums," because there's always a place in the world where the sun shines or the wind blows. That's why supergrids would marginalize the requirement for huge storage capacities and conventional base-load power plants, according to energy expert Dr.-Ing. Gregor Czisch.

In view of so many positive aspects, the question arises why a supergrid isn't crisscrossing our planet yet. "While regional supergrids could bring cleaner, more efficient, and more cost-effective electric power systems, their development is complicated by a number of factors," explains Jessica Lewis, senior research analyst with Navigant Research. "These include limited political will, lack of harmonized standards, complex authorization and permitting procedures for cross-border transmission projects, and a conventional view of energy security as a national imperative, with individual countries reluctant to leave their supply security in the hands of others."

Initial supergrid threads have been connected

Even so, the number of individual high-performance power transmission lines for renewable energy keeps growing. Offshore wind farms in the German North Sea deliver their electric power to the mainland via HVDC lines. The largest HVDC underground cable project in the world is to be implemented along the German SuedLink corridor. In the United States, such a connection exists for wind power across a more than 1,000-kilometer (620-mile) distance from Oklahoma to Tennessee. In Brazil, 600 kV flow through a 2,400-kilometer (1,500-mile) long HVDC line, and in the so-called Champa Project in India, it's 800 kV across 1,365 kilometers (850 miles).

The construction of HVDC lines beyond the magic 1-megavolt limit is pioneered by China, which has been transmitting direct current with 1.1 megavolts from Changji to Guquan across 3,000 kilometers (1,860 miles) since 2019 – with a loss rate of less than five percent across the entire distance. For comparison: only 380 kilometers pass through the German 3-phase AC grid. Via the energy agency GEIDCO initiated by Beijing, the country is planning to drive the construction of a world-spanning energy grid by 2070, even across oceans. Estimated costs: a mammoth amount of 38 trillion U.S. dollars. The enormous costs are no doubt another reason why the global supergrid is currently very large-meshed.

The Chinese megaproject, as a supergrid level, is intended to interlink the continental transmission grids. The cumbersome shipping of energy across the oceans on board of gas and petroleum tankers could then become history and, instead, Saudi Arabian desert sun might heat the fishing lodges on the Aleutian Islands via electric power cables.

The author

From his desk at home, he can almost see Europe's two largest transmission towers in Hetlingen/North Germany connecting North and Central Europe as part of a 380-kV 3-phase AC overhead power line intersection. Electrical energy plays a central role in **Dr. Lorenz Steinke's** life, and even though his first solar pocket calculator from childhood days didn't always work reliably, he's already looking forward to low-cost photovoltaic power from Dubai.

Innovative technology from Schaeffler for sustainable power

Mobility is intended to become more climate and environmentally friendly – for instance by means of electrically propelled vehicles. However, this only makes real sense if the electric power for them is produced in clean ways. Solar, hydropower and wind power systems are suitable for this purpose. Schaeffler supplies crucial components and system solutions for all of them.

Wind power

Worldwide, near-ground-level wind power has the potential of delivering output of more than 400 terawatts – about 20 times the worldwide energy requirement. As one of the world's leading roller bearing manufacturers and development partner of this sector, Schaeffler, with the requisite extensive expertise, has been producing large-scale bearings and other components for wind power systems for more than 30 years. State-of-the art calculation and simulation programs optimize their design. Schaeffler bearings are utilized in assemblies ranging from the rotor shaft to the transmission and generator to the wind tracking and blade adjustment systems. Schaeffler's digital condition monitoring ensures high system availability and reduces maintenance requirements.

Hydropower

Hydroelectric power stations around the world produce clearly more electricity than nuclear power plants and satisfy more than 16 percent of the global electrical energy requirement. Beyond the conventional utilization of hydropower, new technologies using the movement of waves and currents in the oceans to produce electricity are increasingly making headway. Be it for conventional or new approaches to harnessing hydropower – Schaeffler offers suitable bearing solutions and engineering resources.

Solar power

Every day, the sun supplies enough energy to cover the worldwide requirement of a whole year. To achieve maximum capacity, solar power plants have to operate at particularly high levels of efficiency, precision and failure safety. As a development partner and supplier, Schaeffler is currently engaged in a range of projects such as parabolic trough, solar tower, Fresnel and Dish Stirling power plants. Schaeffler offers a diverse portfolio of rolling and plain bearings for the tracking systems of solar power stations.

The mastermind

Gyro Gearloose is the innovative mastermind in Disney's Duckburg universe. Claiming that "U name it I can make it," he invented amazing things like think boxes, magical vibration sensors and bike saucers. As we're seeing today, many of his inventions were definitely those of a true visionary. But read for yourself ...

By Björn Carstens

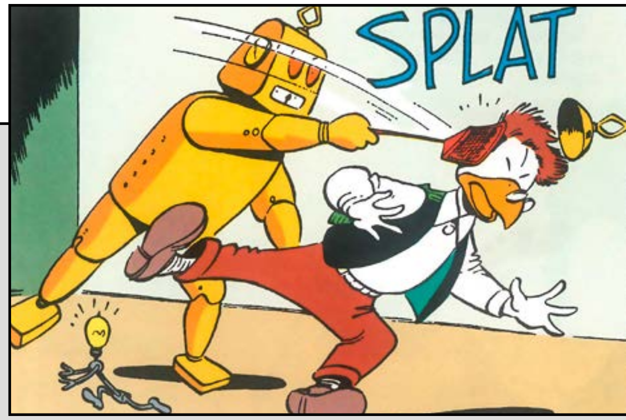
»» *Only half of my inventions turn evil. The rest are just wildly misunderstood*

Gyro Gearloose

Mobility

Mobility is a topic that literally moves the world. The residents of Duckburg, spearheaded by Gyro Gearloose, are no exception. The master tinkerer (promoting himself with slogans like: "Inventions anywhere anytime!") with the distinctive pince-nez glasses sitting on his beak was an incredibly prolific creator of contraptions to get himself and his fellow citizens from A to B. Gyro is particularly fond of flying. "You float and are now finally free," Gearloose muses about an age-old dream of humanity, be it with motorized fairy tale classics like witches' brooms or flying carpets, with hoverboard-like flying scooters – see Hollywood classic "Back to the future" – or with flying cars. Obviously, there's also a flying saucer in Gyro's garage. Off you go. But, like so many geniuses, the clever chicken is at odds with his work. "Good-bye you cushioned chariot," he rails at his flying saucer in the story "Man versus machine." "My trusty legs will be my steeds from now on!" Gyro embarks on an adventurous march – and has to be rescued by two robots. Technology is both a blessing and a curse. Gyro's creator, Carl Barks, has his cartoon character struggle with this ambivalence time and time again, symbolizing humanity's plight. Ultimately, faith in technological progress wins out, because it can produce positives, provided its aims are not just focused on moving faster and flying higher, but also on efficiency, for example. Efficiency is always specified for Gyro's inventions. In fact, it would be fair to call the ingenious cartoon character an environmental pioneer: an inventor, as it were, with a commitment to saving the world. Fond of nature and animals, he develops a noiseless rocket (1952, the year in which Gyro is born, intersects with the beginning of the jet age), uses biofuel (his bike saucer zooms 1,000 miles over the clouds on a pint of peanut oil) and has his car powered by a perpetual motion machine while a solar cell supplies the onboard electronics with sustainable energy. This makes filling station attendant Donald Duck see red. Clad in his sailor suit, Donald blows his top: "Aw, ye cats! If your doggone new-fangled car is such a self-curing everlasting, automatic wonder, why do you come in here, anyway?" Wishful thinking. This is exactly the kind of car we'd love to have today. In 1964, another one of author Carl Barks' intriguing stories illustrates what his untiring innovator does with a jet-pack. Gyro doesn't just dash through the airways without rhyme or reason, oh no. He applies his newfound skills to paint a bridge in practically no time. It makes you wonder if Barks had any inkling that his idea was a forerunner of drones as airborne helping hands?

Smart machines



Thanks to Gyro Gearloose, artificial servants regularly see the light of day in the Duckburg comics universe. Machines, robots and universally skilled computers meant to make everyday life easier fascinate the mental acrobat who has a seemingly boundless wealth of creativity: “I believe that I’ve invented something really sharp here – a robot that can act by picking up my thoughts.” The creator names its innovative yellow tin box Roscoe – apparently, the choice of female names expressing gender equality was not yet in vogue more than 60 years ago. Talking about Alexa, Siri and company, Gyro’s creator Barks draws the early form of today’s commonly used voice-controlled assistants as far back as in 1958, just two years after one of his compatriots coined the term “Artificial Intelligence” and long before AI moved into millions of households. The thinking robot, though, still has some flaws (“Two sensible questions I ask, and get two senseless answers”) but, lo and behold, is also reminiscent of Siri (“I don’t understand your question”). Even so, the ingenious engineer keeps experimenting with the fusion of machine and biological intelligence. On humans and animals. The merging of two worlds. However, with one of the Beagle Boys, the law-abiding inventor throttles back his intelligence machine to half-speed (“If he thinks I will help him succeed at such dastardly mischief, he is dumb”). Using a think box and intelligence beams, Gyro “Doolittle” Gearloose enables animals to talk and a wolf instantly expresses a voracious appetite for roast duck. Yummy! Understandably, this causes a red alert in Duckburg. The metaphysical character of many of his machines is another intriguing aspect, first and foremost, Gyro’s legendary machine fueled by imagination. “Under the hood one experiences everything one imagines in one’s imagination, to a certain extent really,” enthuses the iconic inventor, providing his early, albeit advanced response to Virtual Reality.

Gyro Gearloose’s name in various countries

- **Danish:** Georg Gearløs
- **Dutch:** Willie Wortel
- **Estonian:** Leidur Leo
- **Finnish:** Pelle Peloton
- **French:** Géo Trouvetou, Géo Trouvetout
- **German:** Daniel Düsentrieb
- **Norwegian:** Petter Smart
- **Polish:** Diodak
- **Portuguese:** Professor Pardal
- **Slovenian:** Profesor Umnik
- **Spanish:** Ungenio Tarconi

4 different flavors can be produced by Gyro’s **hay-to-milk machine**: vanilla, chocolate, caramel and cow flavor. Subsequently, his synthetic food production culminates in a survival kit that generates the ingredients for all kinds of dishes exclusively from sand and air: a highly relevant topic today as research scientists have been working on artificial meat and vegetables from the laboratory.

> "No mechanical monster is going to take over the greatest fun I have – work. (...) Duckburg isn't ready yet for total automation."

In 1964, Gyro Gearloose is horrified to see that his vision of a fully automated city has mutated into a nightmare. The Duckburg universe suffers a deeply depressive episode, because there's hardly anything left to do for its residents. Partly automated hovercraft with self-activating "blowhard devices" safely haul Donald & company to their 10-minute shifts in robot-dominated factories. Slides replace the need to walk. And "recording devices in our pillows play scads of knowledge into our empty minds while we sleep." How boring for Huey, Dewey and Louie! Even toys play automatically. Gyro's in the doldrums, too, because a humanoid machine has taken over his inventor's work. The ingenious chicken with the chin-strapped yellow hat finally loses his cool: "Grab a tool und start wrecking this – this Monsterville!" Whank! Bong! The halls of the steel mills reverberate with joy: "The automatic gizmos are kaput, men! Who's for using their hands? Me! I! Me, too! Me, also!" This is another short story taking cues from the prevailing mood in those days, because just two years earlier the world's first robot had started to work at automaker GM's plant in Detroit, evoking amazement and worries, because even back then the diligent machines inspired people's imagination about all the things that could be done with them while also stoking fears of mass layoffs. Today, we know that both machines and digitization have created more jobs than they destroyed and are relieving us of many tedious and unrewarding tasks.

Gyro's loyal companion

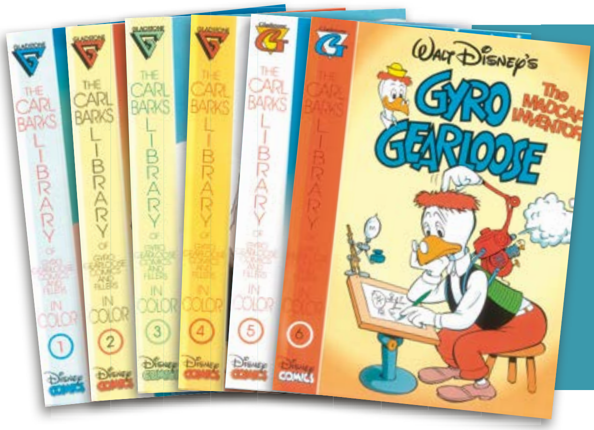
"All my friends are leaving me. Nothing remains for me, as my little helper," Gyro once wistfully complained. Little Helper – a small humanoid robot constructed from pieces of metal and seals, and a light bulb for a head – accompanies Gyro on nearly all of his adventures and gets the inventor off the hook more than once. In stark contrast to most of Gyro's inventions, his cute sidekick proves to be near-perfect. That's why it's deemed to be almost impossible that Gyro created Little Helper himself. But, then, who did? This will remain a mystery which cartoonist Carl Barks never revealed in his lifetime. Little Helper just suddenly appeared in his imagery like an electromechanical foundling and went on to become a regular feature. A small humanoid robot as an omnipresent friend and assistant in any of life's situations. Honestly: who wouldn't like to have something like that?

Climate engineering

When all attempts to protect the climate fail, geo engineering – also referred to as climate engineering (see page 6) – is deemed to be a possible plan B. While many concepts today are still in their infancy, the clever chicken Gyro Gearloose developed a number of ingenious prototypes and solutions such as a "futuristic city with built-in weather controls… for a perfect climate." His rain maker (light sprinkler, 2.49, big gully washers 4.98) that saw him waddling in Benjamin Franklin's footsteps has become an iconic creation. While Franklin, the scientist, uses a kite made of thunderbolt-attracting wooden sticks and silk cloth for his lightning rod, Duckburg's universal genius reverses the principle. Using a model of the same design, he sends a thunderbolt – equating to about 280 kWh of electrical energy – back into the clouds, opening heaven's floodgates. Gush! ("Looks like you'll have a use for those lightning bolts, after all, Gyro!"). Once again, the comics super-brain seems to be a step ahead of his human fellow scientists, who only started trying to harness the energy in thunderbolts for technical purposes in the late 1980s. With modest success, whereas Gyro as a rainmaker might be able to rake in one dollar after another: not a bad idea for business in times of increasingly longer periods of hot and dry weather.

Gyro's intellectual father

Carl Barks purportedly once said that deep down inside he was an inventor because he kept coming up with the craziest things. His ingenuity arguably made him one of the most popular authors and illustrators in the Disney universe. Barks is the "father" of Scrooge McDuck and the Beagle Boys, among others. In 1952, the American author created Gyro Gearloose – as a quiet, likable and extremely unpretentious character. Barks needed an inventor for a brief gag and later said that he'd have adjusted the size of Gyro's body to Donald's or Uncle Scrooge's from the get-go had he known that he'd be filling a whole book with stories about him. Like Gyro, Barks worked largely in seclusion at his home in San Jacinto (California). He'd leave his home no more than twice a month to present his stories to his publisher. Initially carrying only Walt Disney's name, fans were kept in the dark about the author's identity for a long time and so honored him by calling him "The Good Artist." Barks died in 1999 at age 99.

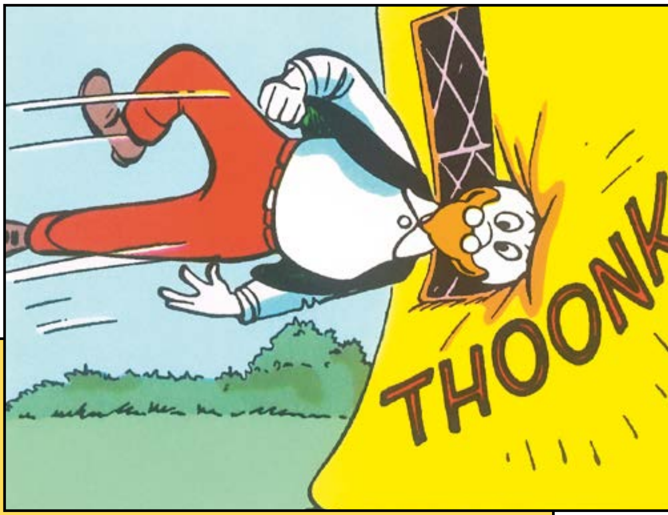


The Barks Library

encompasses the collected works of Disney's iconic comics author Carl Barks which he wrote and illustrated from 1942 until retiring in 1966. The Gyro Gearloose Special consists of 6 volumes including a lexicon of all his inventions. From A like in Alternate Life Machine to Z like in Zoom-Stick.

» Now, try to keep up with my mind-numbing genius

Gyro Gearloose



Material optimization

Refinement of materials, optimization of surfaces: Technology in this field is progressing at top speed. Schaeffler is continuously expanding its expertise in coating technology, too. In the context of research, the developers from Herzogenaurach and their comics colleague are kindred spirits, albeit with differences in areas of emphasis. Admittedly, the clever chicken tends to come up with rather wacky innovations. Or have you ever heard of fur on cold door knobs? Duckburg's rumor mill has it that people suffering from rheumatoid arthritis are forever thankful to him for this brainwave. Just like Scrooge McDuck, for whom the super-brain has built an indestructible money bin – from a newly created element called fortismium (derived from Latin for strong). A substance harder than diamonds on the Mohs hardness scale. It's just super-annoying when you've forgotten the code for the armored lock with 17-fold protection. Gyro's novel foam turns into a super-hard substance, too: "This stuff comes out of the can like whipped cream, but it hardens into concrete in two minutes!" That sounds like a pipe dream of real-world civil engineers. Talking about construction, Gyro opts for the fast track as well. A house without brick and mortar, without wood and metal, built from a "modern plastic material. The whole house can be inflated like a balloon." This is basically an early example of the classic bounce house for kids' parties not invented until 20 years later, in 1977, by an Austrian. It's not known whether or not she was a Gyro Gearloose fan.

The next level

Innovative technologies create new opportunities for athletes. An interdisciplinary overview – from chessboards to race tracks.

By Olaf Jansen

Chess

Data to move

Successful contenders in today's chess matches are those who know as much as possible about the ways their rivals play the game. The reason is that the contenders know each other and the preferences of their opponents: their favorite openings, strategic moves, variants in the middle and end game. Databases and computer programs have created transparent chess players.

That's why in today's top-caliber chess competitions being prepared is the name of the game. Knowing in advance how to best respond to the opponent's maneuvers leads to success. On the other hand, players must continue to play in variable ways and surprise their opponents, who are equally prepared, with ever new variants and strategies. Up until the mid-1980s, the situation was completely different: chess was an analog game. Grandmasters like Anatoly Karpov used to dominate this discipline strictly because of their experienced courses of action, fast thinking and strategic skills on the chessboard.

Until Garri Kasparov came. Or the computers. Or both. Because when Kasparov snatched the world champion's title from his rival Karpov in 1985, he also achieved this with the help of the new technologies. Kasparov is deemed to be one of the first world-class players to have carefully calculated his games by means of computer programs and to have had his computers play and gauge diverse variants. Assisted by the new technologies, Kasparov acquired leading-edge knowledge that rivals like Karpov weren't able to compensate for in spite of all their imagination and playing strength.

Kasparov's title win rang in a new era in chess that was subsequently shaped by databases and computer programs. ChessBase is the worldwide leader in this sector. The Hamburg-based company built a huge database on which by now more than eight million previously played chess games can be accessed. In addition, the providers from Hamburg are selling computer programs enabling players to analyze chess games and play countless variants in a matter of seconds. The most prominent client is the reigning world champion Magnus Carlsen. The 30-year-old Norwegian ascended to the world champion's throne in 2013 – naturally also with the help of modern technologies. Like his rivals, Carlsen is supported by a team that assists him in his work with databases and computers. On his own, the "Mozart of chess" would never be able to calculate his way through the chaos of variants, positions, openings and strategies.

4 hours

of learning. This is how long it took the artificial intelligence AlphaZero to defeat Stockfish, the leading database-supported chess program to date. In 2017, AlphaZero won 28 of 100 games, 72 ended in a draw and none was won by Stockfish. A year later, AlphaZero's tally after the 1,000-game duel involving changes in time for consideration and more data sources for Stockfish reflected 155 wins, 839 draws and 6 defeats. AlphaZero is regarded as a true game changer in the world of chess and stuns audiences with unconventional strategies. Even World Champion Magnus Carlsen adapts the AI to his game without any reservations. "In essence I've become a very different player in terms of style than I was a bit earlier and it's been a great ride," he says. However, AlphaZero's abilities aren't limited to chess. AlphaZero decided the duel against AlphaGo, the computer that in 2016 defeated the world's best Go player for the first time, 60–40 in its favor – after just eight hours of learning.

The Norwegian Magnus Carlsen became the youngest grandmaster in the history of chess at the age of 13 years and 4 months. Now 30 years old, he's held the top spot in the world ranking since 2011 – even though in October, after 125 consecutive wins, he lost two games for the first time

In the “SAP Interactive Data Space” on the training grounds, all sporting and business-relevant data of Bundesliga soccer club TSG Hoffenheim are merged. Coaches and players use the space for interactive team meetings and data-based strategy planning

Soccer

AI kickers

The first thing a professional player from TSG Hoffenheim does when he wakes up in the morning is listen to his inner voice: “Did I sleep well? Am I on top of the world or rather tense? Am I in good health?” Then the player of the Bundesliga club will start the club’s app on his smartphone and send the responses to his employer at the training center.

“In the last ten years, a lot has happened in professional soccer in the wake of digitalization. The development of technical opportunities has fundamentally intervened with the processes of this game and massively changed it,” says Rafael Hoffner, who has been leading the IT & Infrastructure department at TSG Hoffenheim since 2009.

While coaches used to be “soloists,” a whole team is now sitting on the bench of every Bundesliga club. All of them are connected to each other via an internet port and a network. Tracking systems provide running and dueling information about the players, and match analysts distributed across the stadium additionally deliver their impressions and data. The strategy is: stay as variable as possible,

1 million data points

A small tracking system worn directly on the body is all that’s needed to capture a soccer player’s movements. Obviously, it shouldn’t restrict the players’ ability to move. That’s why companies like GPS-Sports and VX Sport install the technology in a sports bra. It sits on the torso without impeding the athletes during their training sessions. Via a GPS signal, the gadget creates a movement profile, records speeds, and analyzes efficiency on the pitch. In a 90-minute training session a million data points are generated. Via radio communications, the data are sent to computers on the edge of the pitch or can be read within a few seconds by means of a docking station.

keep surprising your opponent. “Match plans are subject to constant change today. A team wants to remain as unpredictable as possible for its rivals,” says Hoffner.

But there’s more to all this than just the 90 minutes on matchday. TSG as a pioneer in its field has additionally installed a huge video projection screen and some 80 sensors on the soccer training pitch that transform the complex into a 3D map. The players in turn are wearing sensors in a chest strap and on their back during practice units. Hoffner: “This provides us with information about the physical condition of the players and their cognitive performances. We receive answers to detailed soccer-specific questions. For instance: Did a sprint make sense in a particular playing situation? Did the player move skillfully in a spatial context?”

By now, most top-flight soccer clubs have largely followed suit in terms of technology, although the Hoffenheim team still benefits from its early strategic interest in innovations. “We’ve been gathering data about our players for more than ten years, so we’re familiar with their strengths and know in detail what we need to work on,” says Hoffner. As a result, a player may have to spend more hours working with the sports psychologists while another one will intensify his work with the footbonaut, a ball machine for enhancing a player’s passing and shooting techniques.

In addition to the footbonaut, Helix, a virtual room, can be used by the players to hone their cognitive skills. Video footage displayed across the 180-degree projection area of the screens puts the players into a variety of playing situations, requiring them to respond accordingly. The training is centered on concentration, perception and peripheral vision.

At Hoffenheim, they know a lot about their players. Will the wealth of data soon culminate in a predictable strategy? “No,” says Hoffner, “humans will always remain unpredictable to some extent. And that’s good!”

The digital image of real-world playing scenes (shown here in a demonstration at the SportsInnovation event of the Deutsche Fußball Liga) assists teams in match analysis and enhances the stadium experience of the fans

Sailing

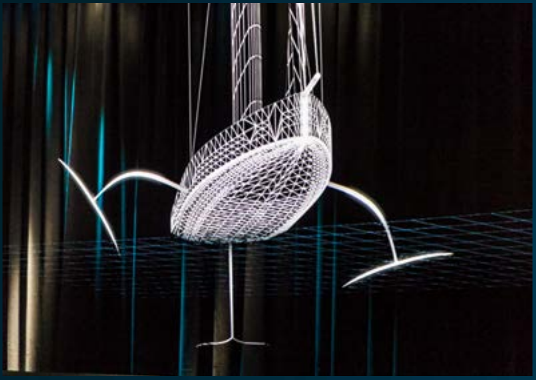
All chips on deck

When Jochen Schümann sailed to his first in a total of three Olympic gold medals in Montreal in 1976, he did it completely on his own. He was solo-sailing a Finn dinghy and used the prevailing forces of nature strictly by instinct: the wind direction and wind force, water currents and assessment of the small- and large-scale weather developments. For the first time Schümann back then proved his by now legendary intuition and talent for sailing to an international audience – and at the mere age of 22 outperformed all of his competitors.

Sailing, today, only has little to do anymore with the sport back in those days. Schümann says: “In the course of time, sailing has become increasingly complex. The progress made in terms of hardware and data analysis has caused an enormous evolution of the sport and turned it into a veritable science.” Lighter and lighter materials for the hull, sails, ropes and masts have been making the boats faster and faster. Most recently, foil technology causing the boats to “fly” across water on wing-like hydrofoils has led to an explosion of speed that was hardly considered to be achievable. These gliders can reach speeds above 90 km/h (56 mph).

Arguably, the most decisive development to have immensely influenced strategy and tactics, as well as the design of the sail boats, is data collection and use: a process that in recent years has been massively accelerated by software companies like Oracle and SAP having entered the sailing arena. Depending on the boat class, dozens and sometimes a thousand and more sensors and GPS trackers capture every movement in water and on board, collecting vast amounts of data in the process. Weather and ocean current data, and even the salt content of the water, are digitally dissected and analyzed. As much as 16 gigabytes per day may be generated in this way.

While in the smaller Olympic boat classes external technical support during a competition is prohibited, the sailors of large boats in multi-million dollar regattas like the America’s Cup and the Volvo Ocean Race take advantage of the enormous new opportunities also during the race: rudder angle and position, tension of sail ropes, angle of list, etc., etc., etc.: All this information is sent “live” to the computer at the command post and affects the helmsman’s decisions. The sailors of smaller boats benefit from the technology primarily after a



Data play a crucial strategic role also in the design of sailboats (shown here is the America’s Cup yacht Luna Rossa)

competition – while preparing for the next race. In interaction with data about currents and wind conditions that sailors once used to have to tediously record by hand, athletes today benefit from an overall analysis within seconds after crossing the finish line that makes completely new tactical and strategic considerations possible between the individual races.

Another advantage: By means of software programs the positions of the sailors can be digitally transmitted. The positions of the boats in front of buoys, at the turning points and before the finish line are depicted with accuracy down to an inch. This is good for the spectators' overview, for organizers and reporters.

The data gathered are worth a mint with respect to the design of the boats as well. "Design without data, well I'm not sure what it is," says Mauricio Munoz, an engineer with America's Cup experience under his belt, and adds that "this is as much a design race as a sailing race."

Jochen Schümann won't go as far as that. "The data analysts," he says, "have an enormously important job today. Based on their information, sailors can build their strategies against the competition." However, in his view, the athlete's intuition is still indispensable even today: "At the end of the day, it's like in any highly advanced performance sport: the existing data volume provides a basis. But on the water, at the crucial moment, ingenious athletes have to make the decisions. And no computer can do that for them."

Nearly 100 km/h (62 mph)

This is the speed at which the new AC75 monohulls of the America's Cup (shown in the photo above is the British Ineos team) glide across water. The battle for the world's oldest sports trophy is regarded as the multi-million-dollar top category in sailing. The key to success is to optimally merge the variables from the areas of hardware (sails, foils), nature (wind, waves, current) and opponents in a suitable strategy.

Motorsport

Innovation from the high-speed lab

Four electric motors, nearly 1,200 horsepower and from 0 to 100 km/h (62 mph) in 2.4 seconds: the demo car of the DTM Electric

2020 DTM finale at the Hockenheimring. Even before the current champion is determined in the last races of the top touring car class this season, the future of the racing series begins. A demo car of the DTM Electric does some laps in the Motodrom section of the race track in Southern Germany. With nearly 1,200 horsepower, the electric car runs on the performance level of Formula One. In terms of vehicle dynamics, it reaches new dimensions, because the four battery-electric motors from Schaeffler can wheel-selectively be controlled for perfect traction in all conceivable track conditions, a technology referred to as torque vectoring. Acceleration is impressive as well. The sprint from zero to 100 km/h (62 mph) takes 2.4 seconds. That's 0.4 seconds less than the current DTM car needs: just a blink of the eye but one that means ages on a race track.

In 2021, further demo runs of the DTM Electric are to follow. The first competitions are planned for 2023. The prototype was developed in close collaboration between the DTM's umbrella organization ITR and Schaeffler, the DTM's future series and innovation partner. In addition to the powertrain and other components, the renowned automotive and industrial supplier contributes to the prototype the Space Drive steer-by-wire technology that has already been tested in motorsport. Together, the partners are showing what the future of motor racing may look like: green, highly performant and electric.

"We look forward to this partnership," says Matthias Zink, CEO Automotive Technologies at Schaeffler. "Our innovative electric powertrain technologies have been producing victories in

» The partnership with the DTM is a perfect fit for Schaeffler. As a pioneer, we want to lead the way, challenge the status quo – and thus make the difference

Matthias Zink,
CEO Automotive Technologies at Schaeffler

Formula E since 2014 and are now used in production vehicles as well. This collaboration is proof of a pioneering spirit and innovative prowess and, as a technology partner, underscores our aspiration of shaping progress that moves the world."

The HYRAZE League, the world's first automotive racing series to use as its energy source hydrogen produced by means of environmentally friendly technology, is planned to start in 2023 as well. Schaeffler is involved in this project, too. The races will be held with 800-hp hydrogen cars. The energy for the zero-emissions powertrain is supplied by "green" hydrogen converted in the two fuel cells of the race cars into electricity for the four electric motors. In addition, energy recuperated during braking events is stored in compact high-performance battery cells.

Other areas of the HYRAZE car have plenty of sustainable innovation on board as well. The body parts, for instance, are produced from a natural fiber composite material. Another unique feature in international motor racing will be the braking system of the all-wheel-drive vehicles: None of the brake dust generated will be released to the environment in an uncontrolled manner but trapped in the vehicle and subsequently disposed of with no environmental impact. Moreover, special tires developed from renewable raw materials will minimize tire wear particles. Combined with a strictly limited number of tires, this will considerably reduce fine dust pollution.

Another example of innovation is the combination of e-sports and real-world motorsport in the HYRAZE League. The teams will have two drivers for each car: one for the real-world classification races and one who will compete in the e-sports events that are also part of the championship. The results of both races will be counted equally in the championship classification so that in the end one team will be the overall winner in both disciplines: an absolute first in motorsport.

Schaeffler inside: this is what the high-tech hydrogen race car of the HYRAZE League looks like

The author

Not a techie himself, sport journalist and book author **Olaf Jansen** (Die Zeit, Deutschlandfunk, 11 Freunde) had everything explained to him in detail by the subject matter experts. At home, the author's younger son proofread the copy because – to his father's surprise – he's got a knack for physics and math.

In motion

Innovations in the course of time

Moving downward

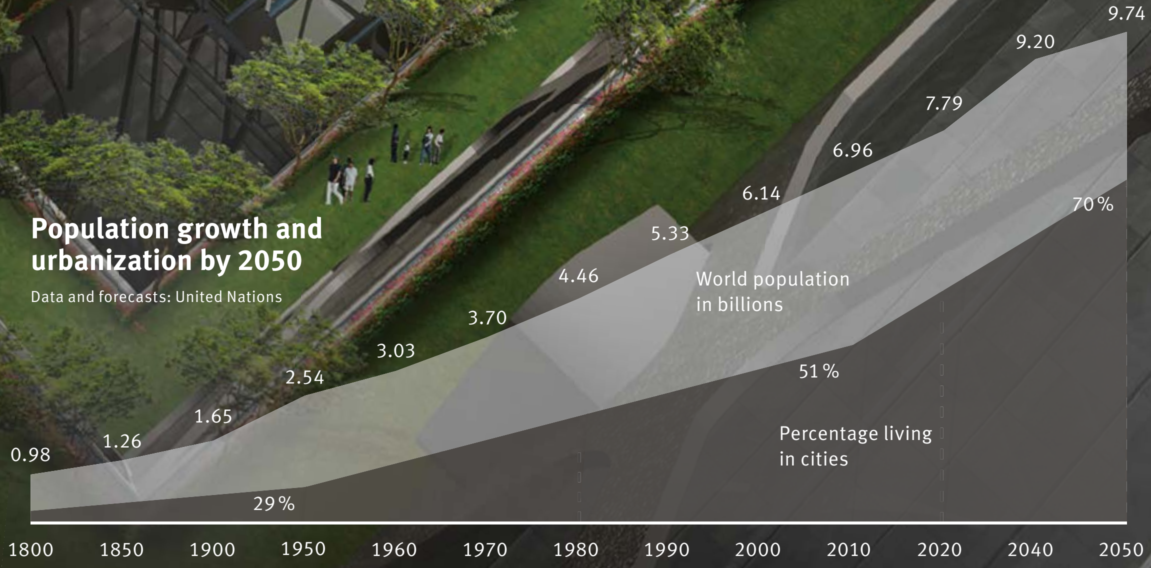
Be it as protection against attacks, wars, cold or heat: Humans have been building habitations underground for more than 2,500 years. As early as in the 8th century before Christ, innovative people in today's Turkey expanded caves into underground cities with up to 19 stories. Today, urbanization is another reason. While at the beginning of the 1950s New York City was the only city in the world with a population of more than 10 million, today there are 41 of them. In 2050, more than two thirds of the world population that will have grown to nearly ten billion by that time will be living in cities, according to United Nations forecasts. But where can they be housed? Megacities like Tokyo, Manila and Paris are already bursting at the seams. The strategy: moving downward. Helsinki is a case in point: in the bedrock of the Finnish capital, the city below the city is home to shopping malls, museums, a sauna, a church and a karting track. A sports arena and cycle routes will follow. Helsinki Underground already covers an area of 13 square kilometers (5 square miles), as much as 2,000 soccer pitches! Other cities are increasingly building downward, too: Atlanta in the United States, Montreal and Toronto in Canada, Osaka in Japan, and Hong Kong. A scenario in Mexico City features an earthscraper built into the ground (pictured). This inverted pyramid with ample glazing is supposed to enable sunlight to reach a depth of as much as 300 meters (984 feet). Planners in Russia have been dreaming of the Eco-City 2020 for years: A 500-meter (0.3-mile) deep abandoned diamond mine near the Siberian city of Mirny is planned to become home to 100,000 people. While Mexico City doesn't want to clutter its cityscape with skyscrapers, the Russian version is a fortress against hot summers (40 °C/104 °F) and freezing winters (–70 °C/–94 °F). At 500 meters (0.3 miles) below the ground, temperatures constantly remain at 20 °C (68 °F) all year – with comfort guaranteed.

» The fascination with nature is caused by the uinhabitabilityof the cities

Bertolt Brecht, German playwright

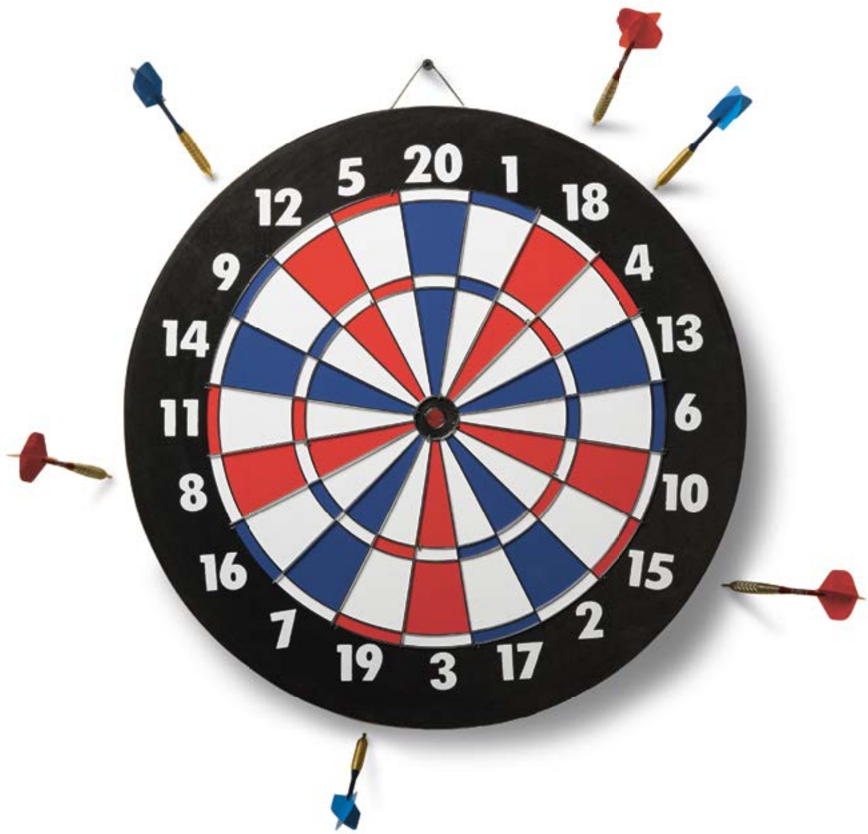
Population growth and urbanization by 2050

Data and forecasts: United Nations



Ingenious misses

The history books of technology are full of misunderstood inventions. Not all of them were bad, but some of them just hit the market at the wrong time.



By Roland Löwisch

Inventors are like gamblers. They keep hoping to hit a jackpot even though the odds are against them. “At least 85 percent of the development time invested in products ends in nothing,” says someone who obviously knows what he’s talking about: Professor Reinhold Bauer, Head of the History of Impact of Technology Department at the University of Stuttgart’s Institute of History. The history of failure is his favorite topic. In this context, he defines “innovation” as the “first economic exploitation of a new solution to a problem, which may be a process or product” and measures success in terms of “having succeeded in recovering the development costs.” Bauer has identified five reasons for failure: “technical issues, superior competition, misjudgment of potential users, excessively radical novelty and/or an unstable development environment.”

Normally, the general public is oblivious to inventions that have been for the birds because, arguably, no company is inclined to open its typically overflowing archives of failures. The situation is different in the case of products and ideas that actually attempted a market launch. We’ve selected a few examples to illustrate the point.

In 1927

AT&T takes its first tentative steps in the field of video telephony. However, with a resolution of 50 lines, the parties to the conversation are only able to see blurred images of each other.

AT&T Picturephone

Now look at this

AT&T's Picturephone is another example of a good, albeit failed idea that technology historian Reinhold Bauer likes to use. Or more precisely: an idea that initially failed because, today, video telephony has become as commonplace as television, thanks to Skype, Facetime, Zoom, and the like. The dream of being able to look into each other's eyes while talking on the phone has been an essential feature even of early science fiction movies. American multinational conglomerate AT&T turns it into a reality in 1964 by launching the Picturephone. Both the professional world and the general public are thrilled because this novelty promises to spare its users extensive travel when all they'd like to do is talk to someone face to face. But that's not all: **AT&T is already thinking about the transmission of class room content, advertisements, stock market prices or weather reports. Even flights are supposed to be bookable using the wonder box at some point in time.** But this plan never materializes – albeit not because of the technology that works amazingly well. The service is just too expensive. In the Picturephone booths AT&T installs in 1964, the costs for the first **three minutes of a call run up to a horrendous 27 U.S. dollars.** Only 71 connections are made in the first six months. In 1970, after a year of having been totally ignored by potential clients, the booths are dismantled. An attempt to sell private subscriptions fails due to the costs as well. Only a scattered group of techies is willing to accept a monthly charge of 160 U.S. dollars (equating to nearly 1,000 dollars in terms of today's purchasing power). Even when the price is reduced by 50 percent, the clientele hardly grows. In 1973, AT&T pulls the Picturephone's plug once and for all.

Ford Edsel

Disappointment included

In 1957, with Edsel, Ford Motor Company demonstrates how not to launch a product. To poise itself against GM's multi-brand market presence, Ford plans to establish Edsel as a sub-brand for more discriminating uptown demands. The company, cost what it may, invests ten years of development in Edsel and the outcome is: **an absolutely average automobile.** Its potential clientele, having been sounded out with in-depth interviews and psychological tests in an unparalleled pre-launch market research campaign, is disappointed. Where's the "technological breakthrough" that has been so highly touted? The greatest innovations on "Never before a car like it" are a hood with an electric opening mechanism and self-adjusting brakes. During a CBS show dedicated to Edsel, Bing Crosby, Frank Sinatra and Louis Armstrong sing the praises of a brilliant future, but cannot prevent the car's demise either. Besides exaggerated expectations inspired among potential customers, the worldwide recession puts an end to the marketing ploy in 1958. **The car's failed design,** especially the radiator grille reminding many straightlaced Americans of female private parts, does the rest. The model – named after Henry Ford's son, Edsel, who died of stomach cancer in 1943, is regarded as the greatest automobile flop ever.

110,847

units of Edsel are produced by Ford from September 1957 to November 1959 before the painful story is over. As many as 500,000 were originally planned – per year!

$ 250 mn.

This is the amount of money Ford loses with Edsel, the equivalent of 2.4 billion U.S. dollars today.

Segway

Spinning off the streets

It's meant to mark no less than a revolution in the mobility market: the **one-person stand-up scooter Segway** launched by its inventor, Dean Kamen, in 2001. The rider of the electric vehicle (38 kilometers/24 miles range, 20 km/h/12 mph top speed) stands on a platform between the wheels, each driven by one motor, holds on to a handle bar and, thanks to gyroscopic sensors, should actually not be able to fall down (only former U.S. President George W. Bush is said to have managed that). Tilt sensors always cause the Segway to travel in the direction desired by its rider. Accelerating and braking are done exclusively by forward or rearward shifting of the rider's weight. The whole thing is as easy as child's play and even fun. **It's just that the fun is too expensive** (available in Europe to the tune of some 8,000 euros, plus 1,400 for a spare battery) while **its uses are a lot more limited than those of a much cheaper e-bike.** Of the forecast 100,000 units per year, only 140,000 are built by the time production ceases in the summer of 2020.

100,000

kilometers (62,000 miles) and more were reeled off by some Segways. Due to their durability, customers owning a Segway never needed to replace it. Good for them, but bad for business.

In 2009

Segway's CEO Jimi Heselden has a fatal accident with a Segway – a tragic event and publicity downer.

Video 2000 and Betamax

A battle of systems

In the 1970s, videocassette recorders provide TV viewers with independence from TV schedules. For the first time ever, they're able to record their favorite programs and watch them as often as they like. **Three systems are primarily vying for the customers' business: Betamax (Sony), Video 2000 (Philips, Grundig) and VHS (JVC, Sharp, Panasonic, etc.).** Amazingly, VHS, the system with the poorest picture quality, wins out in the end, but for good reason: While Betamax offers top picture quality, it comes at the expense of recording time. 60 minutes per cassette isn't fit for consumer use. Video 2000, including turning of the cassette, can even tape 16 hours, and picture quality is good, too. But the technology is expensive and never truly matures. What's more, Philips, like Sony, refuses to grant a user license to the profitable porn market. Hence VHS gets the spoils of victory in the video rental store business and – in spite of inferior technology – wins the battle of the systems.

In 1979

Philips and Sony present the compact disc. The former video market competitors have learned from their setback there and team up in the segment of sound storage media. The CD becomes a resounding success, displacing both cassettes and LPs, and even conquering computers. Today, though, the CD itself has become a niche product. 2019 even saw more money being made with LPs than with CDs. Nearly 90 percent of today's music and video market is served by streaming services. VHS and CDs prove that innovation is ephemeral.

A 45th anniversary

is celebrated in the summer of 2020 by the world's first and now oldest video rental store. The "Film-Shop" in the German city of Kassel seems to have fallen out of time. A club has even been founded to keep this relic alive.

36 people

die in 1937 when, following a successful Atlantic crossing, the 245 meter (804 ft) long airship “Hindenburg” bursts into flames at Lakehurst/USA. The disaster is broadcast live on radio. It marks the death blow for scheduled airship service, the end of which is close anyhow due to the emergence of commercial passenger aircraft.

In 2024

production of the next major airship project, the British “Airlander” is planned to start. In 2016, a full-scale prototype performed initial test flights. Time will tell whether or not this “great British innovation” will actually turn out to be a success.

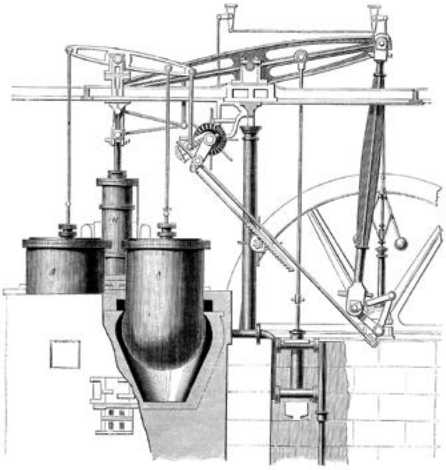
Cargolifter

Air(ship) castle

The history of aviation is full of adventures – and, unfortunately, of crashes, too. Among the biggest ones is that of the Cargolifter. The plan is for a huge airship to haul bulky cargo of up to 160 metric tons (176 short tons) from continent to continent. In September 1996, Cargolifter AG is established for this purpose. **The behemoth named CL 160, measuring 260 meters (853 ft) in length and 82 meters (269 ft) in height, is planned to be built** at a new aircraft production facility on a former Soviet military airfield out in the middle of nowhere in Brandenburg: as an East German lighthouse project in the first decade after German reunification. With all the prevailing euphoria, no one wants to listen to experts voicing early doubts about the feasibility of such a means of transportation. In May 2000, Cargolifter goes public, hoping for Airbus to acquire interest in the company. But the aircraft maker declines with thanks – two years later, Cargolifter is insolvent. What has remained? An indoor water park in the former factory hall with a length of 360 meters (1,118 ft), a width of 210 meters (689 ft) and a height of 107 meters (351 ft).

Stirling engine

A different approach



In 1816, Robert Stirling invents the Stirling engine that's named after him (pictured r.) Its principle: A working fluid (air, helium or hydrogen) is heated inside a cylinder and expands before being cooled and compressed in a second cylinder. The constantly varying pressure caused by the fluid cycling in a closed system drives the piston to perform mechanical work. The advantages of this continuously external combustion: extremely low-noise operation and very low emissions. The Stirling engine keeps being brought into play also as an engine for automobiles. But the major carmakers always reject the idea, most recently when U.S. systems specialist Mechanical Technology Inc. presents a production-ready Stirling engine for a passenger car. **Departing from engine concepts that have stood the test of time over decades entails too many risks and the supposed benefits (fuel economy, emissions, noise) are too small,** especially since these advantages keep shrinking due to catalytic converter technology and advanced TDI diesel engines. These technologies make it possible for automakers to meet increasingly strict emission standards without fundamental conceptual changes. Plus, they don't have to wrack their brains about a design-related disadvantage of the Stirling engine: it has a weakness when starting from rest and requires consistent engine speeds for efficient performance. Outside automobiles, though, the Stirling engine is alive and well. For instance, in the conversion of solar energy (which is used for heating the working fluid), in thermal power stations (use of waste heat), in submarines and in aerospace applications.

» The passenger-car Stirling engine is a good example showing that even a technically viable product doesn't automatically gain access to the market

Professor Reinhold Bauer, technology historian

Propeller car

Not for flying

Before something flies, it has to travel on the ground to pick up speed. So why not drive on the ground using the means of an aircraft? In a prop-driven car, the engine doesn't act on the wheels but on a propeller. There's no need for a transmission, clutch and drive shaft, which makes the vehicle very lightweight. Marcel Leyat is the first to translate this idea into action. In 1913, the Frenchman constructs the three-wheeled Héliocycle. From 1919 on, he produces a small series of the four-wheeled Hélica. In 1927, his Hélica Montlhéry sets the 171 km/h (106 mph) speed record. But even the Hélicron from 1932 (pictured above) fails to achieve the technology's breakthrough. **The disadvantages of the propeller drive outweigh its advantages:** Because the car doesn't have a starter, the propeller and motor have to be started by a cable system before the driver can get in. That's deafeningly noisy, poses a danger to all pedestrians and animals, and completely lacks comfort – all passengers sit in the middle of the airflow. Plus, the vehicle can't be driven in reverse.

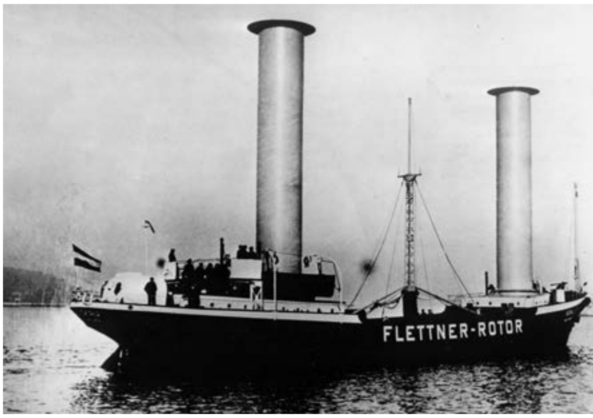
1,500 rpm

That's the speed of the rotors in wind-powered vehicles without engines. The propeller's rotation drives the rear axles of the lightweight vehicles competing in the Racing Aeolus event in Den Helder in the Netherlands. The craft that was most recently victorious converted the wind energy so efficiently that it was nearly 15 percent faster than the headwinds it was facing.

Flettner rotor

Gone with the wind

The gentleman on the left is Anton Flettner. In the 1920s, he equips two ships with a novel type of wind-powered drive, the Flettner rotors that are named after him. The upright-mounted cylinders on deck are caused to rotate by an electric motor. **The energy applied there is magnified by the wind** using the Magnus effect: When the wind is blowing against the rotating cylinder, the air on one side of the cylinder is swept along and flows faster. On the other side, where the surface faces the opposite direction of the wind, the air flow is slowed down. Like in the case of an aircraft wing, this produces a vacuum on one side and overpressure on the other, **resulting in powerful thrust that's ten times stronger than in classic sailing.** Although Flettner's ships navigate the high seas for a few years, oil subsequently gains traction as a fuel – it's cheaper, so the technology disappears. Up until a few years ago: In 2010, Enercon, a German wind turbine manufacturer, presents E-Ship 1 (below) using Flettner column-type rotors. Four aluminum rotors assist the ship's engine. Since 2014, Finnish rotor sail specialist Norsepower has been using lightweight rotors on several ships. The costs are supposed to amortize after four to eight years. The disadvantage of Flettner's idea: of all the seagoing vessels, the huge container ships, where the rotors would make particular energetic sense, can't use them – because there's no space on deck.



90 kW

of electricity for the electric motors in Norsepower's lightweight Flettner rotors multiply into an equivalent of 3 MW of conventional propulsion force in good wind conditions, according to the operator.

Conclusion

The list of failed inventions could be extended at will – Reinhold Bauer, for instance, mentions the huge wind turbine Growian, the fast-breeder reactor, the Wankel engine or the Transrapid high-speed monorail train. But there are some current examples as well. Bauer: "I tend to be depressed by futuristic anachronisms like the Volocopter, with which, in my opinion, obsolete models of personal mobility (the flying car) are carried forward into the future of mobility, for which we'd actually need different, more sustainable solutions." Be that as it may – one thing, says Bauer, is certain: "Failure – rather than success – is the rule when it comes to technical innovations."

The author

While author **Roland Löwisch** has no personal history of technical failure, he does have one in a classic sense: His first thesis in business administration was rejected by the supervising professor as being "too journalistic." There could hardly be a nicer way to fail when you're aspiring to become an editor …

Innovation is trumps!

A brilliant idea paves the way toward a global group. In 1950, Georg Schaeffler revolutionizes the world of technology by improving the needle bearing. For decades, the supplier bearing his name has continually been developing new technologies that make automobiles more reliable and efficient. Join us in playing the Schaeffler innovation card game.

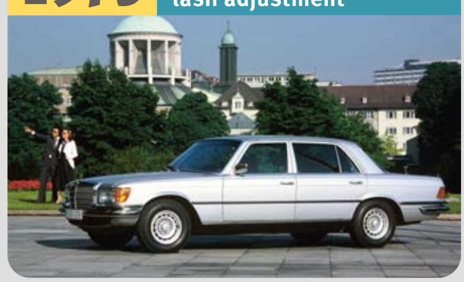
1950 Cage-guided needle roller bearing

From the late 1940s on, Georg Schaeffler develops the cage-guided needle roller bearing and revolutionizes the automotive sector. In 1950, a patent application was filed for these compact, lightweight and reliable bearings. Shortly afterwards, they were used in the **Auto Union DKW F89,** followed by Mercedes-Benz, Adler, and others. Even the avant-garde Citroën DS (1955) becomes fit for freeway driving thanks to the torque-resistant Schaeffler innovation.

1964 Diaphragm spring clutch

In the 1960s, cars are becoming increasingly powerful, which impairs the comfort of the conventionally used coil spring clutch due to its high pedal forces. In 1964, Schaeffler and VW enter into a delivery agreement for the more modern diaphragm spring clutch for the **VW 1600**. The production volume soon increases to 25,000 clutches per month.

1975 Hydraulic valve lash adjustment



Schaeffler is one of the first manufacturers in Europe to supply hydraulic valve lash adjustment elements in large volumes. By 1975, their utilization ensures that the valve train in the V8 engine of the **Mercedes 450 SEL** operates with low levels of noise and wear, and requires no maintenance. This technology quickly becomes the standard.

1985 Dual mass flywheel

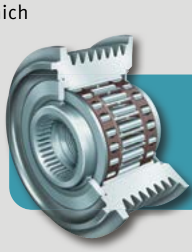
The beginning of the 1980s sees the invention of the dual mass flywheel by Schaeffler's LuK brand. This novel damping element first appears in **BMW 525e** in 1985 and causes an immediate sensation. The innovation is the yellow brick road to the success of the turbodiesel engine, which pushes the clutch disks' torsion springs to their limits in the 1980s. To date, 120 million units have been produced.

1986 Hydraulic chain tensioner

The **959**, launched by Porsche in 1986, represents cutting-edge technology with its four-wheel drive and tire-pressure monitoring system. This super sports car with a top speed of 300 km/h (186 mph) also features hydraulic chain tensioners. A Schaeffler invention that also benefited drivers of the Porsche 911.

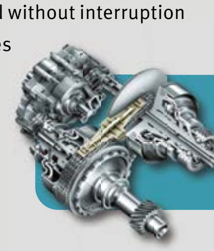
1995 Overrunning alternator pulley

As a systems supplier, Schaeffler develops and manufactures tensioner and idler pulleys, hydraulic and mechanical belt-tensioning systems, and alternator decoupling devices. The overrunning alternator pulley, which reduces rotational irregularities in the belt drive etc., appears in the **Audi A4** in 1995. This results in a smoother ride, improved NVH performance and longer service life of all components.



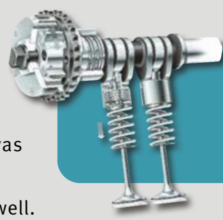
1999 Continuously variable transmission

In 1999, Schaeffler and Audi present an innovative continuously variable automatic transmission – called Multitronic or CVT (Continuously Variable Transmission). Its advantage: the transmission varies the ratio – smoothly and without interruption of traction – and thus optimizes the acceleration process. The first production-level three-liter model **VW Lupo 3L** owes its extremely low consumption also to the CVT.

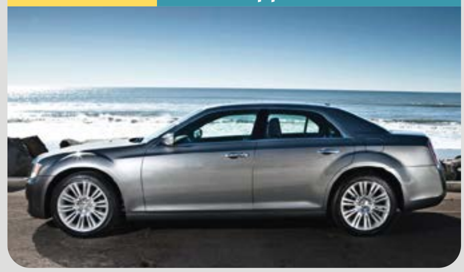


1999 Variable valve control

With its VarioCam Plus variable valve control system, the **Porsche Turbo** in the first-ever water-cooled model range 996 in 1999 starts setting new standards in terms of efficiency and performance. The engine’s characteristics can be matched to the relevant driving situation with this technology supplied by Schaeffler. VarioCam Plus was subsequently used in other cars of the model range as well.



2004 Switchable roller tappet



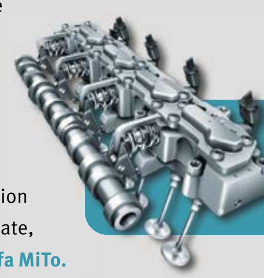
When the **Chrysler 300C** hits the road in 2004, Schaeffler demonstrates its expertise in the field of variable valve trains once again. The large eight-cylinder engine uses a switchable roller tappet that allows cylinders to be deactivated, which helps reduce fuel consumption and exhaust emissions by switching between full stroke and zero stroke.

2008 Dry and wet double clutches

Driving with uninterrupted traction: This is made possible by dry and wet double clutches from Schaeffler (LuK). Thanks to this technology, the engine’s torque can be transferred to the wheels – and thus to the road – without interruption. The dry double clutch first appears in the 2008 VW Golf and **VW Touran**. This transmission technology is also used in Volkswagen’ s high-tech XL 1 vehicle.

2009 Electrohydraulic valve control system

By introducing UniAir – the world’s first fully-variable electrohydraulic valve control system – in volume production in 2009, Schaeffler creates new opportunities for the development of engine technology combining eco-friendly and dynamic performance. The UniAir system, of which more than one million units have been sold to date, makes its debut in the **Alfa MiTo.**

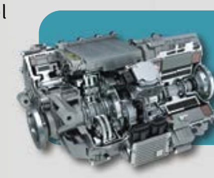


2015 Mechatronic roll stabilizer

With the mechatronic roll stabilizer Schaeffler opens a new chapter in suspension technology. The technology is launched in the **Bentley Bentayga** in 2015, making this innovation the world's first 48-volt application in the suspension system of a production vehicle. Its highly dynamic and precise control enables a perfect vehicle setup with maximum spread between comfort and sporty performance.

2018 E-Axle

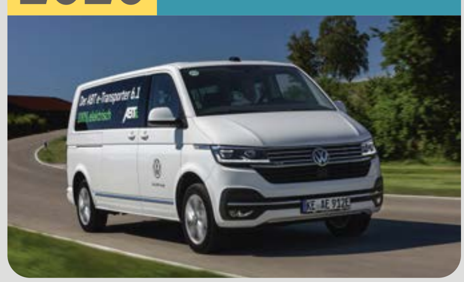
Electric mobility is one of the innovation drivers for Schaeffler. The supplier has a long track record in large-volume production of components such as transmissions for electric axle systems, e.g. for the **Audi e-tron**. They can either be used as stand-alone systems or extend an existing front- or rear-wheel drive to a full-fledged all-wheel drive system. The specific torque distribution between the right and left wheel noticeably enhances safety, driving dynamics and ride.



2019 Space Drive

As part of the supporting program for the 24-hour race at the Nürburgring, Schaeffler Paravan presents an **Audi R8 LMS** with Space Drive steer-by-wire technology: the first race car without a steering wheel. Other race cars and appearances follow. The experience gathered there supports the development of the system that has its origins in mobility solutions for people with disabilities. Space Drive is a key technology for automated and connected driving.

2020 XTRONIC XCU



The **VW T6.1** electrified in collaboration between Schaeffler, ABT and VW Commercial Vehicles is equipped with the XTRONIC Control Unit (XCU). The XCU combines safety, monitoring, control and convenience functions in just one system. In addition, the XCU connects all advanced driver assistance systems, and collects and standardizes all relevant vehicle and system data. Thus, the XCU provides the technological basis for autonomous driving.

Of players and helpers

Automaton, machine, robot, humanoid, android, cobot – no matter what names the artificial entertainers and workers have been given and what they imply, the foundations of this success story brimming with innovations were laid as far back as 3,000 years ago.

By Roland Löwisch

Arguably, no one would challenge the notion that robots only exist because Homo sapiens, by nature, loves entertainment and has an aversion to work. Or, to put it in a more positive light: strives to maximize efficiency. We can find relevant proof points even in mythology, for instance, in the myths of ancient Greece, where Hephaestus, the god of blacksmiths, is said to have built automatons and watchmen to help him in his workshop. Vulcan, the Roman god of fire, even purportedly crafted slave girls from gold. Jewish literature includes tales of the golem, a giant brought to life by means of clay and gematria that serves and protects its creator without the ability to act autonomously or speak.

So, the urge of humans to create an artificial likeness of themselves for the purpose of performing useful work is astonishingly old, albeit the first true automatons fell short of being universally usable helpers. Yan Chi's singing and dancing doll of wood and leather in the 10th century before Christ is deemed to be the first known mechanically operating figure resembling a humanoid. According to contemporaneous writings, it must have appeared very realistic: "The king stared at the figure in amazement. It walked at a fast pace while moving its head up and down, so that anyone would have thought it to be a living human being."

Aristotle (384–322 BC), as always, was far more forward-thinking, believing that automatons could put an end to slavery: "There is only one condition in which we can imagine managers not needing subordinates, and masters not needing slaves. This condition would be that each (inanimate) instrument could do its own work."

In the 3rd century before Christ, Philon of Byzantium also took at least a small step in this direction with his "automatic servant." Controlled by pressure, a vacuum and change in weight, this mechanical lady was able to serve a mixed drink of wine and water. According to various sources, Heron of Alexandria in AD 60 supposedly created the first programmable robot. The engineer and author of numerous works on innovation such as

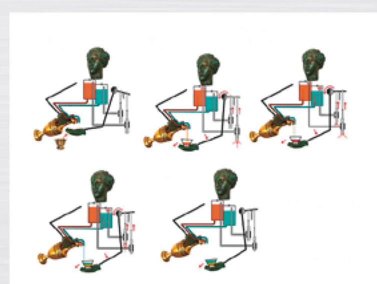
Pneumatica and Automata designs a cart powered by a sand motor to entertain audiences at amphitheaters. The driverless vehicle was able to change directions and move along a pre-programmed course. This primitive mechanism bears great resemblance to a modern binary computer language; old-fashioned punch cards worked according to exactly the same principle. Another mechanical party piece is the fully automated play originated by Philon of Byzantium and refined by Heron. Amazingly, the performance of the ancient, binarily controlled animation was nearly ten minutes in length.

Truly early robotics, though, can only be found in the works of the Arabian engineer al-Dschazarī,

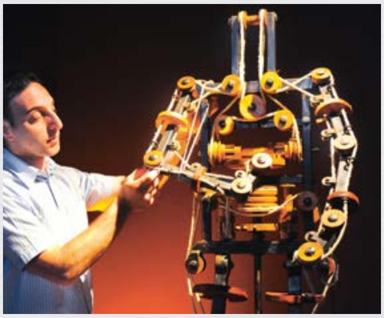
1000 BC

Let someone else do the job ... an idea captured in many ancient tales and mythologies **in the form of artificial creatures** lending a helping hand to the gods – like robots are to humans today. Pictured above is a golem, a giant with its origins in Jewish mythology that's supposed to serve and protect its creator with humongous abilities and power.

3rd century BC



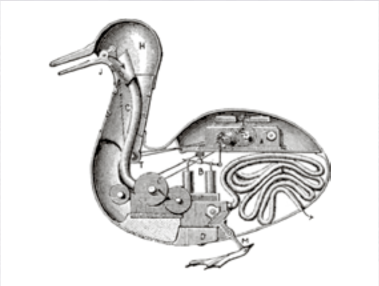
The "automatic servant" created by Philon of Byzantium **was able to serve a mixed drink of wine and water** simply when a cup was placed into her free hand. The cup's weight would activate the mechanism. When the cup was full, the process – again controlled by weight – would automatically stop.



Around 1500

The universal genius Leonardo da Vinci (1452–1519) designed dozens of automatically operating machines including a **robotic knight**. These sketches are regarded as the first historic documentation of a humanoid. In 2002, NASA robotics expert Mark Rosheim brought da Vinci's design to life using drawings and materials from those days. This model (pictured) has been exhibited on numerous occasions.

1740



Jacques de Vaucanson (1709–1782) was a French engineer who dreamed of creating an artificial human that would function as accurately as possible. It was to remain a dream. At least his mechanical flute player performed a repertoire of twelve songs using a mechanical pin roller moving in two directions. **Even truer-to-life was Vaucanson's mechanical duck with more than 400 movable parts.** In the end, tough, it was just a gimmick, too. The first fully automatic loom the Frenchman presented in 1745 was clearly more of a breakthrough achievement.

who designed humanoid and programmable automatons in the 12th century. Leonardo da Vinci may have been inspired by this early Homo sapiens 2.0: In his drawing of a robotic knight, he created the first historically documented humanoid. Theoretically, it could have executed various movements such as moving its jaws, straightening up its spine and beckoning. Da Vinci's anatomical studies of the human body were probably of help in this project.

Frankenstein's forebear

When it comes to creating artificial humans, the alchemists make their mark in those days, too. For example, in 1538, the Swiss naturalist Paracelsus describes his creation of a "homunculus": with horse manure and male semen, which should be heated in a vessel "for 40 days or for as long as it takes for it to come alive and start moving …" Good nourishment provided, "it will evolve into a rather lively human child with all its limbs …" A forebear of Frankenstein's monster – even though it wasn't until 1888 that this creature began giving readers the creeps.

Less frightening but all the more realistic was the creation of the robotic duck by the master toymaker Jacques de Vaucanson in 1740. It was able to flap its wings, quack, drink water and eat kernels of grain which it was even able to excrete again via a rubber bowel. A soldier with a trumpet produced by Friedrich Kaufmann in Dresden in 1810 is regarded as the first real humanoid robot of a modern design. Its value, too, was rather of an entertaining than a useful kind. The same applies to the Japanese compressed-air humanoid Gakutensoku (1927) or the aluminum man Eric (1928) that was set in motion and remote-controlled by electric motors and magnets. In 1939, Elektro came into the world. The behemoth (2.1 meters (7 feet) tall and weighing 120 kilos (265 pounds)) was even able to speak – 700 words that came from a record player.

All of these machines were no doubt mechanical masterpieces of their time, albeit as distant from the many stories about the idea of a "smart machine" that kept emerging over the centuries as Wolfgang von Kempelen's Automaton Chess Player in 1783 – there was no artificial intelligence at work inside Kempelens miraculous machine, but a small human being.

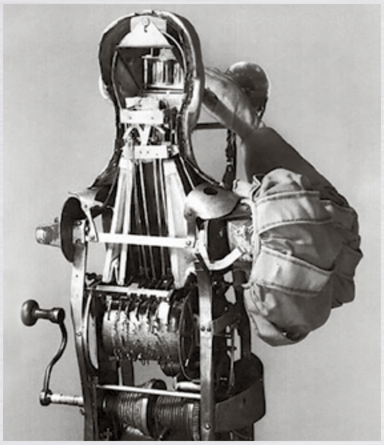
From tortoises to piece-workers

Robotics did not experience a rapid rise until after the Second World War – boosted on the one hand by Konrad Zuse's first computer in 1938 and by the invention of the transistor in 1947 on the other. The first electronic autonomous robots with complex behaviors were built by William Gray Walter in 1948. However, his creatures, Elmer and Elsie, were so slow that they were nicknamed "tortoises."

Today's articulated robots typically used in industrial environments are all based on inventions by George Devol and Joseph Engelberger. In 1954, they developed and built Unimate, the first electronic industrial robot. According to Engelberger, servo mechanisms, binary logic and solid-state physics were the most important tools for the development of robots after the Second World War. By the way, in 1961, Unimate – as the first industrial robot worldwide – ended up in manufacturing at GM's Trent plant for lifting and stacking hot metal parts from a die-casting machine.

From then on, robotics really picked up momentum: The first hydraulically actuated robots appeared in 1960. The Stanford Research Institute got the first autonomously mobile robot, Shakey, off the ground in 1970. Shakey was even able to independently navigate by means of image processing. In 1973, Japanese research scientists at Waeda University in Tokyo started developing their humanoid robot Wabot 1. German robotics pioneer KUKA built Famulus, the world's first industrial robot with six electromechanically driven axes. In 1974, the Swedish company Asea presented the first fully electric robot, IRb6 – the first to be programmed using a microcomputer. In 1984, Wabot 2 delivered an impressive performance – thanks to ten fingers and two feet the robot was able to play an organ, read music and accompany a person.

Automaker Honda began to dedicate itself to robotics engineering in 1986, with its research, in 2004, culminating in the humanoid robot Asimo, the first



1810

The trumpeter created by the Dresden instrument maker Friedrich Kaufmann (1785–1865) is deemed to be the **first real humanoid robot** and was even a step ahead of human trumpeters: the machine was able to produce dyads of the same intensity and high purity or, as a contemporary of Kaufmann wrote, "of truly heavenly harmony."

1948

In the robots Elmer and Elsie created by William Gray Walter (1910–1977), **light- and touch-sensitive sensors, like nerve cells**, controlled a motor. This enabled the tortoise-like machines to actually find their way around obstacles and therefore they're regarded as the first electronic autonomous robots.

2014

In the summer of 2014, the Japanese company Softbank presented Pepper which, according to the company, was the **world's first social humanoid robot able to recognize faces and basic human emotions.** Today, far more than 10,000 of the beady-eyed humanoids are in use worldwide. The interactive helpers are well on their way toward becoming a mass product.

ever to copy the human gait. Japan loves humanoids anyway. In 2014, the "emotional robot" Pepper hit the market and has since been sold more than 10,000 times. In Japan, it has long become common practice for electromechanical copies to greet and serve real humans in hospitals and hotels. Humanoid robots have become established in healthcare settings as well and other countries are following the Japanese trend. Around the globe, humanoids are getting in close touch with humans – and making huge development strides also on an emotional level.

Robots producing themselves

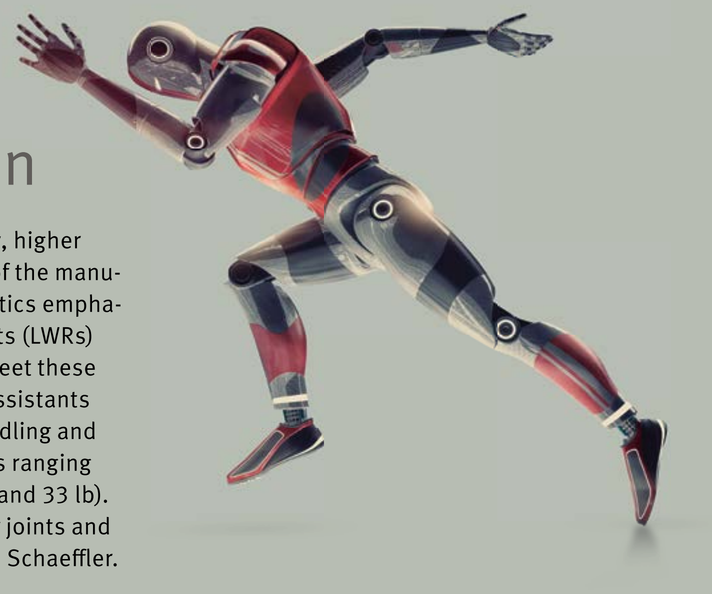
A decisive threshold in robotics evolution has been reached when the machines begin to develop and build themselves, and they've already embarked on this path. As early as in 2006, Cornell University unveiled its Starfish, a four-legged robot that was able to model itself and taught itself how to walk again after having been damaged. Growing intelligence accelerates such developments, which many people perceive as dystopian. Areas such as robotics law and robotics ethics are gaining traction in this context.

It's high time to deal with such issues because even at this juncture our world has become unthinkable without robots. By 2022, some two million industrial robots will have been installed worldwide. Plus, millions of service robots that mow lawns, vacuum-clean floors, care for the elderly, etc. etc. are added year after year. In 2016, the robotic bricklayer Hadrian X even built an entire one-family home in two days. Brick upon brick, taking cues from Aristotle: "... that each (inanimate) instrument could do its own work."

Research scientists, by the way, are pursuing the playful goal of developing a soccer team of autonomous two-legged robots by 2050 that could be pitted against the World Soccer Champion. A more substantial project is the perfection of the human body, for instance by mechanical parts or high-resolution sensors, with the objectives of walking faster, jumping higher or seeing better. This culminates in ideas of the robotically extended human body as a posthuman being that might be able to colonize the universe. Even visionary Aristotle didn't think that far ahead.

The author

Roland Löwisch (not pictured) is cut out for writing about the history of robots, because he feels like one himself – ever since a dog has been calling the shots at home. Let's face it, a dog's master is nothing but a helper and entertainer in any of life's situations and supposed to perform ...

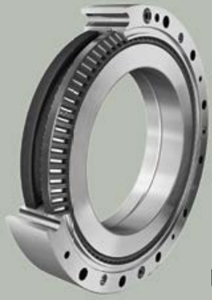


Dynamic motion

Higher productivity, higher availability, higher process reliability: The requirements of the manufacturing industry keep growing. Robotics emphasize the utilization of lightweight robots (LWRs) and collaborative robots (cobots) to meet these demands. They are agile, connected assistants performing high-precision work in handling and assembly processes with service loads ranging between three and 15 kilograms (6.6. and 33 lb). Downsizing of robots also affects their joints and poses new challenges to suppliers like Schaeffler.

Robot manufacturers primarily demand smaller and more rigid joints with consistent friction levels as low as possible. Gearboxes with greater torsional rigidity and high torque ratings, and bearings with higher tilting rigidity are in demand as well. Service life and wear resistance of the components should not be neglected in this context. Two new developments created by Schaeffler's engineers come into focus here:

XZU conical thrust cage needle roller bearing



Compared to the crossed roller bearings previously used as articulated arm bearings, the innovative conical thrust cage roller bearing features a larger number of load-bearing rolling elements, while retaining the same design envelope. As a result, customers have the option of using smaller-sized bearings, which saves space and weight. This opens up new opportunities in LWR and cobot development, resulting in a constantly growing array of applications for users. Due to the X arrangement of the needle rollers in two raceways, rigidity increases by at least 30 percent, depending on the installed size, compared to crossed roller bearings. By housing the rolling elements in cage guides and having them configured in two raceways instead of just one, the XZU delivers a 20 percent reduction in friction, resulting in more precise movement and less overshoot on reaching the end position. Overall, applications using these bearings require fewer control processes and can operate at higher speeds, thereby making the production cycle much more efficient.

DuraWave precision gearbox

Schaeffler offers ready-to-install silk hat-type speed reduction gears, aka "speed reducers," for use in robot articulated joints. By harnessing the functional principles of strain wave gearing, high reduction gear ratios – and correspondingly high torques – are achieved with a relatively lightweight design. Schaeffler's precision gearbox is characterized by lash-free operation, positioning accuracy, compact design and durability, i.e. long service life. The latter is a key factor in robots, which need to operate with maximum reliability and minimal downtimes. Schaeffler offers reduction ratios of 50:1 to 150:1. The resulting torques are transmitted reliably and accurately due to the robust design of the gearbox and its combination with the rigid XZU conical thrust cage needle roller bearing. As a result, robots using this technology are highly efficient and able to move to their end positions dynamically, accurately and without excessive overshoot, so that sorting, handling and assembly tasks can be performed quickly and efficiently.

A stroke of genius

70 years ago, Dr.-Ing. E. h. Georg Schaeffler filed a patent application for the cage-guided needle roller bearing that has revolutionized bearing technology until today.

By Stefan Pajung

70 years ago, Dr.-Ing. E.h. Georg Schaeffler revolutionized bearing technology. His idea was to enhance guidance of the needles in a needle roller bearing by means of a cage. Testing began in February 1950. The results were convincing, as the components exhibited extremely low wear and friction. The patent application was filed in September 1950 and shortly afterwards the first production contracts were awarded. “With this invention, my father laid the foundation for the rapid growth of our company. The cage-guided needle roller bearing is one of the most important innovations in our company’s history as an automotive and industrial supplier,” says Georg F. W. Schaeffler, Family Shareholder and Chairman of the Supervisory Board. “The development of this product impressively shows what distinguishes us: for the cage-guided needle roller bearing, we used the full gamut of synergies to serve all relevant target markets with this innovative product and to generate real customer value – both in the automotive and the industrial sector.”

Higher rotational speeds, lower friction

With his invention, Georg Schaeffler eliminated major disadvantages of the previously used full-needle roller bearings: The long needle rollers tended to skew, which resulted in jamming. In addition, a lot of friction was generated between the counter-rotating needle rollers. The cage-guided needle roller bearing made it possible to achieve higher rotational speeds while simultaneously reducing friction and made an invaluable contribution especially to the development of smaller, more powerful and lower-priced automobiles. In mechanical engineering, in construction and agricultural machines, and in handling technology, needle roller bearings were gradually gaining traction as well.

Continuing to be indispensable

In electric mobility, needle roller bearings are essential to the functioning of numerous electrified gearboxes. An example of an application is the Schaeffler e-axle transmission for the Audi e-tron that has been produced since 2018. In industrial applications as well, the utilization of needle roller bearings has made it possible to downsize the areas of the joints to reduce weight and achieve more compact designs in lightweight robots for which there is an increasing demand. The most recent example is Schaeffler’s XZU conical thrust cage needle roller bearing that is used as both an articulated arm bearing for lightweight robots and cobots and as a main bearing support in precision gearboxes for speed reducers in robotic joints. “The future will continue to see things moving by mechanical

» The future will continue to see things moving by mechanical means. The cage-guided needle roller bearing is central to this – a perfect component!

Andreas Schick,
Chief Operating Officer Schaeffler

Ancestor and descendant: A replica of the first cage-guided needle roller bearing from 1950 (left) and a modern XZU conical thrust cage needle bearing for lightweight robots

» The cage-guided needle roller bearing is one of our most important innovations

Georg F. W. Schaeffler,
Chairman of the Supervisory Board of Schaeffler AG and Shareholder of the Schaeffler Group

means. The cage-guided needle roller bearing is central to this – a perfect component. It is cost-efficient and makes ideal use of space," says Schaeffler's Chief Operating Officer Andreas Schick.

Technological development

What began with an ingenious idea of Georg Schaeffler's has undergone a continuous evolution by Schaeffler's engineers in terms of performance capabilities and diversity of product types over the past 70 years. Compared to a solid needle roller bearing from the nineteen-fifties, service life has increased fifteen-fold and static load-carrying capacity tripled while the dimensions have remained the same. The massively improved performance density delivered by the needle roller assembly offers significant downsizing potential for energy-conserving and resource-saving applications. The variety of product types has consistently grown as well: Today, Schaeffler's needle roller bearing portfolio encompasses more than 15,000 variants for a wide range of requirements. The length of the wires used in the annual production of 60 billion needle rollers would suffice to wind them around the equator 18 times. Nearly 170 million needle rollers are produced from them per day. 100 billion needle roller bearings have been produced at Schaeffler since the patent application was filed in 1950.

Here and now

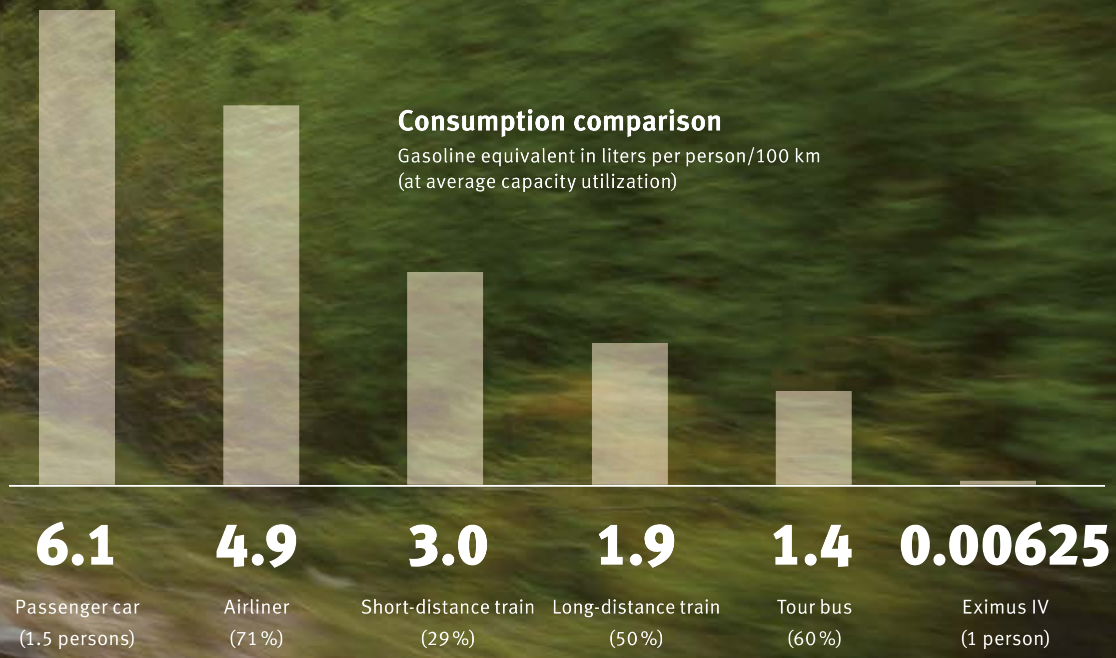
Living with progress

Give me six hours to chop down a tree and I will spend the first four sharpening the axe

Abraham Lincoln

On a roll

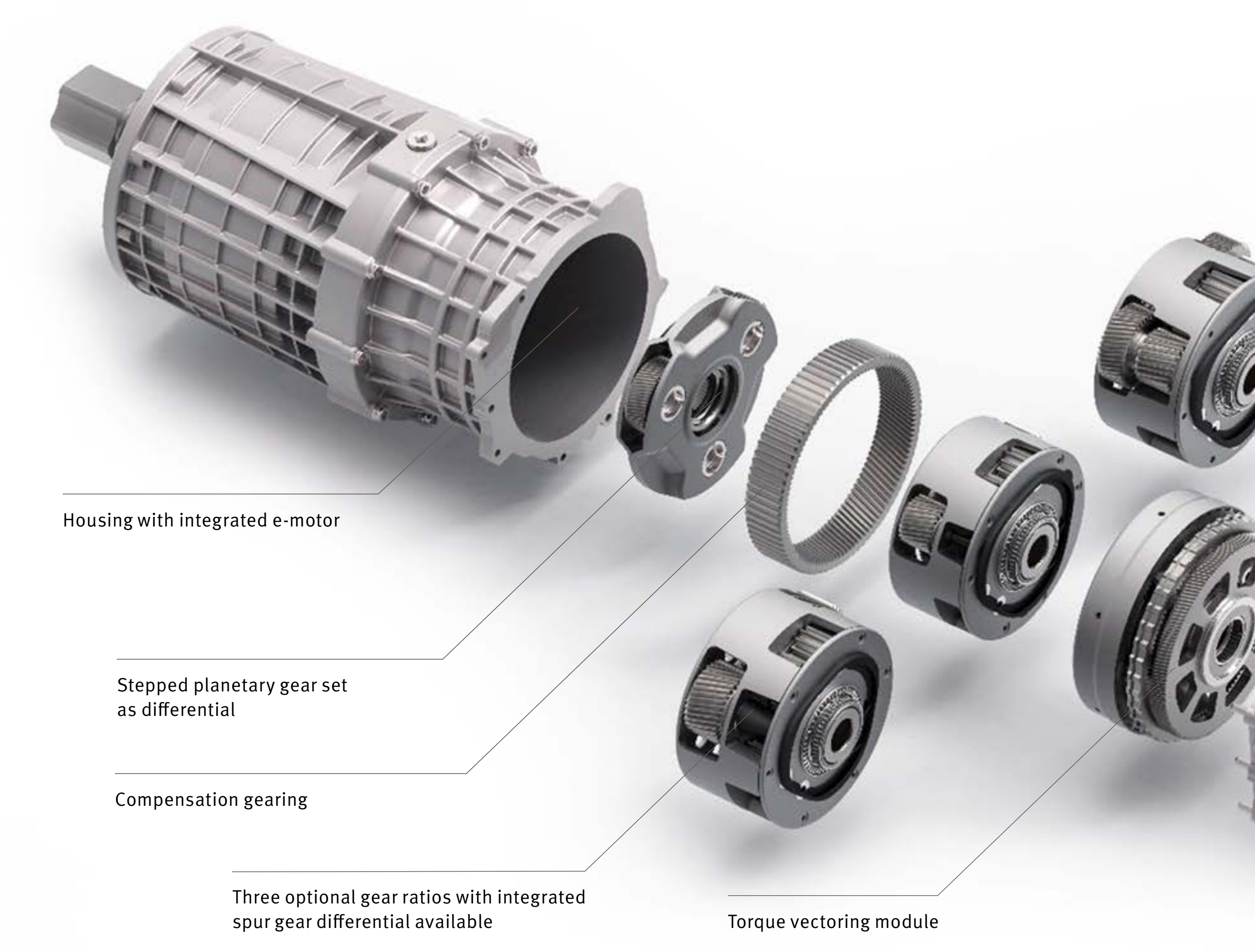
Friction is a decelerator. Who'd be in a better position to know this than bearing specialist Schaeffler? Weight and aerodynamic drag hamper the urge of moving forward as well. The designers of the Eximus IV rail vehicle tweaked its project in many areas to propel it with maximum ease and efficiency. The outcome is more than amazing: while the first Eximus version in 2016 still required 0.84 watt hours of electrical energy to haul one passenger across a one-kilometer (0.62-mile) distance, the current Eximus IV needed merely 0.517 watt hours – a new efficiency world record. How little this is becomes evident, not least, when converting "gasoline" as a value: with the energy content of one gallon the Eximus IV, in mathematical terms, would be "on a roll" for more than 60,000 kilometers (37,500 miles).



Source: Umweltbundesamt (UBA) (German Federal Environmental Agency)

An innovative solution for any system

The transformation of propulsion technology is rapidly moving forward. Hybrid or all-electric systems are complementing or replacing conventional powertrains. Based on decades of expertise, Schaeffler has developed a modular e-axle kit enabling an extensive, universal product portfolio.



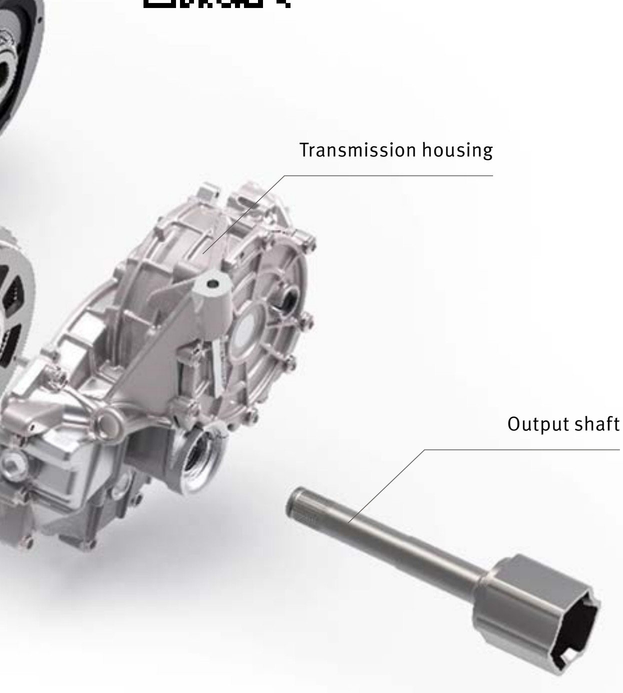
By Stefan Pajung

With the e-axle kit, Schaeffler makes it possible for its partners in the automotive industry to tailor their platforms to suit all demands of the market – thanks to high vertical integration, modularity and scalability.

Thanks to the modular e-axle configurator, efficient, compact and highly integrated systems with high power density can be developed within short development cycles for both 48-volt hybrid and 400- and 800-volt technology. The performance range extends from 15 kW to more than 300 kW. Both axially parallel and coaxial arrangements are possible.

With excellent manufacturing expertise and high development flexibility, novel solutions become ready for market within a very short period of time: across the entire product pyramid – from winding processes to components such as electric motors and clutches to complex 3in1-e-axle and hybrid systems – including power electronics and software.

Visit our virtual exhibition "Powertrain & Energy" and learn more about drive technologies from Schaeffler

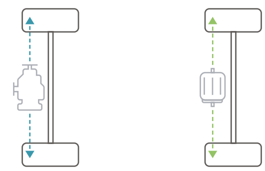


Propulsion strategies

Schaeffler's portfolio includes a suitable solution for any form of powertrain

Strategy 1

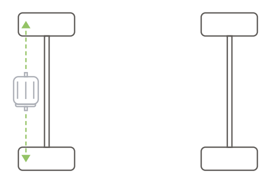
One IC engine + one e-axle



The IC engine propels one axle and the e-motor the other one. E-drives from Schaeffler can be configured for either arrangement at diverse performance levels.

Strategy 2

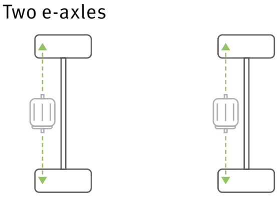
One e-axle



Fully electric drive – supplied by a battery or fuel cell. The e-drive can optionally be installed on the front or the rear axle in this case as well.

Strategy 3

Two e-axles



Fully electric drive, but using one electric motor each on the front and rear axle – for greater dynamics and efficiency.

Example of an e-axle: 3in1-e-axle system featuring a coaxial arrangement with integrated power electronics

No limits

Limits exist for the purpose of being pushed and shifted. Just like technological innovations have done time and time again with the limits of what's feasible. Janis McDavid is happy that this is so, because only high tech makes it possible for him to enjoy his freedom of mobility, be it in his own van or, most recently, in a 334-hp race car. What makes this young man's enjoyment of personal mobility special is the fact that he was born without arms and legs.

By Björn Carstens

Janis McDavid will arguably never forget this particular weekend at the end of October 2020: slipping into his purpose-made fire-proof racing suit, donning a helmet and hopping into the BMW race car to zip down the Hockenheim ring at a top speed of 200 km/h (124.3 mph). Through the legendary Parabolika, without hands on the wheel – how else? Instead, there's a joystick stuck in his armpit. Janis' maxim is to think without limits. "Even as a child I dreamed of driving cool sports cars," says the man who's in his late twenties. Now this dream has come true in a BMW M3. But how does someone without limbs drive a race car?

A seat adapted to his specific needs provides Janis McDavid with the required support in the BMW M3. He uses the joystick in his left armpit to drive the high-tech race car

Janis McDavid owes the fact that a seemingly impossible feat becomes possible to Space Drive drive-by-wire technology with which Paravan GmbH has been enabling severely disabled people to independently drive cars for nearly 20 years – and as a joint venture with Schaeffler since 2018. The Space Drive system uses cables instead of the traditional mechanical connections. Electrical impulses are used to actuate steering, braking and acceleration functions. Three mutually monitoring control chips ensure the system's safety. Roland Arnold, founder and CEO of Paravan, is the innovator of this technology: "Now seeing Janis driving even on a race track is incredible. Going forward, this technology will be playing a pivotal role in the development of future vehicle concepts and benefit everyone." Space Drive is regarded as a key technology especially for autonomous driving.

320,000 kilometers of freedom

The dream of driving cars has played a major part in Janis McDavid's life from early childhood on. To personally choose where and when to go somewhere means ultimate freedom to him. For ten years, he's been driving his Mercedes Sprinter that was modified by Paravan, having covered a distance of 320,000 kilometers (200,000 mi) in it without accidents. Via a loading ramp he steers his high-tech wheel chair, also from Paravan, into the vehicle's rear and hops forward into the driver's seat. He operates his mini bus just like the race car by using a 4-way joystick. Backward means accelerating, forward means braking, and to the left and right means steering. "The rest I handle via

Janis McDavid and his Paravan PR 50

Steering Janis McDavid uses a joystick to operate his wheel chair. Rearward means accelerating, forward means braking. A pad at the level of his right arm is used for other functions

Lifting function The best tool for communicating with others at eye level

Branding The wheel chair (Paravan PR 50) bears the same number as the BMW race car: 49. September 4th is Janis McDavid's birthday

Drive system Two powerful 300-watt motors take him wherever he's headed. Either at 6 (3.7) or 10 km/h (6.2 mph). The batteries have an approximate range of 30 km (19 mi) and are charged on downhill sections

a multi-functional button at the level of my right arm," says Janis. Operating the turn signal, for instance. It's a technology that literally moves. In fall of 2019, the idea of installing this technology in a real race car was born. Roland Arnold showed Janis his most recent project, an Audi R8 LMS GT3, the world's first sports car without any mechanical connection between the steering unit and the steering gearbox – approved by the German Motorsport Federation (DMSB). So, why not test this technology on a race track using a 4-way joystick? For Janis McDavid, it was clear that he'd accept this driving challenge. "Breaking the 200-km/h (125 mph) 'sound barrier' for the first time was a mega feeling. My driving instructor said to me, 'hey guy, don't focus on the speedometer, look at the road!'" he says with a smile.

Space Drive has increasingly been gaining traction in racing. In 2020, the Schaeffler technology has been used in five race cars in various sprint races and tests. The plan is for it to be fielded in the new DTM as well, starting in 2023. Following his successful debut in a race car, Janis McDavid is going to keep track of the continuing development: "Who'd have thought that you don't even need arms and legs to drive a race car?" Right, who'd have thought that! It goes to prove that limits are redefined thanks to innovations.

Hydrogen the all-rounder

Use as a storage medium, as propulsion energy and as a carbon substitute in industrial applications: There are quite a few expectations pinned on hydrogen. Schaeffler's hydrogen expert Dr. Stefan Gossens looks at current trends.

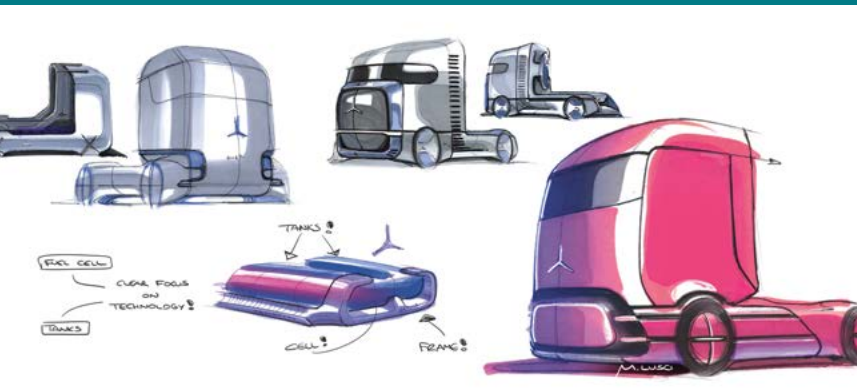
By Oliver Jesgulke and Volker Paulun

The three tanks of the new Toyota Mirai have a hydrogen capacity of 5.6 kg (12.3 lb). The WLTP-based range is 650 km (404 mi), compared to the predecessor's 500 (311). Another major stride compared to the predecessor was the reduction of the production time for a single fuel cell stack from 15 minutes to a few seconds

H_2 in passenger cars

A nice PR success for Toyota: The Japanese automaker delivered to the Pope as a gift a Mirai converted into a "Popemobile," which made positive headlines and caused the Holy Father to be inducted into the exclusive club of hydrogen car users. Even 40 years after the German Aerospace Center (DLR) presented Europe's first hydrogen passenger car (a modified BMW 5), this vehicle category is still a niche product, although there's a lot speaking in favor of green hydrogen in automobiles: especially their long achievable range, fast refueling and, obviously, their emissions, which, ideally amount to nothing but water. A sparse filling station network (of currently 140 stations in all of Europe, of which 76 are in Germany, according to the European Automobile Manufacturers' Association (ACEA)), an offering of models that can be counted on the fingers of one hand and, above all, the high vehicle prices that are almost twice as high as those of comparable cars using IC engines, have been preventing any appreciable spreading of the technology so far. Toyota is confident that this is going to progressively change. While of the first Mirai generation 11,000 more or less hand-made units were produced in five years, this number is planned to increase to 30,000 mass-produced units of the successor – per year. Toyota's competitor Hyundai is planning to sell 110,000 fuel cell vehicles by 2025, equating to one in six of its electric cars.

Dr. Stefan Gossens, Innovation Program Manager for Energy Storage and Conversion at Schaeffler: *"In terms of technology, Toyota, Hyundai and Honda are showing an impressive level of maturity. In terms of price, that's not the case yet. The manufacturers currently competing in this segment are not generating any profit, but securing an advantage over the competition. Once the vehicle prices drop, which they did, for instance, by nearly 20 percent from the first to the second Mirai generation, it's certainly possible that a market for hydrogen passenger cars will develop."*



Like many truck manufacturers, Daimler Trucks is pursuing fuel cell technology in the electrification of its vehicles, from urban distributors to international long-distance haulers. Pictured above are sketches of the GenH2 concept vehicle with a targeted range of 1,000 km (621 mi). Its mass production launch is planned for the middle of this decade

H_2 in commercial vehicles

In the commercial vehicle sector, hydrogen as a propulsion source has already become well-established. For instance, 50,000 forklift trucks worldwide now have a fuel cell on board. Most manufacturers such as Linde, Jungheinrich, Toyota and Still offer a hydrogen version of their forklifts and many large companies are gradually changing their intralogistics fleets as part of their transformation towards CO_2-free manufacturing. The industry network Clean Intralogistics Net (CIN) supports this development and Schaeffler is on board as well. Together with other partnering companies, CIN is driving the market activation and market development of the fuel cell in intralogistics. With 77 production plants, Schaeffler is also a potential user of fuel cell powered forklifts. The network members represent the entire value chain, from manufacturers of forklifts and fuel cells to component and gas suppliers to users of the technology. In the truck segment, there's a lot of momentum towards hydrogen. Practically every manufacturer is currently working on hydrogen models and the first prototypes have already been deployed to fleets. Volvo and Mercedes recently entered into a joint venture for mass production of fuel cells. The advantage of commercial vehicles over passenger cars is that they travel according to pre-planned schedules and routes, so that the sparse filling station network is not as critical. Plus, due to the fact that commercial vehicles are typically on the road all the time, the operation of an IC engine with liquid hydrogen is conceivable as well. Consequently, the disadvantage of hydrogen evaporating when the vehicle is not being used for longer periods of time is clearly less critical than in the case of passenger cars. Fuel cell technology is near-perfectly suited for use in garbage trucks because green hydrogen for their powertrains can be produced directly from biogenic waste at incineration plants. German vehicle manufacturer Faun is planning to launch mass production of such a garbage truck in 2021 featuring a hybrid powertrain with a fuel cell serving as a range extender for the battery-electric drive system.

Dr. Stefan Gossens: *"High performance, long range, fast refueling and lower weight compared to batteries: in commercial vehicles, hydrogen can display its strengths even more effectively than in passenger cars. The tens of thousands of forklifts existing by now have shown that the technology is also suitable for mass deployment in the field. Increasing use of hydrogen trucks would also boost the expansion of H_2 fillings stations. Hyundai has projected that such a facility would be profitable if just 15 trucks would regularly fill their tanks there."*

34 grams (1.2 oz) of gaseous hydrogen are sufficient for propelling the hydrogen bike presented by Linde in 2015 across a distance of 100 kilometers (62 miles). Afterwards, the tank would be refilled in six minutes. At CES in Las Vegas in 2019, the French company Pragma Industries unveiled another hydrogen bike called Alpha 2.0 that's primarily intended for use by fleet operators. Initial prototypes are on the road in the motorcycle segment as well. However, Schaeffler's expert Dr. Stefan Gossens feels that the H_2 bike market is an absolute niche. His conclusion: "There's no potential there for hydrogen."

ZEROe is an Airbus concept aircraft. Two hybrid hydrogen turbofan engines provide thrust for the blended-wing-body aircraft. The liquid hydrogen storage tanks are installed underneath the wings

H_2 in rail, air and maritime transportation

Although the rail sector has been working on hydrogen-powered trains for 20 years, the first production hydrogen fuel cell train – the Coradia iLint produced by the French manufacturer Alstom – has only been in service for two years in the Netherlands, Germany and Switzerland. Fuel cell trains can replace diesel-powered locomotives on routes that aren't suitable for electrification. In maritime transportation, fuel cells could replace diesel engines as well. The first ferries using the technology are planned to be deployed in 2021, with the largest one of them measuring more than 80 meters (262 feet). The Swedish-Swiss ABB Group is working on a fuel cell buffer battery solution in the medium two-digit megawatt range that may even be usable on huge ocean liners. The DFDS shipping company is planning to develop a 23-MW fuel cell propulsion system for a liner serving the Oslo–Frederikshavn–Copenhagen route. The green hydrogen for it is supposed to be supplied by a large-scale electrolyzer that receives its electric power from a nearby wind farm. In the aviation sector, hydrogen is getting ready for take-off as well. This fall, Airbus announced that the company is planning to have an H_2 jet airborne by 2035. In this case, the hydrogen will either be burned in a gas turbine and/or converted into electric power for electric motors in a fuel cell. The biggest challenge this entails is that a hydrogen tank for comparable range would have to be about four times as voluminous as a kerosene tank. This limits the utilization of this new technology to short and medium hauls of up to 3,700 kilometers (2,300 miles). For long hauls, scientists are working on hydrogen-based synthetic fuels that are intended to replace the currently used kerosene.

In

2017

the 30-meter (98-foot) catamaran Energy Observer embarked on a six-year expedition at sea. A fuel cell makes the vessel energy self-sufficient. The required hydrogen is produced by an on-board electrolyzer, which in turn is supplied with electric power by deck-mounted solar cells.

Dr. Stefan Gossens: *"In this sector, regulatory requirements are forcing both manufacturers and operators to pursue CO_2-free, or at least clearly reduced, mobility as well. In the rail sector, the fuel cell has already proved to be a viable alternative to the diesel engine that can be implemented quickly. However, I'm currently not seeing fuel cells actually being able to replace the huge ship diesel engines in the foreseeable future, but on ferries or smaller ships this is already a very realistic proposition. In aviation, my main hope is that it will boost the industrialization of synfuels by using green hydrogen that can also be utilized in other areas."*

84 %

efficiency in the production of green hydrogen is achieved by the world's largest high-temperature electrolyzer (HTE) GrInHy2.0 operating at the steel plant of Salzgitter Flachstahl GmbH. At high temperatures (around 850 °C/1,560 °F), the reduction kinetics of the electrolysis process improves so that electric power consumption decreases. HTEs are particularly effective where waste heat from other processes can be supplied.

H_2 in industry

Hydrogen is already an important raw material for industrial purposes. It's used not only for refining crude oil into kerosene, gasoline or diesel, or for producing fertilizers and chemical products, but also in iron and steel production. Today, however, so-called gray hydrogen is typically used for these purposes (see also box on page after next), during the production of which CO_2 is released into the atmosphere. This is prevented by shifting to green hydrogen, in other words hydrogen that's produced in carbon-neutral processes. In refineries, for instance, electrolyzers can use waste heat for the purpose of splitting off H_2 molecules from water. In primary steel production, green hydrogen can be used instead of coal and natural gas for carbon-neutral direct reduction of iron ore into crude steel. In this case, waste heat can be used to reduce costs in hydrogen production. In the chemical industry, H_2 is a key component for the production of ammonia or methanol and co-processed for many types of polymers. Shifting from gray to green hydrogen would massively reduce CO_2 emissions in the chemical sector.

Per metric ton (1.10 short tons) of crude steel, 1.34 metric tons (1.48 short tons) of CO_2 are produced on average. As a result, the steel industry causes roughly one third of all CO_2 emissions within the industrial sector – so the utilization of green hydrogen in this area is correspondingly climate-friendly

Dr. Stefan Gossens: *"For industry, hydrogen from green electricity is practically the only way to achieve a climate-neutral use of resources. However, this requires massive capital expenditures. At the moment, promising large-scale electrolyzers are appearing on the market, but they entail an enormous hunger for energy. We're talking about many gigawatts here to make industry climate-neutral."*

Producing, storing and transporting H_2

Hydrogen can only provide sustainable relief to the climate if it's produced in green ways, in other words by using renewable energy sources. The energy chain with green hydrogen consists of the following stages: With electricity from renewable energy sources, hydrogen is produced by electrolysis in an emission-free process and subsequently used at the same or another location to provide energy, for instance, through a fuel cell or in production processes. The sources of the required green electricity (wind, sun, water) are largely located not only in Europe, North America or Asia, in other words the regions where energy is mostly consumed, but also in Africa, South America, Australia or the Middle East, among others. In such regions with favorable energy conditions, hydrogen can be produced in large quantities and subsequently transported regionally as well as globally. The greater the distance between the place of production and consumption the more important is transportation. As a material-based energy carrier, hydrogen has the advantage over electricity that it's easier to store over longer periods of time and in larger quantities and can be transported with greater flexibility, for instance by ships. However, its transportation is far more complicated than that of natural gas or oil because hydrogen has the lowest atomic mass of all elements and therefore is the most volatile gas of all. Another consequence of this is that, due to its low density, hydrogen, in its uncondensed state, requires large volumes: 33 kilograms (73 lb) of H_2 would fill a balloon with a diameter of 13 meters (43 feet). Various physical-based and material-based methods can be used for transportation and storage. The physical-based ones include compressed storage (350 to 700 bar/5,000 to 10,000 psi), liquefication at –253 °C (–423 °F), a combination of liquefication and pressure (cold and cryo-compressed hydrogen, CcH_2) or cooling down to the melting point (–259 °C/–434 °F), at which hydrogen changes into a gel-like substance and its energy density increases once again. Currently, the energy consumed by these methods amounts to between 9 and just over 30 percent of the energy contained in hydrogen. Theoretically, 4 to 10 percent are attainable. In the material-based storage method, hydrogen is linked to carrier materials and subsequently split off again. Most of these methods, which are energy-intensive as well, are still in development. They include metallic hybrid storage systems that, due to their high weight, tend to be more suitable for stationary use. Microporous adsorption materials which, in powder form, can achieve high volumetric storage densities are at the beginning of their development. The third version, which has seen the furthest development so far, is liquid organic hydrogen carriers (LOHC). The mixture that's hydrated due to the addition of hydrogen has physical-chemical properties similar to those of diesel fuel and can be stored and transported accordingly. There are plans for converting such LOHCs directly inside a fuel cell. In this way, electric propulsion power could be generated directly on board of the vehicle. When carbon dioxide is added to green hydrogen, the result is methane (power-to-gas method). The methane in turn can be fed into existing natural gas grids and distributed. As a result, emissions by the CO_2-intensive heating sector can be significantly reduced without incurring major infrastructural costs.

***Dr. Stefan Gossens:** "Generally, in order to take advantage of hydrogen's enormous potential for a global energy transition, we have to drive its industrialization and establish a completely new industry – with new technologies, production facilities and supply chains. With our core competencies in materials, forming and surface technology, Schaeffler can make a major contribution to efficient large-volume production of key components such as electrolyzers and fuel cells."*

The 116-meter (380-foot) long Suiso Frontier, the world's first hydrogen tanker, transports 1,250 cubic meters (44,100 cubic feet) of H_2. To liquefy it, it's cooled down to –253 °C (–423 °F), which causes the volume to shrink to one eight-hundredth of the gaseous state. The liquid H_2 is stored in double-walled vacuum tanks

Green hydrogen – in other words hydrogen produced by means of renewable energies – will reduce emissions in a wide range of applications such as steel and concrete production, refineries, decentralized heat and energy generation and mobility

H_2 color theory

Even though hydrogen is actually a colorless gas, it comes in all kinds of colors. Today, hydrogen is green, gray, blue and turquoise, because there's a color etiquette based on what H_2 is produced from:

Green hydrogen is produced from water by means of electrolysis and the electric power this takes is generated by renewable energy sources such as the sun, wind or hydropower.

By contrast, **gray hydrogen** is produced from fossil fuels, typically natural gas that's transformed into hydrogen and CO_2 by application of heat – a process that's also known as steam reformation. This has the disadvantage of the CO_2 generated in the process being released into the atmosphere, plus the production of one metric ton (1.10 short tons) of hydrogen generates about ten metric tons (eleven short tons) of CO_2.

Blue hydrogen is produced from natural gas as well. However, the CO_2 is permanently stored in deep geological layers on land or under the seabed as solid or gaseous carbon. The advantage of the so-called carbon capture and storage (CCS) method is that the carbon dioxide is not released into the atmosphere. Blue is regarded as a transitional technology toward green hydrogen. However, the methods it involves are controversial because critics fear that it may entail huge environmental risks.

Turquoise hydrogen is a mix of blue and green hydrogen and produced by thermal fission of methane. Unlike in the case of blue hydrogen, the use of methane pyrolysis does not even produce any gaseous CO_2, but carbon or carbon compounds. Again, the crucial factor is whether or not green electricity is used in this process. Conclusion: Ultimately, only the production of green hydrogen is a clean method for producing hydrogen from the environmental point of view.

Dr. Stefan Gossens: *"It's unlikely that we'll be able to produce all the green energy in places where it's needed. There's no way around imports for us and other EU countries, so we need to emphasize international cooperation."*

DNA made visible

A pioneering spirit and innovation prowess are Schaeffler's hallmarks – today, just like 70 years ago. In a new campaign billed as "We pioneer motion," the Group is bringing into focus its core competencies that have been built and continuously grown across generations.

» The objective of this campaign is to visualize what we stand for and to clearly communicate that Schaeffler is a strong company. A company with a strong brand. A brand that makes the difference

Klaus Rosenfeld,
Chief Executive Officer of Schaeffler AG

By Volker Paulun

Since the invention of the cage-guided needle roller bearing by the company's founder, Dr.-Ing. E. h. Georg Schaeffler, the world and Schaeffler as a company have massively changed – and reinvented themselves over and over, while a pivotal component has consistently been part of the process: motion. "We've always been a company that has driven technological progress, and that's what we'll continue to be," says Klaus Rosenfeld, CEO of Schaeffler AG. "The objective of this campaign is to visualize what we stand for and to clearly communicate that Schaeffler is a strong company. A company with a strong brand. A brand that makes the difference."

The campaign is centered on the idea of "Green makes the difference" displaying, in a symbolic way, that Schaeffler is a pioneer of motion. Based on this concept, the campaign features visuals designed to surprise and inspire viewers while showing Schaeffler's pioneering spirit.

Nadja Lemke, the marketing executive at Schaeffler who is responsible for the campaign, outlines its objectives: "It's important that we elevate our brand to the next level of communication. By pursuing this path, we concentrate the messages of the Schaeffler brand and ensure that it's positioned with even greater clarity going forward."

Schaeffler's message addresses not only existing customers and prospects. Another key aspect of the campaign is to position Schaeffler as an attractive, forward-focused employer for potential employees.

Viewers won't immediately associate every visual with Schaeffler. But thinking out of the box was already successfully practiced by the company's founder, Georg Schaeffler

Outlook

Technology for tomorrow

» Every good and perfect gift is from above

James 1:17

High tech in medicine

Facts and figures

›4,200

units of the robotic **da Vinci Surgical System** are already being used worldwide.

19

grams (0.67 oz.) of weight and dimensions of 3.7 x 4.1 x 0.6 millimeters (0.15 x 0.16 x 0.02 inches) – MicroPort CRM Teo, the world's **smallest cardiac pacemaker** is truly tiny.

36.1

billion U.S. dollars: that's the expected **sales volume to be generated by AI** in healthcare by 2035, compared to 2.5 billion in 2018.

6

instead of 9 process steps are required in the **production of hearing aids** using 3D printers.

Flying help

Innovation and high tech are playing an increasingly important role in medicine – and this includes transportation because there's enormous improvement potential in delivering healthcare. Consequently, more and more projects rely on a strategic use of drones, like Medifly in Hamburg. Ever since its first flight in early 2020 medical tissue samples have been transported between hospitals in the city. The objective: significant time savings compared to blue-light transportation through urban traffic.

Another drone project exists in Kenia and Rwanda where the start-up company Zipline is flying blood samples, vaccines or medicines to remote hospitals. The autonomous drones have a range of up to 110 kilometers (68 miles) and can carry cargo weighing up to 1.8 kilograms (4 pounds) that's dropped on parachutes at the destination. Zipline is planning to also test the drones in the United States where more and more emergency hospitals in rural regions are being closed and life expectancy is decreasing.

Setting the future course

Europe has the most close-meshed railroad network in the world. However, it will take an innovation boost for rail operators to seriously compete with airlines in transcontinental passenger transportation. This merits a side glance at China.

By Volker Paulun

China doesn't think small, but big. In the case of rail transportation, thinking big refers to a high-speed railroad network traversing the country over a 35,000-kilometer (22,000-mile) distance – a project that was put on a fast track as well. Planning began in 2004 and the first high-speed trains hit the tracks in 2008. In 2020, China is ranked in the top spot worldwide and planning to lay an additional 13,000 kilometers (8,000 miles) of tracks by 2035. These are dizzying statistics and dimensions even when just reading about them.

Obviously, a territorial state like China is hardly comparable to the European union of countries, both politically and geographically. The financial dimensions are different as well: The Middle Kingdom invests enormous amounts of money in the expansion of its China State Railway Group (in short: CR). CR has a debt of 650 billion euros. Greece's national debt is only half as high. For Transport Minister Li Xiaopeng, such numbers are no reason for hitting the brakes, because the transportation infrastructure drives economic growth and provides the basis for a more comfortable society, he says.

For Schaeffler's Industrial Division, the Chinese railroad market is a growth engine as well. In August, the Group signed a cooperation agreement with the China Academy of Railway Sciences (CARS). Through this cooperation Schaeffler plans to adapt its rail products more precisely to the Chinese market and grow its market share. The agreement includes the establishment of a joint venture between Schaeffler and CARS for the development of railroad bearings, the reconditioning and assembly or axle box bearings, and the development and production of condition monitoring systems for bogies.

China Railway is planning the deployment of self-driving trains at speeds of 350 km/h (217 mph) by 2022

Even at this juncture, the outcome of the arms race on rails makes European long-distance train travelers look toward China with envy. The Fuxing super-train travels the 1,200-kilometer (750-mile) distance between China's capital Beijing and the business metropolis Shanghai in just under four hours. An important "sound barrier," because various surveys of travelers have shown that trains can particularly score in comparison to airliners when travel time is less than four hours.

Train travel is faster than flying

The motherland of the high-speed train idea is China's neighbor Japan. The island state started the speed arms race on rails back in 1964: Right in time for the opening of the Olympic Summer Games in Tokyo, the first Shinkansen train zipped down the tracks to Osaka. In the following nearly 60 years, the high-speed train system has been perfected step by step. Innovation boosts in braking and tilting technologies have caused the speedometer needle to continuously rise. Accordingly, the travel time for the 500-kilometer (310-mile) distance has dropped from the original four hours to currently 2:22 hours. Rail engineers are now aiming for two hours.

The Shinkansen network already outperforms air travel on many routes today: due to fast connections, low headways, favorable fares, and extremely high punctuality and reliability. The major Japanese railroad company JR-East says the average delay is 50 seconds. This number would be close to zero without the delays caused by natural disasters like earthquakes and typhoons, which are not uncommon in Japan.

Europe is high-speed-capable, too

Spearheaded by Germany (ICE), France (TGV) and Spain (AVE), Europe is sending a number of high-speed heavyweights into the race as well. As far back as 30 years ago, the ICE broke the 400 km/h (249 mph) record. However, the train is struggling with the problem of an insufficient number of routes on which to fully exploit its speed potential. One of the reasons for this is that, when the ICE project was launched, Deutsche Bahn chose to minimize the distances between the places where its passengers live and the nearest ICE train stations. Consequently, there's a large number of stops and even if an ICE doesn't stop in a particular city, it has to reduce speed while traveling through it.

Japan's JR-Maglev high-speed train: By 2037, it's planned to "fly" from Tokyo to Osaka at a speed of more than 500 km/h (311 mph) in 67 minutes, so who'd still want to board a jet aircraft?

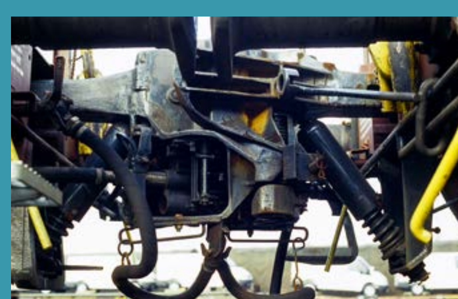
The Thalys high-speed train connects 17 cities in Western Europe. Its top speed: 300 km/h (186 mph)

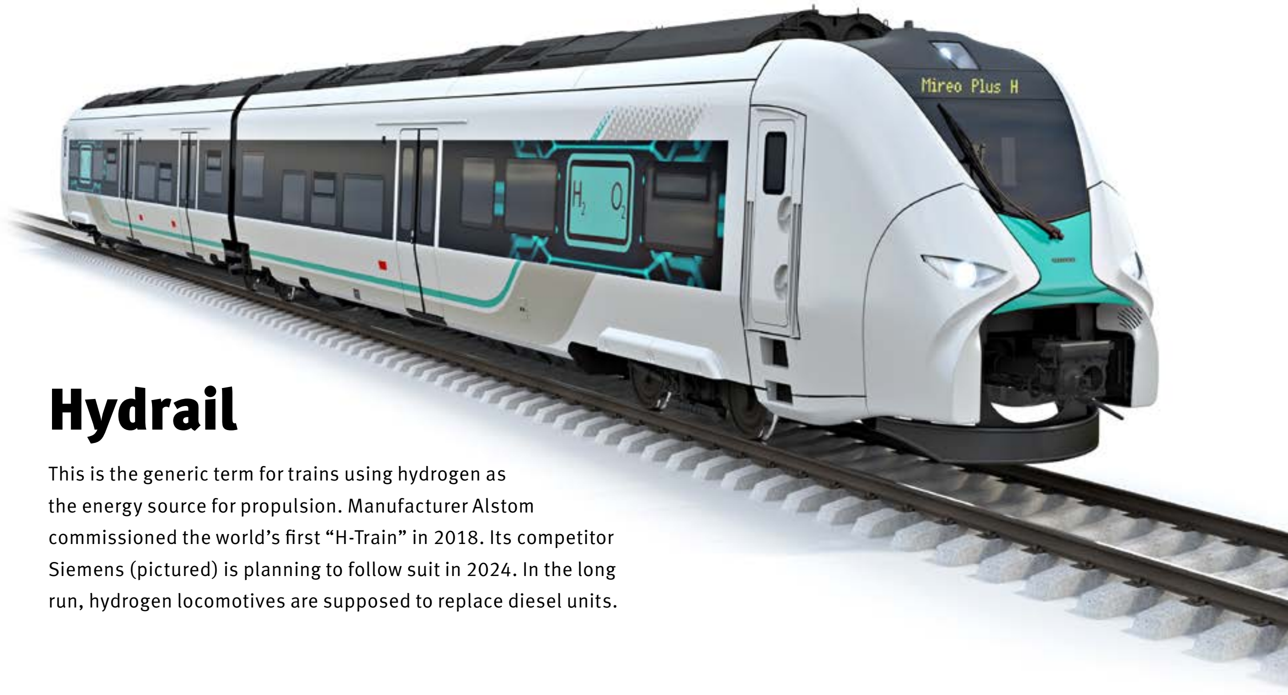
By contrast, the French TGV preferably travels the country at full speed. Its tracks were laid in ways that circumvent the cities at which it doesn't stop. This accelerates the pace but makes boarding more difficult. There are good reasons for both strategies. The advantages of the TGV can be read on a clock. The fast French train travels the 765-kilometer (475-mile) distance from Paris to Marseille nonstop in a little more than three hours. It takes the ICE a minimum of 5:35 hours, and usually even an hour longer, to cover nearly the same distance from Hamburg to Munich (780 kilometers/485 miles) with half a dozen stops in between. As a result, it clearly surpasses the four-hour mark and has a hard time competing with the temptations of air travel. The situation is different on the newly built high-speed track between Berlin and Munich. It takes the ICE just under four hours to cover the 623 kilometers (387 miles). Although that's 1.5 hours longer than it takes the Spanish AVE to travel the 621 kilometers (386 miles) between Madrid and Barcelona, the time still has the magic four as a prefix. This pays off: According to Deutsche Bahn, in 2018, its first year of service, this new connection motivated more than one million travelers to switch from cars and 1.2 million from airliners to trains, making this means of transportation the most popular one on this particular route. Even the time-consuming stop in Nuremberg has paid off: Eurowings canceled its service from Nuremberg to Berlin – the train had wooed too many passengers away from the airline.

Germany is planning to make train travel more attractive with yet another signature project: the revival of the Trans-Europe Express (TEE) that was discontinued in 1987. “Such a TEE network for high-speed and night trains can be accomplished by 2025. We need to get started now,” says Germany's

Digital coupling

It's hard to believe, but true: On cargo trains and those with classic cars, European railroad operators are still unanimously using the screw couplings introduced in 1861 (top picture) that are manually connected by workers. Subsequently, the rows of cars have to be entered on lists – of course, manually as well. This is to change – with an automated digital coupling (below). The “Allianz pro Schiene” (“Pro-Rail Alliance”) association welcomes this initiative by the German federal ministry of transportation. “The Digital Automatic Coupling” can provide the long hoped-for boost to climate-friendly rail transportation in Europe,” says Managing Director Dirk Flege. The Europe-wide system change that's projected to take several years targets 2030 for completion. The forecast costs amount to some ten billion euros to be shared by governments and railroad operators.





Hydrail

This is the generic term for trains using hydrogen as the energy source for propulsion. Manufacturer Alstom commissioned the world's first "H-Train" in 2018. Its competitor Siemens (pictured) is planning to follow suit in 2024. In the long run, hydrogen locomotives are supposed to replace diesel units.

Minister of Transportation Andreas Scheuer, verbally accelerating the pace. Now actions must follow, because the need for innovations for a TEE 2.0 is as high as the need for capital expenditures. Electric power and train control systems, as well as distribution and fare systems, vary across the EU, not to mention the lack of high-speed tracks, especially in the eastern and south-eastern regions of the continent. Other key infrastructural projects such as the underground train station billed as Stuttgart 21, the Fehmarn Belt Fixed Link including a back-country train connection linking Germany with Scandinavia, and the Brenner Base Tunnel that's important for south-bound traffic are still pending completion – and devouring billions of euros.

The Thalys train between Paris and Brussels, the Eurostar that chases in 2:14 hours from Paris to London, and the increasingly converging high-speed network of the neighboring countries Spain and France are bilateral examples that already work. Lines for longer distances such as Paris–Warsaw and Amsterdam–Rome could be implemented within a short period of time and make convenient inter-urban travel without changing trains possible. By contrast, other connections, like Stockholm–Munich and Paris–Budapest, call for major infrastructural upgrades. But even when the main routes are in place, all systems are running smoothly and average speeds of more than 200 km/h (124 mph) are achieved: transcontinental train travel across several international borders will remain a time-consuming – and costly – proposition. That's why critics put a damper on the expectations pinned on a resurrected TEE. In the price war with the civil aviation sector and its low tax burden, non-subsidized long-distance train connections would hardly stand a chance, says, for instance, Walter von Andrian, editor-in-chief of the special-interest magazine "Eisenbahn Revue."

The deterring time factor on long-distance routes of more than eight hours of travel time could be mitigated by the deployment of night trains. Austrian ÖBB and Swiss SBB have already presented plans for establishing a Europe-wide night train network. This is another project that will require massive subsidies. The TEE is a project requiring a willingness to afford it, just like China affords its attractive, albeit uneconomical high-speed network. At the moment, two thirds of the 18 CR routes are losing money.

Airlines are heading for the tracks

That trains are becoming increasingly indispensable as a means of mass transportation in view of climate change has also dawned on airlines. In February, IATA, the International Air Transportation Association, and UIC, the International Union of Railways, decided to develop standards for simplifying the links between air and train travel. "We will develop a product to fly to London and take the train back," says KLM executive Boet Kreiken, naming an example in the special-interest magazine "Aero Telegraph," adding that "I think in the long term, short distances will be covered by trains."

The Hyperloop idea is picking up momentum: The American company Virgin performed the first crewed test run over a 500-meter (0.3-mile) distance this fall. The Korea Railroad Research Institute first broke the 1,000 km/h (621 mph) record with a 1:17-scale model.

Maybe they'll be hyperloop pods. These high-speed trains are supposed to chase through vacuum tubes at jet speed of up to 1,000 km/h (621 mph). The first crewed tests have begun, but critics of the technology remain skeptical. China and Japan, on the other hand, are pushing the magnetic levitation train system, an innovation that was born in Germany. The JR-Maglev is planned to connect Japan's capital Tokyo with Nagoya starting in 2027. At an average speed of far above 500 km/h (311 mph), it will take the train 40 minutes to cover the 286-kilometer (178-mile) distance. The extension of the route to Osaka is planned to be completed by 2037, with a target travel time of 67 minutes – half as much as the current Shinkansen. Bon voyage!

3 questions for ...

Dr. Michael Holzapfel, Senior Vice President Business Unit Rail at Schaeffler

What major technical challenges will railroad operators be facing?

Rail traffic will considerably increase. In Germany, for instance, policy makers are targeting a 100-percent increase in passenger and a 25-percent increase in cargo transportation. It's expected that there will be no proportional growth in the number of rail vehicles, so the existing trains will have to be used more intensively and longer. Propulsive power will increase as well in order to achieve lower headways and higher loading capacities. For us as a component manufacturer, this means that we have to offer products delivering even longer service life, allowing for more intensive operation, with even longer maintenance intervals, plus featuring more compact designs than before because more space for passengers or cargo is desired. In view of this requirements profile, a rolling bearing quickly turns into a high-tech product.

How is Schaeffler planning to meet these growing requirements?

We intend to continue driving developments with our know-know in materials, forming and surface finishing technologies even in areas where we already have a competitive advantage. Here's an example: For iron-ore trains in Australia, we deliver rolling bearings enabling an axle load of 45 to 50 metric tons (50 to 55 short tons). This is twice as much as is currently required in Europe. But such dimensions are important in Australia as a prerequisite for cost-efficient operation of the trains.

Schaeffler is increasingly emphasizing mechatronic and digital product offerings – because you feel that the end of the rolling bearing is in sight?

No, not at all. Products like our condition monitoring solutions and the axle box generator are value-adding offerings for our customers, which they favorably respond to. But rolling bearings will continue to exist for as long as trains run on rails. Even a Hyperloop train creates contact for tracking in its vacuum tube and therefore requires rolling bearings.

Learning for a complex world

An innovation-driven world changes all of our lives, which results in many opportunities and few risks. Here are five areas education and training should focus on to prepare people for the new digital knowledge society.

By Christian Heinrich

What does it mean to be an educated person today? "We live in a world where the kinds of things that are easy to teach and test have also become easy to digitize and automate," writes Professor Andreas Schleicher, Director for Education and Skills at the Organization for Economic Cooperation and Development (OECD), in the OECD Learning Compass 2030. In the digital knowledge society, computers, programs and algorithms help us manage, outsource, interlink and apply knowledge.

This is nothing short of a revolution, because it means that the human being is assuming a new role: the one of a responsible decision maker and impetus provider using computers as powerful tools or even working on a par with artificial intelligence. This new role also changes the concept of education. Success in education, today, not only means language, mathematics or history, but also identity, ability to act and sense of purpose, according to Schleicher. The future, he says, is about pairing the artificial intelligence of computers with the values and skills that are uniquely human. In this way, human skills complement those of computers rather than compete with them, and people are prepared for jobs, applications and things of everyday life that don't even exist yet today.

Especially the following five skills, some of which build upon and complement each other, should be cultivated in order to prepare people, from cradle to grave, for the new digital knowledge society:

1. Self-reflected learning

We're able to access the entire knowledge of the world on the internet using smartphones. We're able to use computers for learning even seemingly boring things in the form of exciting experiences – while determining the pace ourselves. Digitization, if you will, provides us with enormous freedom, also in the context of learning. Yet enormous freedom can also become a problem. For those who digress, for those who don't know which way they're headed and how to get there, the threat of drowning in the sea of possibilities looms. "That's why self-reflected learning is one of the keys to education today," says Professor Christian Stamov Roßnagel, a learning researcher at Jacobs University Bremen.

Self-reflected learning, above all, encompasses two things. First: jotting down two or three specific items describing what you'd like to be able to do by means of what you've learned – such action-oriented learning often has a more lasting effect than knowledge-oriented learning. Second: checking yourself during your learning journey and once you've achieved your learning goal to see whether you're actually able to "work" with what you've learned. "That's far less to be taken for granted than it sounds," says Roßnagel. He works with large corporations and keeps seeing that people of all ages have problems with this. "In that case, we try to assist them in the context of learning and development." A viable self-test may be to ask: Can I summarize this lesson in three sentences? And put the main, often highly condensed points of the subject matter into concrete terms? Here's an example of a main point: "Belt drives withstand very high loads." Appropriate self-test questions, depending on the learning goal, might be: In what operating ranges do such loads occur? How do I measure the level of the load? "Ideally, though, the foundation for reflected learning is laid as early as in classroom instruction in school," says Roßnagel.

2. Empathy

In a structurally unbalanced world, diversity always also entails differences that have a separating effect. Digitization may exacerbate this effect: "Algorithms behind social media are sorting us into groups of like-minded individuals. They create virtual filter bubbles that amplify our views and leave us insulated from divergent perspectives; they homogenize opinions while polarizing our societies," writes OECD expert Schleicher. Empathy, in other words, the ability to put ourselves in someone else's shoes, is a key skill for preventing this.

Empathy, though, is more than a builder of social bridges. Be it on the job, at home or within our communities, be it as a scientist, banker, worker or artist: We need this understanding of others in order to be able to act and cooperate in situationally appropriate ways. Especially since we, as human beings, will be more empathetic than machines for an indefinite period of time going forward, skills in this area are becoming increasingly important in the job market. However, empathy is not just an educational goal, but also a key skill for the explainer, because the ability to adopt perspectives is an essential and basic prerequisite of being able to explain things to others and of providing them with guidance.

3. Learning to think in integrative ways

Equality or freedom? Independence or solidarity? Efficiency or democratic processes? Innovation or consistency? The significance of such conflicting concepts keeps growing in a heavily connected world. Increasing complexity also leads to increasing dilemmas. Consequently, the ability to think in integrative ways and to find ways of replacing the "or" in pairs of opposites by an "and" is all the more important.

The way to impart this skill from the teaching side and to acquire it on the learning side lies in consciously dealing with complexity and ambiguity and the ways in which they have an impact. Using this approach, holistic systems can be actively elaborated as early as in school, for instance, the linking of water, energy and food supply. When students search for diverse opportunities for change and discuss and think through the related effects, they "develop their ability to recognize multiple solutions and work successfully with ambiguity," it says in the OECD learning compass 2030.

4. Ability to act

Understanding things is the first key step, influencing and changing them is the second one. That students do this or at least try to cannot be taken for granted. This requires a relevant skill. In the OECD Learning Compass 2030, this skill is called "student agency:" "It is about acting rather than being acted upon; shaping rather than being shaped; and making responsible decisions and choices rather than accepting those determined by others," it says in the Learning Compass.

This learning journey begins in early childhood: When a child experiences that its actions matter to its surroundings, that it can make an impact, the child will develop a sense of self-efficacy, which lays the foundation for student agency later in life. During the years in school this can be developed further by independent elaboration and establishing areas of emphasis. Co-determination and democratic processes in school can promote this as well: students that help shape a schoolyard practice learning by doing that will subsequently benefit them in their professional careers and in everyday life.

Learning researcher Stamov Roßnagel from Jacobs University Bremen views self-management skills as a primary educational goal, too – across all age groups. In teaching his students, he primarily promotes the skills of making evidence-based choices and developing new approaches – skills that will subsequently be in demand in their careers, irrespective of their roles or sectors of the economy. The best was to do this, says the professor, is by actively involving students from their first semester on in research and research-based consulting.

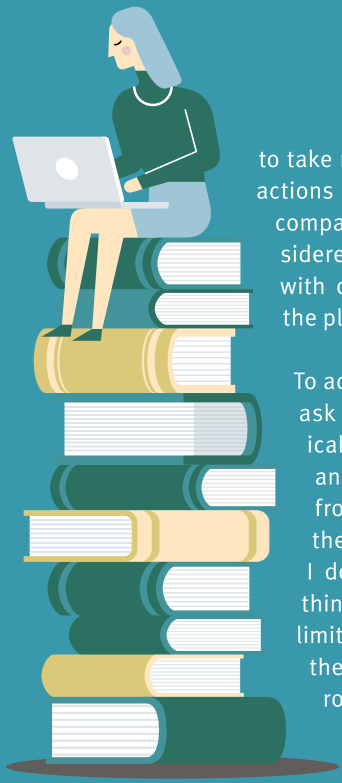
5. Ethics as a compass for choices

Those who make choices, those who are able to take action can make an impact – in various directions. That's why taking action always implies an assumption of responsibility. Assuming responsibility for one's own actions should always directly be part of taking action. The OECD Learning Compass 2030 says: "Students who have the capacity

Examples of new and emerging jobs and matching educational areas of emphasis

from the OECD Learning Compass 2030

Occupation	Description	Examples of skills	Examples of knowledge	Examples of attitudes and values
Robotics engineers	Research, design, develop or test robotic applications	Critical thinking, complex problem solving, quality-control analysis	Engineering and technology, robotics, design	Exploration, precision, observation
Biostatisticians	Develop and apply biostatistical theory and methods or systems to the study of life sciences	Inductive reasoning, oral expression, mathematical reasoning	Mathematics, English language, education and training	Project/program management, execution, inquisitiveness
Fuel cell engineers	Design, evaluate, modify or construct fuel-cell components or systems for transportation, stationary or portable application	Judgment and decision making, critical thinking	Physics, mathematics, chemistry	Focus, reliability, feedback
Solar sales representatives and assessors	Contact new or existing customers to determine their solar equipment needs, suggest systems or equipment or estimate costs	Active listening, persuasion, social perceptiveness	Sales and marketing, engineering and technology, customer and personal service	Accountability, focus, results orientation
Video game designers	Design core features of video games; specify innovative game and role-play mechanics, story lines, and character biographies; create and maintain design documentation	Programming, critical thinking, complex problem solving	Design, communications and media, psychology	Inquisitiveness, playfulness, passion



to take responsibility for their actions have a strong moral compass that allows for considered reflection, working with others and respecting the planet."

To achieve this, we have to ask ourselves some critical questions – before and after taking action – from which we learn for the future: What should I do? Was that the right thing to do? Where are the limits? When considering the consequences in retrospect, should I have acted exactly in this or a different way?

All the players in the educational system should try to impart and promote such practice: parents as well as educators, teachers as well as lecturers.

The author

Christian Heinrich has been covering educational topics for the German weekly newspaper DIE ZEIT for more than a decade. Since 2014, education has been of highly personal relevance to him: it was the year in which his twins were born. The most recent choice he had to make in this context was just a few months ago: pre-school or another year at the childcare center? He opted for pre-school.

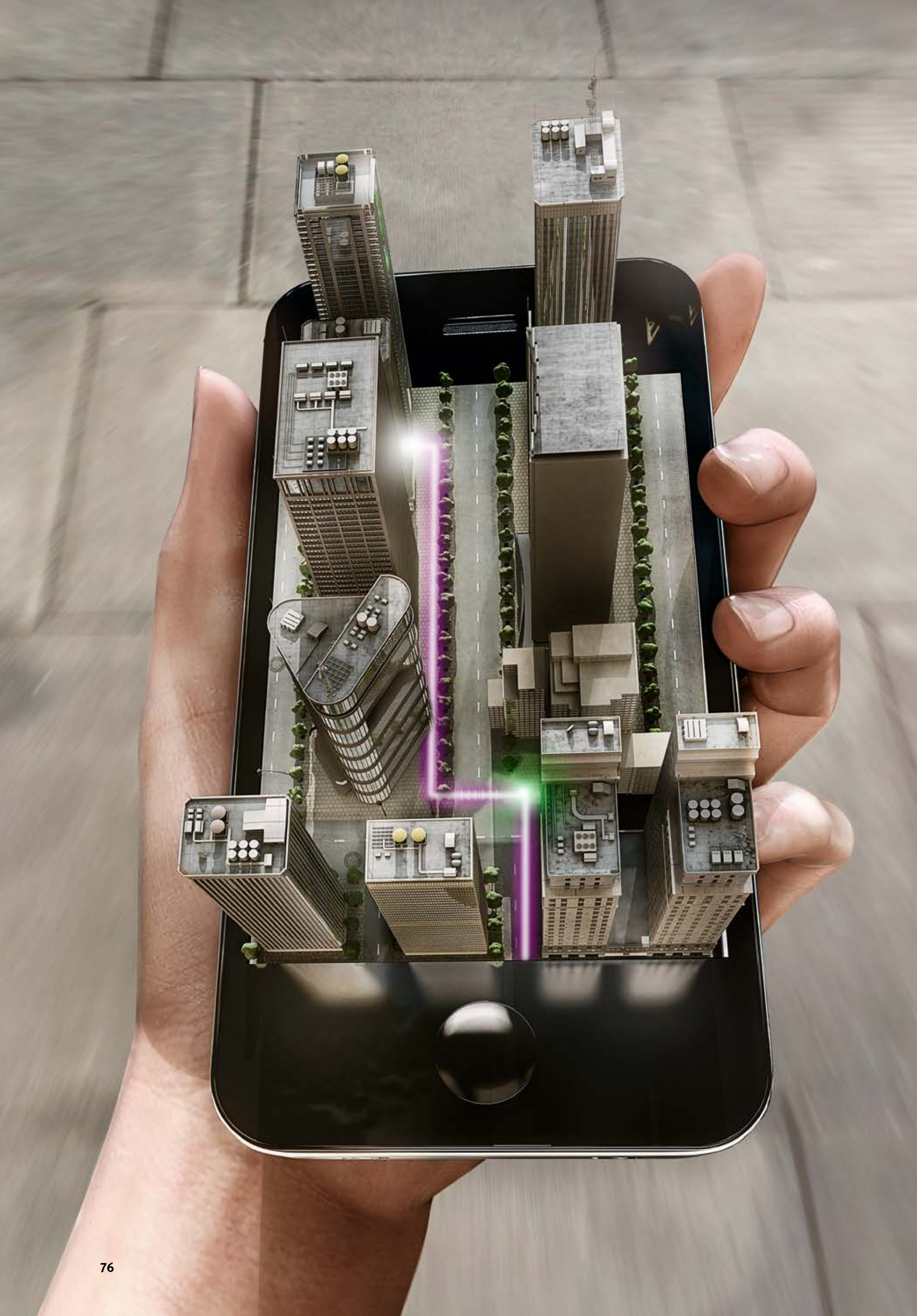
Three questions for …

… Paul Seren,
Training Manager, Schaeffler Germany

Industry 4.0, digitization, the world of work is changing faster and faster. Companies are required to adjust their training. What is important in this context?
Industry 4.0 means that everything is interlinked with everything else – not only the machines, but the workers in particular. That's why the ability – and more importantly, the willingness – to think out of the box is expected of new employees. Schaeffler therefore encourages apprentices and students to be flexible in their reasoning. They should have the capacity for managing change in order to upset the apple cart of things they've been trained in today and to learn something totally new. This, by the way, also applies to the trainers, who continually have to be sensitized regarding their personal readiness for change through respective training activities.

Under these prerequisites, how is Schaeffler adapting its training content in order to keep pace with technological progress?
For the past four years, all apprentices in Germany, irrespective of being trained in an industrial/technical or a commercial vocation, have been able to build a functional 3D printer – with everything that this entails – during their apprenticeships. Networking is important in this context. An aspiring mechatronics specialist communicates with an industrial business management assistant, a software developer with an industrial mechanic. Aside from fostering teamwork as part of an apprenticeship, this reveals further hidden potential. This form of training at Schaeffler has been successfully rolled out in the United States and Europe as well and is also planned to be exported to China in the near future.

What other innovations is Schaeffler planning to use in making apprentices fit for the future?
Virtual Reality and Augmented Reality will become central training tools. Virtual welding simulators have been used for quite some time, but this entire area holds additional potential – especially in manufacturing. For instance, handling, loading and repairing machines can be virtually trained in this way. This is an important innovation also in view of the fact that we'll probably have to continue observing distancing rules for a longer period of time.



Brave new building world

Digital transformation is changing the world of construction and helps save time, costs and natural resources. Much of this is still a vision, but even at this juncture, efficient energy supply can be simulated in advance. Robots are able to lay bricks, cut wood to size and join it. Formwork is supplied by 3D printers and the requisite data by a digital twin. Is an all-new world of construction in store for us?

By Robert Schütz

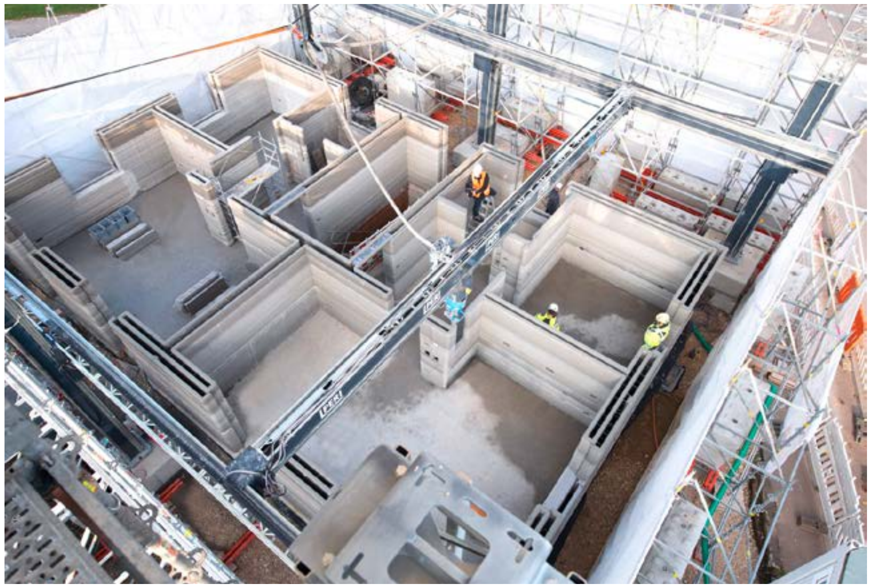
When it comes to Manufacturing 4.0, the automotive and mechanical engineering industries are frequently referred to for orientation. In these sectors, everything is stored in digital models as well and the interaction between digital drawing and designing (CAD) and digital manufacturing works perfectly. The presence of human workers in factory halls is becoming an increasingly rare occurrence. Robots are moving swiftly and with pinpoint accuracy through digitally connected bays. Plus, the material that's picked from high-bay warehouse racks by self-driving forklift trucks autonomously moves on self-driving pallets, guided by induction loops – at the right time to exactly the right place. Welcome to Factory 4.0. And what about construction sites? Digital transformation is forging ahead here as well. While GPS-controlled surveying instruments and autonomous construction machines have long been part of site equipment, Building Information Modeling (BIM) is a term that's now becoming increasingly important.

The BIM planning method

So, what exactly is BIM? Building Information Modeling is no special software but describes the perfect interaction between a variety of software solutions and database systems. Just like every technical construction crew uses specialty tools, the software applications for planning, procurement, construction and utilization processes vary. BIM is like a digital machine that sorts and connects these processes. One of the key prerequisites for this is the availability of all data according to the IFC (Industry Foundation Classes) standard.

Building Information Modeling is still in its early development stages, but already improves adherence to project deadlines and budgets. The reason is that BIM – marking a major evolutionary milestone in this context compared to CAD – provides digital renderings of three-dimensional rooms, but also calculates time and cost parameters as a fourth and fifth dimension. Unsurprisingly, BIM is now a mandatory element of public tendering procedures in many countries.

Evolutions are planned to elevate BIM to a level of creating a dedicated, connected virtual world: a digital twin of the entire construction project. Provided that the plan pans out, this new construction world will also incorporate the Internet of Things



3D printing of a building – something that was still a pipe dream just a few years ago has become reality

(IoT) and cyber-physical systems including machine control, sensors and real-time monitoring.

In spite of all the digitization and connectivity it features, BIM cannot and should not replace personal dialog and the shared understanding of a standardized organizational structure and workflow. The hardware and software as well as the databases here merely supply the requisite infrastructure and provide all the parties involved in a construction project with direct access to the relevant information at any planning stage. Plumbers and tilers are able to match their data and also share them with painters and electricians as needed. And if a crane for installing an elevator fails, all the technical crews affected by the equipment downtime will receive an alert in real time. Ideally, a plan B that minimizes the loss will be sent along with the alert.

From planning to teardown

BIM supports the entire lifecycle of a building or facility, from initial planning to construction and use to potential dismantling including environmentally compliant disposal. The latter aspect can be taken into account as early as in the planning stage and therefore closes the loop.

In the construction stage, the machines involved can be controlled using so-called BIM2Field applications. This is an increasingly important factor, because – just like factories – construction sites are using more and more advanced technologies. Even at this juncture, self-driving machines exist that distribute materials at the site just in time. Drones assist with surveying work and inspections. The successor of the bricklaying robot Hadrian X is said to be able to join 1,000 bricks together per hour instead of the previous 200. Plus, a huge 3D printer produced the first three-story 12.5 by 17.5 by 7.5-meter (41 by 57 by 25-foot) residential building on-site in Germany this fall – at a breathtaking speed of processing 10 metric tons (11 short tons) of a special cement per hour.

At the end of October 2020, construction equipment manufacturer Hilti unveiled its semi-automated mobile construction robot for overhead drilling jobs. The so-called Jaibot is able to independently and accurately position itself in interior spaces, drill holes and subsequently mark them for the various construction crews. The autonomous system is easy to use without expert knowledge. Hilti has no doubts that digitally planned construction projects and their implementation using BIM-capable robotic solutions promise to deliver a significant productivity gain. In addition, robotic solutions can mitigate the shortage of skilled labor.

Perfect planning, saving resources

The digital twin can supply not only the control data for such high-tech machines. Even traditional construction machines like excavators, dozers and road pavers have long begun to feature 3D machine control units that are fed with digital BIM and terrain models. Entire civil engineering models are shown to the machine operator on a display and facilitate faster and more precise work.

Look before you build

The digital twin offers another major advantage even before the first sod is turned: Thanks to VR headsets, clients can take a virtual walk through their projects to get a highly realistic impression of the planned outcome. As a result, the client's wish can be compared with reality while the project is still in the planning stage, which practically precludes the risk of costly corrections after construction has begun. Even if the client should subsequently desire modifications, BIM will concurrently inform all the technical crews involved and warn them of potential issues that may be caused by the change in plans. In addition, material orders can automatically be adjusted and documented down to the smallest washer.

But BIM-optimized logistic processes not only cut construction costs and time. They also help reduce the consumption of so-called embodied energy, in other words, the energy required for production, storage, shipping, processing and disposal of construction materials.

The subsequent operation of the facility as a whole is significantly simplified and incurs less costs due to digitally connected planning as well. Experts refer to this as BIM2FM, with FM standing for Facility Management. In this context, it's important to know that the lion's share of a facility's total costs is not incurred during the planning and construction stage, but that the greatest savings potential exists in the utilization stage. That's why, as early as

Bearings for buildings

For 75 years, engineers in the construction industry around the world have been relying on Schaeffler's plain bearings and consulting expertise. Hydraulic motion control cylinders for construction machines, grinding rollers in cement mills, continuous casting lines in steelworks, articulated pendulum joints for optimal steerability in roller-compactors, train doors and bogies, escalators and luggage belts at airports: all of them require plain bearings.

In buildings, plain bearings are used at particularly critical interfaces like in the glass roof of Berlin's Central Train Station. The roof structure covers approximately 300 meters of railroad platform. Countless spherical plain bearings and bolt systems from Schaeffler are installed in the trussed frames, providing the necessary length compensation in the steel structure when external influences, particularly wind, act on it.

The weight of the roof structure at London's Wembley Stadium rests on just two bearings from Schaeffler. Each of them supports a weight of 7,500 metric tons (8,270 short tons) and has been designed for a service life of 100 years.

Installed in the roof of Berlin's Central Train Station are spherical plain bearings and bolt systems from Schaeffler

» Digitalization is bringing a new building culture. For the architect, it is a paradigm shift

Matthias Kohler, Professor of Architecture and Digital Fabrication ETH Zürich

An industrial robot (in situ fabricator) fabricates a 3D grid structure filled with a type of concrete that has specific flow characteristics

in the planning phase, all parameters such as insulation performance, heating output and ventilation data as well as the subsequent room temperature and energy costs at varying times of the day and during different seasons are calculated in advance. As a result, the digital BIM facility model becomes a real-time based control, monitoring and measuring center that technically and economically optimizes a building's entire lifecycle. Here's a case in point in this context: even before construction starts, architects can rotate and move the digital twin around the site, and simulate various locations in fast-forward mode across the four seasons in order to identify the building's energetically optimal orientation and design, among other criteria.

All-new opportunities

The latest digital applications are the subject of intensive study at ETH Zurich as well. Matthias Kohler, Professor of Architecture and Digital Fabrication, says: “Digitalization is bringing a new building culture. For the architect, it is a paradigm shift.” At ETH Zurich, which provides important impetus in this area, researchers from eight departments are working together with industry experts and planning professionals. They explore and test how digital fabrication can change the work of designing and building. The objectives pursued in this context are flexibility in design, sparing use of materials, time and cost efficiencies, and enhanced quality control. An S-shaped wall featuring so-called mesh-mold technology (pictured left) is an example of such digital fabrication. The new construction technology combines the functions of reinforcement and shaping in a steel mesh fabricated by robots, enabling the cost-efficient and sustainable production of reinforced concrete structures of any desired shape without the need for complex casings. A functionally integrated floor featuring an unusually complex shape was placed atop this digitally fabricated wall. The slab formwork was produced by 3D printing. In this case, all the data of the structure were provided by a BIM model as well.

Sorting the data maze

To prevent users from getting lost in the data spaces of a BIM model with many terabytes, the total information and complex pictures are split into layers in which the relevant data for the respective construction teams are stored. Structural

Digitally planned, additively manufactured: The curved ceiling elements that were cast in a 3D-printed casing are joined together at the construction site

engineers, for example, are only interested in data pertaining to the building's design and structure, while façade planners will only be dealing with its exterior shell. Every planned, used or potentially used component is stored in a BIM-compatible database. In addition to the classic dimensions, facts about materials such as their thermal conductivity and flammability are important. Even the source from which a material was purchased can be identified at a later point in time by just clicking the relevant detail. The gaps and relations between adjacent components are captured as well.

Much of the BIM potential described here is still a vision. But when Henry Ford introduced the moving assembly line, he was a visionary, too. Nobody was ready to believe that it was possible to break down the production of complex goods or products into individual, monotonous steps. And that was just the beginning of progressive industrialization and automation. Aldous Huxley's novel "Brave New World" begins with an epigraph in French that might be translated into English as "Utopias appear much more attainable than formerly was believed." The construction industry has been following this proposition more than ever before. The BIM digital planning method and innovative production technologies create all-new opportunities for design that can also be achieved faster and at lower costs. Perhaps living in style and in complex architecture will soon become affordable for everyone. This would be true progress. The odds are in its favor. Welcome to the new building world.

The author

Robert Schütz is a trade journalist covering the fields of architecture and digital construction, and CEO of Bautalk. The communications agency based in Frankfurt a. M. specializes in architecture and construction. His favorite buildings: Frank Lloyd Wright's famous private residence Fallingwater and Casa Gilardi in Mexico City, Luis Barragán's last building that was completed in 1976.

With the power of the wind

Over the course of millennia, the wind has been working for humans: It grinds grain or pumps water. It propels ships across the sea or balloons and gliders to awesome altitudes. In the future, the wind will become an increasingly powerful ally in the battle against climate change – thanks to constant technological innovation.

By Daniel Hautmann

107 meters (350 feet). This is the length of a single rotor blade of the world's most powerful wind turbine. When all three blades are installed, they describe a circle in the sky with a diameter of 220 meters (722 feet). To put these dimensions into perspective: the world's largest Ferris wheel, the High Roller in Las Vegas, is "only" 167 meters (550 ft) tall.

The record-breaking Haliade X wind turbine from American multinational conglomerate General Electric (GE) is currently being tested at the port of Rotterdam in the Netherlands. It has a total height of 260 meters (853 feet), which makes it just a little smaller than the Eiffel Tower. Most impressive, though, is its rated capacity of twelve megawatts. Not too long ago, such behemoths were regarded as mythical creatures. Today, they're reality – and far from marking the end of their evolution. Other manufacturers have already announced 15-megawatt machines. According to GE, Haliade X generates electric power for up to 16,000 households and it takes just three rotor revolutions to charge the battery of a Tesla Model 3 – providing the car with a range of more than 500 kilometers (311 miles).

Obviously, such giants are installed only on the high seas, far away from coastal waters, where they do not bother anyone. Offshore systems are also better for wind yield, delivering up to 4,500 hours of maximum power per year compared to just around 2,000 supplied by those onshore. This perceived megalomania has a logical background. The larger the systems the more power they generate – plus, the simpler the logistics chain: "Larger systems have massive advantages," says wind power specialist Manfred Lührs from the consultancy firm 8.2. "They optimally exploit the sites."

Floating structures

Europe (including the UK) – or more precisely, the North Sea – is the epicenter of the offshore wind industry with a currently installed rated capacity of around 22 gigawatts. The water is shallow, and the demand for electricity high. Shallow in this case means 40 meters (131 feet), which is ideal for offshore wind power. Large steel foundations can be placed on the bottom of the sea here or gigantic

Offshore double pack

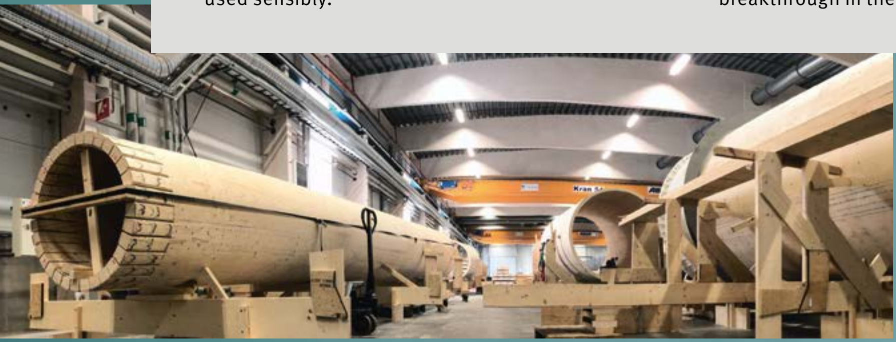
Aerodyn engineering based in Rendsburg, Germany, puts **two wind turbines on a floater.** This twin concept reduces costs and increases the power rating, according to the manufacturer. Due to its floating structure, the system can be used in in deeper waters. Its name is Nezzy^2. The towers of its two wind turbines are separated from each other by 90 degrees, which is reminiscent of the fork of a tree branch. The two self-aligning rotors turn in opposite directions and are controlled so that they won't get in each other's way. This rotational concept prevents slipstream between the twins and stabilizes the floater. However, it's still uncertain when the first twin system will be deployed offshore. A 1:10-scale prototype with a height of 18 meters (60 feet) was tested this fall in the Greifswalder Bodden lagoon of the German Baltic Sea and proved its seaworthiness even in hurricane-like winds. **China has already expressed an interest in commissioning a 1:1 version with a height of 180 meters (600 feet) for testing.** This full-scale system is supposed to be able to withstand even waves of 20 meters (65 feet) in height. Steel mooring cables in the seabed hold the system in place.

Wood meets wind

Before wind power systems can provide renewable electricity, they generate a negative climate footprint: The installation of the huge masts and foundations of concrete and steel results in 2,000 and more metric tons (2,200 short tons) of climate gas emissions, depending on the size of the systems. Due to the utilization of wood, which binds CO_2 during the growth stage (notably, one metric ton per cubic meter/63 lb per cubic foot), wind power systems can be established in climate-neutral ways. Plus, wood as a material offers other advantages:

- The modular design and the material **reduce the weight of the towers**. The composition of the modules does not presuppose any special quality of the access routes because the modules are assembled on-site, which eliminates the need for heavy haulage.
- A wooden tower has longer fatigue life and is **not prone to corrosion.**
- **Wooden systems are much easier to dismantle** and dispose of than systems of concrete and steel. Appropriate combustion of end-of-life system components will not cause any additional environmental burden and the energy can be used sensibly.
- **Hub heights of up to 200 meters** (650 feet) can also be achieved with this natural material.
- Wood is even suitable as a material for **foundations and rotor blades.**

In spite of these advantages, wood has not been able to crack the dominant position of steel and concrete with large-scale wind power systems because these materials are established in the marketplace at high levels of vertical integration. The 1.5-megawatt system from German manufacturer Timber Tower that was commissioned near Hanover in 2012 has so far remained a pilot project in spite of announcements that it would be followed by others. In Sweden, Modvion, an engineering and industrial design company, commissioned an initial prototype using prefabricated glued laminated timber modules in April 2020. The first projects with heights of up to 150 meters (490 feet) are planned to be implemented for Swedish energy corporations starting in 2022. Modvion expects that wooden wind energy towers cannot just be constructed in more climate-friendly but also in clearly more cost-efficient ways than those of steel. Wood is a work in progress – but still waiting to achieve its breakthrough in the wind energy sector.



Diverse ideas of wood: Modvion in Sweden (above) uses prefab, self-supporting formed modules. At Timber Tower (right) in Germany, a wooden structure – also featuring a modular design – initially grew tall and was subsequently reduced in size

Setting sail

90 percent of global trade is handled by ship. The potential of **reducing emissions by revitalizing sailing cargo ships is correspondingly high.** Although the planned Oceanbird (pictured) is making slower headway than current motor ships, it does so with 90 percent less CO_2. While the Oceanbird uses metal telescopic sails, other ideas feature huge kite-sails or sail-shaped high-rise hulls. At the same time, the search for maritime routes with favorable wind conditions is in progress.

Remaining flexible

Due to the huge rotor diameters of modern wind power systems of 200 meters (650 feet) and more, the rotor blades during one rotation cycle are exposed to heavily varying wind speeds, especially on the tips of the blades. **A control concept that takes this phenomenon into account cannot just improve the electricity yield of a turbine but also avoid fatigue-induced damage due to pitch misalignment.** So far, turbines have typically been using control systems that simultaneously adjust all pitch angles to the prevailing conditions, which may significantly reduce energy yield. With modern large-scale systems, individual blade pitch adjustment has been gaining traction. Its potential benefits: higher energy yield, reduced fatigue, lower noise emissions and a better flow field behind the rotor.

steel tubes, so-called monopiles, be driven into the seabed to stabilize the systems.

Other oceans are as shallow as the North Sea only in very few places. Nearly everywhere in the world, the water is too deep for large tripods supporting the wind turbines. About 80 percent of the worldwide wind resources are located above waters that are at least 60 meters (200 feet) deep. But there's a solution to this profound problem: floating wind turbines.

Dozens of prototypes are currently being tested worldwide, some of them with capacities of up to eight megawatts. In Asia, Europe and the United States, commercial projects in the gigawatt range are in the planning stage. By the end of this decade, floating wind turbines with a combined capacity of 6.2 gigawatts could be built, according to the Global Offshore Wind Report. This roughly corresponds to the capacity of eight coal-fired power plants.

European countries are pushing the technology. According to Kimon Argyriadis from the consulting firm DNV GL, Europe's western coast and the Mediterranean Sea are deep waters with good wind conditions and close to major consumers. What's more, Europe was previously the technology driver of ground-based offshore wind power and is not inclined to miss out on the floating wind turbine business. This comes as no surprise because experts expect the technology to become standard with incredibly low kilowatt hour prices of just a few Euro cents. The twin-rotor floater Nezzy^2 from North German engineering company Aerodyn (see info box on page 83) is such a European project. Klaus Ulrich Drechsel, an offshore expert at electric utilities company EnBW that acquired interest in Nezzy^2, sees major potential in such systems because they can be used in virtually all coastal regions of the world, even those with steep drops that soon lead to great depths.

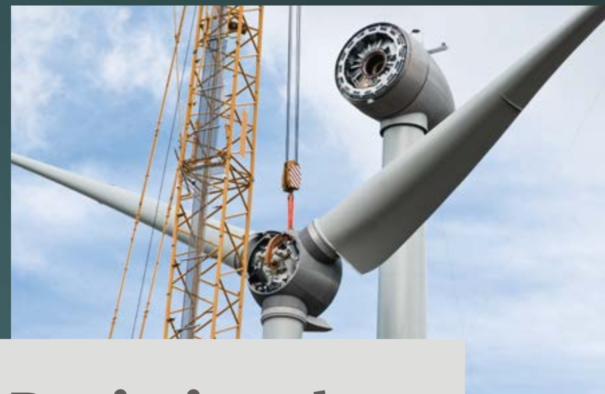
Harnessing upper-level wind

The floaters' potential can be driven to even greater heights because the wind blows more intensely and persistently at higher altitudes. That's why modern wind turbines are installed on towers that are as tall as possible. But there are limits to how tall they can be, so different ideas are needed. One of them is airborne wind power generation (see right-hand column). These machines look completely different than the customary three-bladers. Just like kids' kites, airborne wind turbines are tethered and climb high into the sky. The tethers, however, are up to 600 meters (1,970 feet) long – and have to resist awesome forces. Although the commercialization of airborne wind energy systems is not yet in sight, its advantages are impressive, especially their minimal use of materials. They neither need a tower nor lengthy blades, and the foundation can be a lot more light-footed, too. Best of all, though, is the fact that, thanks to their higher yield, two-megawatt airborne wind power systems could achieve higher annual electricity outputs than conventional three-megawatt wind turbines. This is precisely the argument Fort Felker, CEO of airborne wind power pioneer Makani, uses to promote the technology as one that enables more energy to be harvested with less powerful systems.

High in the wind

Although numerous airborne wind energy systems have already been deployed, all of them – strictly speaking – are still prototypes. **Some of the technologies they use exhibit major differences.** Two basic approaches have emerged: One of them features an airborne generator producing in-flight electricity which is then conducted to the ground via special tethers that simultaneously transport the electric power. The other approach prefers power generation on the ground. While the kite or wing rises, it reels off a rope that in turn drives a generator producing power in the process. This principle is also referred to as "yo-yo" because the wing keeps being retracted – without generating energy during this phase. Master of the airways is the U.S. company Makani that was supported by Google for many years. At the moment, the Americans' M600 flyer features a carbon fiber wing with a length of 26 meters (85 feet) hanging on a rope. **Ideally, in other words, in adequate wind conditions, eight generators installed on the wing deliver an impressive output of 600 kilowatts.**

In upper level winds, companies like Makani (pictured here) harvest up to 50 percent more energy with systems that are actually less powerful than others



Energy for green hydrogen

All the wind turbines, whether standing on land, floating on the sea or even flying through the airways, could supply huge amounts of green electric power. Green electricity could charge all the battery-electric vehicles or – by means of electrolysis – produce the coveted green hydrogen that may either be used in the steel and cement industry or be reconverted into electric power in fuel cells. In this way, wind power might lend wings to the planet's decarbonization. In any event, wind as an energy source is available in abundance. Experts tells us that 18 terawatts of installed capacity would be enough to cover the world's primary energy requirement – the space available for this purpose would suffice for generating 400 terrawatts.

Wind energy in mobility

There are other industries besides the energy sector that can use the power of the wind, and not necessarily just when converted into electricity. Examples include sea trade and aviation. Ocean-going cargo ships haul about 90 percent of all the goods we consume – from the aluminum foil we wrap our lunch in to industrial chemicals to tooth brushes. Plus, what used to work in the old days, still works today: sailing. Reliable winds blow around the globe, so more and more freighters are now putting to sea powered by the wind or at least using its force for assistance. Some of them rely on special sails like the Dyna-Rigg or kite rigs such as the SkySail. The planned cargo vessel Oceanbird with a length of 200 meters (650 feet) features five wing sails, each up to 80 meters (260 feet) tall. Due to using wind power, the Oceanbird's carbon savings potential amounts to 90 percent. Others rely on the more than 100-year-old Flettner principle (see also page 37) to save fuel. Instead of sails,

Resisting the elements

Rotor blades consist of fiber-reinforced polyester or epoxy resin. Rotational speed is particularly high in the area of the blade tips (70–80 m/s; 230–260 ft/s). The force multiplies when rain – or worse yet, hail – hits them, which causes the surfaces to be attacked. This in turn increases friction drag that reduces the system's efficiency. Intrusion of water in the blades is even worse. If lighting strikes, which is not uncommon in such exposed high-rise structures, the water trapped in the blades can cause the overstretched outer skin to crack and burst. Even if this should not occur, the water deposits change the distribution of weight. The resulting **imbalances and vibrations stress the gearboxes and bearings, which reduces the life of the entire system.** In an approach to solving this problem, the Norwegian research organization SINTEF has successfully experimented with diverse **nano particles such as carbon nano tubules and silicon dioxide particles** to make coatings more resistant against the impact of precipitation.

Horizontal instead of vertical

In a test bed in the western German town of Grevenbroich, a **vertical machine rotates and converts wind energy into electrical power.** The principle of vertical axis machines is as old as the hills. Some 1,700 years BC, the Persians set up the first mills with flat-rotating wings. Obviously, their modern-day descendants are clearly more powerful – and taller, with 750 kW of rated capacity achieved by a design height of 105 meters (345 feet). Even so, modern systems with upright propellers and similar hub height deliver about 30 percent higher output. The vertical axis systems have the major advantage of being **three times quieter** than conventional systems and can thus be established in closer proximity to residential areas without violating legal requirements.

huge cylinders rotating with wind power provide propulsion in this case.

Surfing the stratosphere on lee waves

Commercial aviation could drastically reduce its emissions as well by making efficient use of the wind. Gliders are masters of this art and have long been deemed to be pioneers, both in terms of flight maneuvers and materials. Record-setting pilots glide over distances of more than 3,000 kilometers (1,850 miles) and up to altitudes of 23 kilometers (14 miles) – without burning a single drop of fuel. They use huge lee waves forming above mountain ranges in conditions of strong wind. That's what the pilots of large airliners aspire to do, too – and therefore learn from the gliders.

Even race cars made of high-tech carbon fibers with sophisticated hybrid powertrains use the awesome power of the wind to pick up speed, while so-called wind cars look like wind turbines on wheels and are driven right against the wind. Strangely enough, they reach higher speeds than the opposing wind itself. This is the principle of the annual Racing Aeolus competition that has been held on a dike in the north of the Netherlands since 2008 and in which teams from all over the world participate with race cars they've developed and built themselves, using the wind as their fuel.

The author

Freelance science journalist **Daniel Hautmann** has dedicated a whole book to the wind: "Windkraft neu gedacht – erstaunliche Beispiele für die Nutzung einer unerschöpflichen Ressource" ("Rethinking wind power – amazing examples of using an inexhaustible resource") deals not just with wind power systems that generate electricity but also with many other ideas that show how humanity can harness the power of the wind – without polluting the atmosphere with harmful greenhouse gas emissions.

3 questions for ...

... Rudolf Walter, Vice President Business Unit Wind at Schaeffler.

Wind power is already playing a crucial role in the global energy transition process today. In your view, will its importance increase even further, going forward?
Yes, the global energy transition process is unthinkable without wind power. Its share in the energy mix has prospects of further growth. Take China, for example, which is already the world's biggest market for wind energy. The rate at which its expansion is being accelerated in order to achieve climate neutrality by 2060 is awesome. In the next five years, new systems with a total capacity of 50 gigawatts on average are planned to be installed there per year, and even more in the subsequent years. This more than doubles the current growth rate of 20 gigawatts per year. Of course, that's an interesting prospect for Schaeffler's Industrial Division as well.

With what innovations is Schaeffler planning to achieve further efficiency increases of wind power systems?
Among other things, we're using special technologies to enhance the robustness of larger bearing solutions which can then achieve greater output and, as a result, reduce power generation costs. For instance, that's why we use an induction curing technique allowing us to produce bearings with an outer diameter of more than 2.5 meters (8 feet) more economically.

In terms of predictive maintenance, Schaeffler is planning to field another innovation. What exactly is this?
That's right. We've developed technologies enabling us to permanently measure the water content in oil as well as detecting and feeding back a bearing's exposure to electrical current. Both are warnings that indicate so-called white etching cracks, in other words, structural changes below the surface of bearings. As a result, we're able to reduce cost-intensive bearing failures. At the moment, we're in the prototype operation stage. The plan is to start production next year.

Masthead

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Schaeffler Communications
Thorsten Möllmann
(Senior Vice President Group Communications & Public Affairs)
Martin Mai
(Head of Newsroom, Global Editor-in-Chief Schaeffler Group)

Executive Editors
Volker Paulun,
Stefan Pajung (Deputy)

Coordination
Carina Chowanek,
Gina Fernandez,

Pre-press Stage
Julien Gradtke,
Anke von Lübken

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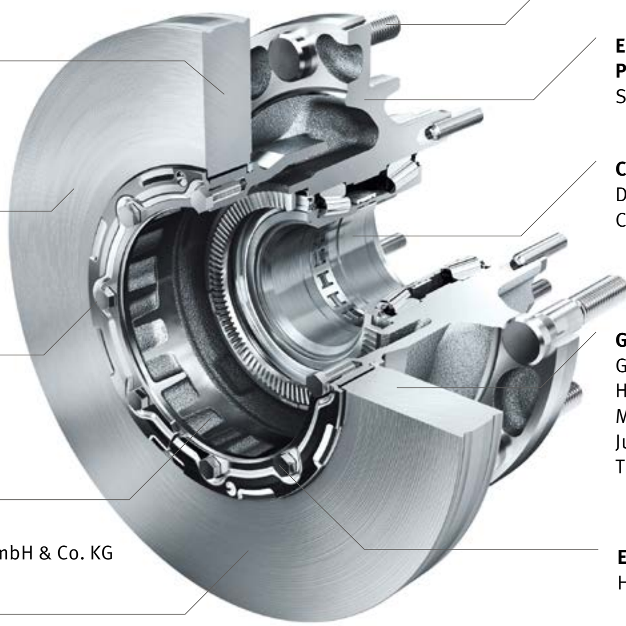
*



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Martin Mai

Editorial Team and Production
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David Feist,
Christoph Kirchner

Graphic Design
Gökhan Agkurt, Jana Herbst, Manuela Mrohs, Janina Roll, Julian Schmaljohann, Thomas Wildelau

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* Schaeffler wheel bearings in the commercial vehicle segment, like the one shown here, have undergone constant evolution in recent years. In the wake of growing cargo volume, higher performance and changes in drivability, the requirements keep increasing. Long lifespan of more than one million kilometers (621,000 mi), high reliability and maintenance-free operation are key criteria because a wheel bearing is not only the connecting link between the wheel and suspension but also absorbs all of the vehicle's dynamic forces.

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tomorrow All previous issues

01/2015
Mobility for tomorrow

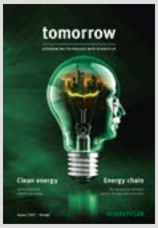
02/2015
Productivity

03/2015
On the move

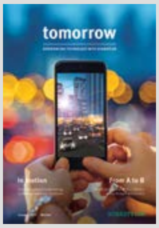
01/2016
Innovation

02/2016
Sustainability

03/2016
Digitalization



01/2017
Energy



02/2017
Motion

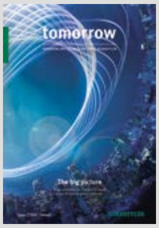
03/2017
Machines

01/2018
Transformation

02/2018
Urbanization

03/2018
Acceleration

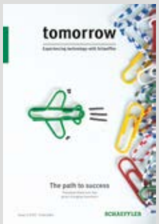
01/2019
Challenges



02/2019
Holism

03/2019
Work

01/2020
Opportunities



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