tomorrow

Experiencing technology with Schaeffler

Embracing new paths

There are more ways than one to reach a goal, but the most common one isn't always the best

Issue 3/2021 · Pioneering spirit

SCHAEFFLER

Pi|on|eer|ing spir|it; [ˌpaɪəˈnɪərɪŋ ˈspɪrɪt]

Drive to lead the way and break new ground in the pursuit of solutions combined with the resolve to tackle the challenges, uncertainties and risks involved in the resulting course of action.

tomorrow has won recognition

Special Mention
"Communications Design Editorial"

Silver
Special Award "International Communication"

Special Mention
for "Outstanding Branding"

Award of Excellence
for Cover (2/2017) and cover story "Electric Leader"

Gold Winner
"Websites: Customer Magazine"

Award of Distinction
"Cover Design, Overall Design, Corporate Communications, Copy/Writing"

Gold Winner
"Websites, Feature Categories, Best Copy/Writing"

Gold Winner
"General Website, Categories- Magazine"

Silver
"Writing: Magazines Overall"

Grand Winner
"Magazine"

Dear readers,

The Schaeffler Group recently celebrated its 75th anniversary. Our company was founded in 1946, in the midst of the post-war turmoil, by the two brothers Georg and Wilhelm Schaeffler. They demonstrated courage, foresight and pioneering spirit galore. And that takes us to "pioneering spirit" as the focus topic of this issue.

Pioneers have been helping to shape the world since time immemorial. Whether they're bold explorers venturing into uncharted territory or clever scientists decoding and explaining the formulas of the world. Or visionary inventors whose innovations drive progress. Like our company's "initial invention," the cage-guided needle roller bearing by our founder, Dr.-Ing. E. h. Georg Schaeffler. We continue to be committed to the pioneering spirit of the Schaeffler brothers today, which, not least, is expressed in our claim "We pioneer motion." We want to shape progress that provides momentum to the world! You'll be able to discover how we go about that in a few places of this issue of "tomorrow."

All of us are born with a large dose of pioneering spirit. Especially the first years of our life are an exciting voyage of discovery. Our curiosity turns us into investigators. Admittedly, as we get older, awakening this exploratory urge over and over is not always easy – but it's worth it. Like a light bulb needs electricity to emit light life needs electrifying excitement. Discovering and coping with something new provides precisely this kind of excitement that electrifies people all over the world. By combining things that are known with others that are unknown, they develop ideas with determination and perseverance that provide momentum to the world. Just like Wilhelm Conrad Röntgen did in his day. His discovery of the X-rays, which quite literally marked a breakthrough, has long made its way from medical into industrial applications and into digital worlds, where X-ray images provide enlightening findings as well. Starting on page 26, you'll be able to read more on this subject.

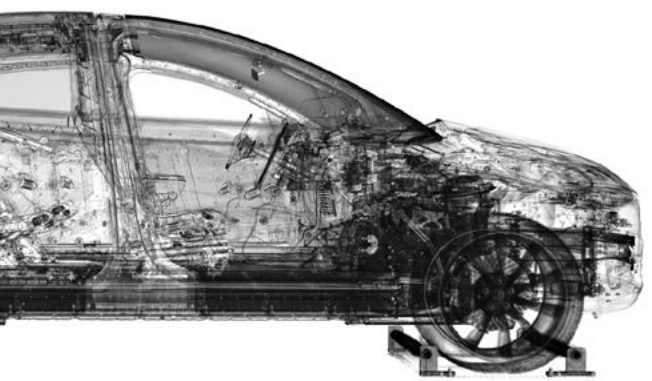
Imbued with pioneering spirit is the startup scene. Everywhere in the world, highly energized entrepreneurs are developing business ideas. Starting on page 74, a number of remarkable men and women share with us how they came up with their brilliant ideas and what drives them, as well as the hurdles they had to overcome during the development process, which I find particularly exciting. Apple's founder, Steve Jobs, appropriately said that about half of what separates successful entrepreneurs from the non-successful ones is pure perseverance.

Another story I'd like to recommend to you is the interview with Jutta Kleinschmidt (starting on page 36). The female racer who is the only woman to date to have won the famous Dakar Rally is pioneering spirit personified. The picture that shows her preparing her motorcycle for the next race in her kitchen at home is legendary. Her paths have repeatedly crossed those of Schaeffler. In 2021, she competed in the new Extreme E electric offroad series, which – in line with our key topic – is another innovative pioneering project.

For the new year I wish you and yours all the best – especially good health, of course. And if in this issue of "tomorrow" we've managed to kindle your personal pioneering spirit as a source of energy for coming challenges, so much the better.

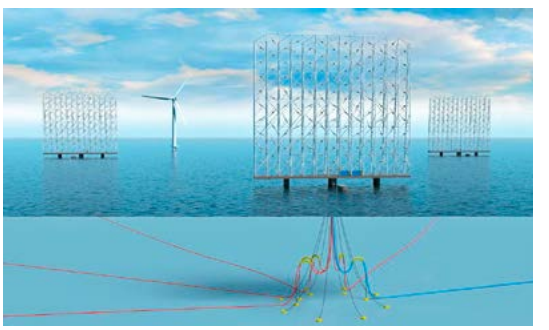
Klaus Rosenfeld
Chief Executive Officer

Engineering



In Motion

Think Green



Digital

Future Life

Engineering

Developing existing things to new levels, getting new things off the ground: Technology pioneers accelerate the evolution of the world with creative ideas.

Autonomous agriculture

Agricultural machinery manufacturer John Deere is planning to launch a fully autonomous tractor in 2022. To enable this pioneering project to be developed to market level, the American corporation acquired Bear Flag Robotics, a startup company specialized in automating farm work. **Using six pairs of stereo cameras, the autonomous tractor scans its surroundings for obstacles.** Information captured from the images is analyzed by an artificial intelligence system with a neural network structure. "Each pixel is classified in about 100 milliseconds. The system then decides whether the machine continues or stops, depending on whether an obstacle is detected," says Deere's Chief Technology Officer Jahmy Hindman. **For accurate classification, the AI has been trained with more than 50 million images.** Using GPS navigation and a virtual fence ("geofence") for orientation, the tractor moves exactly to the places where it's supposed to work – with an accuracy of 2.5 centimeters (1 inch). Workers monitoring the machine can also do so remotely using smartphones, tablets or PCs.

Night-time solar cell

The invention of the solar cell ranks among the most important pioneering feats in the more recent history of technology. A disadvantage that's hardly surprising: when there's no sun, there's no current. Researchers at the University of California have tackled this problem and are setting their sights on a solution: **anti-solar cells producing electricity even in total darkness.** Whereas a regular solar cell generates voltage by absorbing the Sun's short-wave infrared light to set electrons in motion, which in turn causes current to flow, the anti-solar cell uses long-wave thermal radiation that is emitted to the cold night-time sky. **54 watts of power** can be achieved per square meter (11 square feet) of an anti-solar panel array, equating to about a quarter of a conventional solar cell, according to the research scientists.

Art. 81

of the European Patent Convention (EPC) says that every patent application shall designate the inventor. This inventor has to be a human, according to a recent ruling. **An AI system cannot be registered as an inventor.**

Source: EPO cases J 8/20 and J 9/20

"Technology made large populations possible; large populations now make technology indispensable"

Joseph Wood Krutch (1893–1970). American author and philosopher

An idea that pushes and pulls

Schaeffler has been recognized with the "Hardware Innovation Award" for its GraviKart solution at the International Conference on Social Robotics (ICSR). **The multifunctional robotic push trolley** was developed at the Schaeffler Hub for Advanced Research (SHARE) at Nanyang Technological University (NTU) in Singapore. Thanks to intuitive user controls and feedback GraviKart is easy to operate and performs physically strenuous jobs such as moving heavy goods in the manufacturing industry. GraviKart is equipped with **sensitive haptic and voice recognition technology,** understands human gestures and communicates by providing visual cues via its built-in LED lights. The smart push trolley is agile enough to navigate even extremely tight spaces.

Game changers

Gutenberg, Benz, Edison, Curie, Röntgen, Gates or Musk – almost everyone is familiar with the names of these innovation drivers. But do you know to whom we owe the zipper, industrial paper production or ferroconcrete? Nine brief, exciting portraits of people without whose pioneering spirit today's world would be a different one.

approx. 800–880

Fatima Al-Fihri

The oldest active university of the modern era is, of course, located in London. Or is it Athens? Paris, Berlin or Rome? None of these cities is correct because the city of Fès in Morocco can lay claim to this distinction. Plus, it wasn't an old scholar or prince seeking to expand his knowledge that **founded this institution of higher learning in 895 A.D.** but a merchant's daughter named Fatima Al-Fihri. A horrific year for the devout Muslim, in which her father, brother and husband die within just a few weeks of each other provides the impetus – at least according to the written accounts of chronicler Ibn Abi Zar' in the 14th century. Together with her sister, Al-Fihri inherits a significant fortune. The two women use it to build a mosque in Fès. **Fatima Al-Fihri's spiritual building, in the planning of which she participates with profound architectural knowledge,** is called Al-Qarawiyyin and, in addition to places of prayer and education, encompasses an extensive library. As a result, the complex is regarded as the first modern university and its founder as a pioneer in education and early trailblazer for academic careers of women.

Why her work changed the world

- Her institution of prayer and education, Al-Qarawiyyin, **became the blueprint for modern universities**
- It provided a **gateway to education** for members of many social classes
- She was **a thought leader in academic exchanges** between the Western and the Arab world
- Al-Qarawiyyin graduate Pope Silvester II (950–1003) united **letters in the Latin alphabet and Arabic numerals**

1602–1686

Otto von Guericke

Does nothingness exist? That's a question the philosophers in Ancient Greece already wrestle with (and that remains unanswered). In the middle of the 17th century, several scientists, independently of each other, try to experimentally **prove nothingness in the form of a vacuum.** The mayor of Magdeburg and amateur physicist Otto von Guericke manages to do so most impressively. To create a vacuum, he incidentally invents the principle of the vacuum pump that's still in use today. In his "Magdeburg hemispheres experiment" (in 1657, pictured below) he pumps so much air out of a sphere formed by placing two metal hemispheres together that the resulting pressure difference between the inside and outside is so great that it takes several horses (up to 16, according to lore) to pull the hemispheres apart again. **He goes on to demonstrate that light, but not sound, can penetrate vacuums.** Later, Guericke wants to prove another natural phenomenon – the existence of unicorns – but fails in this attempt.

Why his work changed the world

- His experiments with air pressures inspired Guericke's idea to use a barometer for weather forecasts, so making him a **pioneer in meteorology**
- The subject of vacuums to which Guericke provided decisive impetus laid the **foundation for countless inventions,** from the incandescent light bulb to packaging solutions to the supersonic Hyperloop train that's supposed to glide in vacuum tubes

1882–1935

Emmy Noether

Mathematics and all the worlds of thought that are behind it: Emmy Noether wants to explore them. However, at the end of the 19th century, her real world in Germany blocks the educational pathway into all natural sciences for women. **In 1900, her diploma as a language teacher opens a back door to the university in her home town of Erlangen for her,** so she begins her studies of mathematics as a guest student. In 1903, Bavaria allows women to enroll in the state's universities for the first time and Emmy Noether blossoms into an academic superstar, provides fundamental insights relating to structural algebra and revolutionizes theoretical physics. Her most important proposition, Noether's theorem published in 1918, states that every differentiable symmetry (e.g., time or space) of a physical system with conservative forces has a corresponding conservation law (e.g., energy or impulse). **In spite of her global recognition, not a single German university appoints her as a full professor.** Only after Noether, a Jew, emigrates to the United States in 1933, does she find her first appropriately salaried position. Emmy Noether dies in 1935 following tumor surgery. Her professional friend Albert Einstein honors the 53-year-old in an obituary in the New York Times, calling her "the most significant creative mathematical genius since the higher education of women began."

Why her work changed the world

- Noether has made **algebra the leading research topic in mathematics worldwide**
- Her abilities, her courage and her mental strength have made her a **role model for many STEM talents** until this day
- Noether's theorem is regarded as a **fundamental of theoretical physics**

1880–1954

Gideon Sundbäck

Buttons, ribbons, bands, strings, buckles, clasps, hooks and eyes – all of them are time-tested fasteners around 1850, but they require the use of two hands. The zipper makes closing and opening bags, shoes, jackets and trousers much easier. In 1851, the American Elias Howe obtains a patent for an "automatic, continuous clothing closure." However, his mechanism fails in practical use. **In 1912, Gideon Sundback ultimately makes the concept practically usable.** The mechanical engineer who has emigrated to the United States from Sweden invents a row of slats cut from a metal tape. One each is sewn to the edges of the pieces of fabric to be connected. By means of a slide – today called a zipper – the rows of slats located on the left- and right-hand side or the delicate spirals that are used later as well can be easily hooked together or unhooked, in other words closed and opened. **Sundbäck uses zippers on a larger scale for the first time in 1917,** for combat uniforms of the U.S. Navy. In 1930, they start becoming a mass product used in everyday clothing. Today, annual sales of zippers worldwide amount to 20 billion U.S. dollars.

Why his work changed the world

- Zippers are truly usable universally, even for sheathing an underwater cable as a **632-meter (2,073-feet) long XXL-size version**
- **Drivers copy the zipper method** for fluid alternate merging at bottlenecks in the road
- **Zipper bandages** are even used to treat wounds

1906–1992

Grace Hopper

"Man of the year" is a title that a woman can earn only in America. It happens in 1969 when the Data Processing Management Association in the United States presents the coveted award to Grace Hopper. Hopper, who becomes a **computer science research fellow at Harvard University and a reserve admiral of the U.S. Navy is fascinated by technology at an early age.** After high school, she studies physics and mathematics. In the Second World War, Hopper gets a job with the Navy and is assigned to the Mark I computer programming project team for the first programmable mainframe in the U.S. She's only the third person to do programming work there. It's a tedious task, so in 1949 **"Amazing Grace" starts developing a revolutionary method** enabling programmers to work with source code taking cues from human language instead of with cryptic machine codes. In 1952, the program called Compiler is ready for use. Hopper delivers the corresponding computer language shortly afterwards: FLOW-MATIC. The further development called COBOL (Common Business Oriented Language) makes her the superstar of the computer scene once and for all. COBOL is still being used today, especially for business applications. "Grandma Cobol" continues to serve science and the Navy, which even names one of its ships "Hopper," until her 80th year of age. **In addition to her "Man of the year" recognition, she receives more than 90 other awards and more than 40 honorary doctorates.**

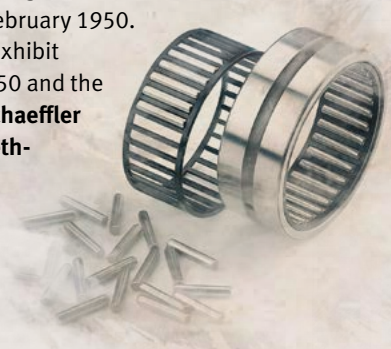
Why her work changed the world

- 60-year-old COBOL is the "wedge writing" among programming languages – **but still drives computing systems around the world**
- **The demand for COBOL programmers has been continuously increasing** again in recent years, which is another fact that demonstrates the timelessness of this computing language
- **The term "bug" for software flaws** was coined by Hopper
- She also expressed her pioneering spirit in famous quotes such as: **"If in doubt – do it!" or "It's easier to ask forgiveness than it is to get permission"**

1849–1899/1917–1996

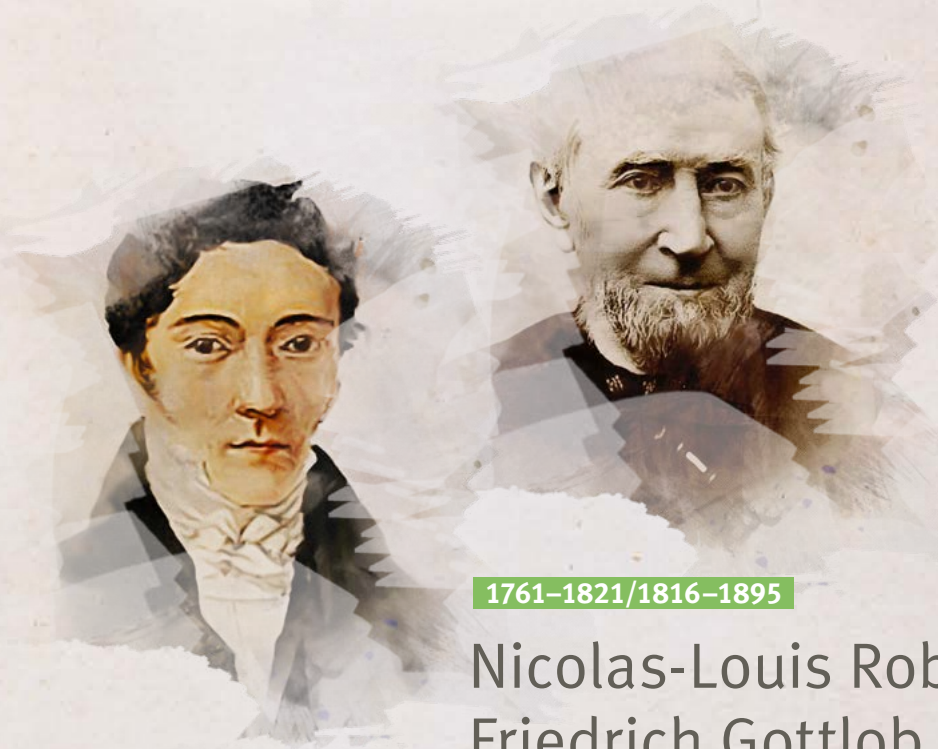
Friedrich Fischer & Georg Schaeffler

They lived and worked in different centuries, yet they were driven by the same basic motive: "to get things rolling" – as effortlessly as possible. **The men we're talking about are the two "titans of roller bearings" and company founders,** Friedrich Fischer (pictured left) and Dr.-Ing. E. h. Georg Schaeffler (r.), whose paths merged posthumously in 2001. But let's begin with the locksmith Friedrich Fischer from Schweinfurt. He not only inherits his tinkering genes from his father, Philipp Moritz Fischer, but also his love of bicycles. Fischer senior is regarded as the inventor of the pedal-crank bicycle, his son starts selling bicycles. But business could be better. In the 1870s, the bicycle is still in the infancy of its evolutionary development and pedaling is truly hard work. Fischer junior wants to change that to make his merchandise more attractive to customers. **What he's lacking to minimize rolling resistances is ball bearings with perfectly shaped rolling elements.** But they're simply not available in the marketplace, so Fischer takes action himself. Following time- and cost-consuming experiments, he presents his ball grinding mill in 1883 (l.). At the end of a grinding process, the sophisticated device **spits out balls that are exactly of the same size and exactly round, plus it does so in large volumes and therefore at low costs.** The ball grinding machine that is patented in 1890 helps the ball bearing previously sketched out by Leonardo da Vinci to finally achieve its breakthrough and plays a significant part in the first bicycle boom in the eighteen-nineteens as well. In addition, the ball grinding mill lays the technological foundation for Fischer's joint-stock company, Fischer's Aktien-Gesellschaft, or FAG for short. **Like Friedrich Fischer some 70 years before him, Georg Schaeffler is not happy with the bearings available in the marketplace.** Except that in his case they're needle roller bearings instead of ball bearings. The needle roller bearings at that time are full-complement types, which means that the needle rollers are in contact with each other, run against each other with a lot of friction and, in the worst albeit not rare case, start locking. Although Georg Schaeffler has not been trained in a technical vocation or profession, he – like Fischer – is a gifted inventor, obsessed with detail and constantly challenging things. The problem that's on his mind at the moment inspires an idea in him as well. As time will prove shortly afterwards, it's a brilliant idea: providing the needles in the needle cage with greater guidance. The first tests start in February 1950. The results are convincing, Schaeffler's cage-guided needle roller bearings (r.) exhibit extremely low wear and friction. The patent application is filed in September 1950 and the first production orders are won shortly afterwards. **With this invention Georg Schaeffler lays the foundation for the rapid growth of the family business he founded together with his brother Wilhelm in 1946.** In 2001, five years after Georg Schaeffler's death, then INA-Holding Schaeffler KG acquires FAG Kugelfischer AG, and so the paths of the two inventors and "rolling bearing titans" merge.



Why their work changed the world

- The ball bearing invented by Leonardo da Vinci only turns into a **truly perfect component as a result of Fischer's ball grinding mill**
- One in three roller or plain bearings sold in the world is a ball bearing. **The global market volume amounts to some 40 billion dollars**
- Whether toys, household appliances, robots, automobiles or aircraft – there are **few devices involving motion that don't use roller bearings**
- Today, Schaeffler's needle roller bearing portfolio includes **more than 15,000 versions**
- **100 billion needle roller bearings** have been produced by Schaeffler since the patent application was filed in 1950



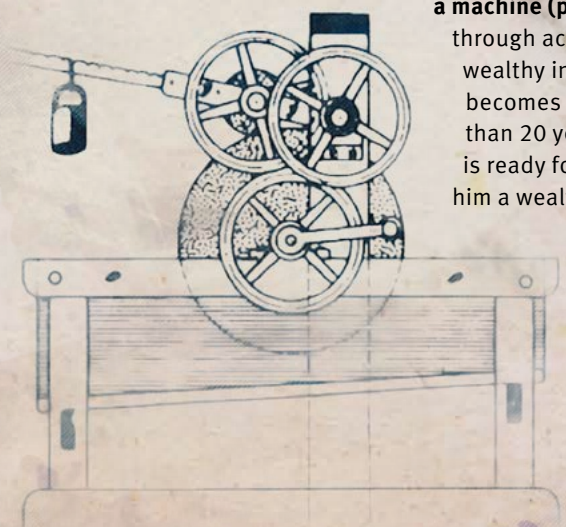
1761–1821/1816–1895

Nicolas-Louis Robert & Friedrich Gottlob Keller

Why their work changed the world

- Affordable **books and magazines for everyone –** practically inconceivable without cheap paper
- Paper as a mass product is still an important **basis for education, research and exchange of information**

In the old days, rags are the raw material predominantly used for paper. When demand skyrockets at the end of the 18th century and rags become scarce, a fight ensues among the workers of the handmade paper trade in Europe. Exactly this feud drives the French engineer Nicolas Louis Robert (above, left) to replace the complex process of handmade paper by a machine. **In 1799, Robert files a patent application for the first machine using the long-screen principle with which continuous paper can be produced on a continuous web – which still provides the basis for modern paper production.** So much for production technology. Paper per se, the way we know it today, is invented by someone else. Friedrich Gottlob Keller, a weaver from Saxony, while observing wasps build their nests and recalling the grinding of cherry stones from his childhood days, comes up with the idea of **developing a cheap raw material for paper by defibering wood by means of a machine (pictured below).** In spite of their breakthrough achievements, neither inventor becomes wealthy in his lifetime. Robert sells his patent, becomes a teacher and dies in poverty. More than 20 years will pass before Keller's invention is ready for mass production – too long to make him a wealthy man.



1823–1906

Joseph Monier

Why his work changed the world

- There would be **no skyscrapers** without Monier's invention
- Monier²: The utilization of high-tech fibers instead of steel has raised the **performance of reinforced concrete to even higher levels**
- Many composite materials such as **carbon fiber-reinforced plastic and lightweight constructions** use Monier's reinforcement idea

What does the Empire State Building have to do with a gardener from Paris? Quite a bit! But one thing after another. In the middle of the 19th century, Joseph Monier, a gardener in the Baroque gardens of the Louvre, is looking for **a new material for his planters.** It's supposed to be lightweight, cheap and, above all, more weather-resistant than the wood that's been used so far. He experiments with various cement mixtures. Once he's come up with the right one, he uses it to encase a wire mesh that provides the required shape and support. Et voilà: here's Monier's reinforced concrete. Monier is not the only one who's thrilled with his material that combines pressure resistance with tensile strength in equal measure. **Alongside the gas engine and hydraulic elevator his reinforced concrete aka ferroconcrete is one of the admired novelties at the International Exposition of 1867 in Paris.** He files six patent applications including addendums: for pipes, troughs and coffins, for stairs, façade slabs and a system for manufacturing "fixed or portable hygienic and economical houses from cement and iron." The technical term "Monier iron" can still be heard at construction sites today. And skyscrapers like the Empire State Building wouldn't even be thinkable without reinforced concrete.

*1946

Shirley Ann Jackson

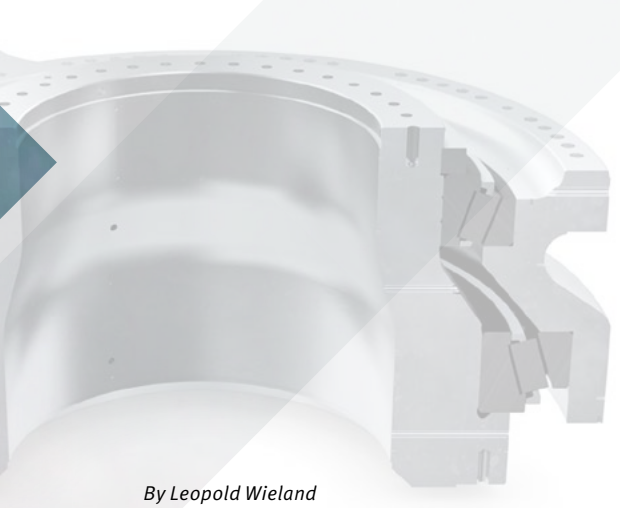
"Colored girls should learn a trade." **In 1964, Shirley Ann Jackson defies this "good advice" of a professor.** After her first year in college, the native of Washington D.C. majors in physics. In 1973, she's the first African-American woman to earn a PhD at the renowned Massachusetts Institute of Technology (MIT). After superconductors and elementary particles, Jackson successfully does research work in solid state and quantum physics, followed by **her greatest breakthroughs in the field of telecommunications,** where she provides the scientific foundations for fiber optics cables, touch-tone phones, caller ID and fax machines. U.S. President Barack Obama makes Jackson one of his most important advisors for technological progress. From 1999 until today – as the first woman and first African-American to do so – she has been president of the Rensselaer Polytechnic Institute (RPI). Shirley Ann Jackson leads North America's oldest technical university back to the top of the world's ranking both academically and financially.

Why her work changed the world and still does

- She has provided research fundamentals for **modern telecommunications**
- She has been a trailblazer for **women and ethnic minorities** in STEM subjects
- A worldwide **leader and unifying figure** especially for young natural scientists

A matriarch with foresight

Will she rise to the challenge? This question occurred to many observers when Maria-Elisabeth Schaeffler took the helm of the company after the death of her husband, Dr.-Ing. E. h. Georg Schaeffler, in 1996. Today, 25 years later, the answer is: yes, she did. Alongside her son, Georg F. W. Schaeffler, supported by the company's management and by using technological, economic and social foresight, she transformed the former medium-sized company into a successful technology corporation.



By Leopold Wieland

"The exceptional success of Schaeffler AG is inconceivable without the exceptional talent of its shareholder." Prof. Dr. Wolfgang Reitzle conveyed these words of utmost recognition for Maria-Elisabeth Schaeffler-Thumann in August 2021 on the occasion of her 80th birthday and her 25th anniversary at the helm of one of the world's leading technology corporations. Reitzle, as former CEO of Ford Germany, BMW and Linde, and today as chairman of Linde's board of directors and chairman of Continental's supervisory board one of Germany's most notable business leaders, expressed his praise in even more precise terms: "I personally know only few entrepreneurial or managerial personalities – be they men or women – who proceed in more rational, calculated and strategically foresighted ways than she does."

Global group perfected

Maria-Elisabeth Schaeffler-Thumann, who in 2014 also adopted the last name of her second husband, Jürgen Thumann, originally wanted to become a pianist or physician. But then, in 1963, the young medical student met Georg Schaeffler. They got married in the same year and started a family. Maria-Elisabeth Schaeffler, born Maria-Elisabeth Kurssa in Prague in 1941 and at home in Vienna since 1945, became the "First Lady" in the German technology pioneer's family-owned company in Herzogenaurach. Since his death in August 1996, she has been continuing his life's work in his stead – strong-willed, determined, disciplined. As the only co-shareholder her son, Georg F.W. Schaeffler, supports her. Today, Georg F.W. Schaeffler, who has a degree in business administration and is a business lawyer, also serves as chairman of Schaeffler AG's supervisory board.

In the mid-nineteen-nineties, Germany was Europe's backmarker in terms of growth but, driven by new technologies such as the internet and mobile telecommunications, new opportunities emerged. Today, Maria-Elisabeth Schaeffler-Thumann, then 55 years old, describes her start into full entrepreneurial responsibility like this: "That was no mean feat because INA had been created by Georg Schaeffler and was tailored to him. Some people advised us back then to sell the company but that was never an option for my son and me. I was determined to continue Georg Schaeffler's life work and to take advantage of the development potential that presented itself in view of the dynamic global changes."

As early as in the first ten years under the auspices of the two shareholders, Maria-Elisabeth and Georg F.W. Schaeffler, the family-owned company grew faster than ever. LuK – co-founded in the mid-nineteen-sixties by Georg Schaeffler and his brother, Dr. Wilhelm Schaeffler – was fully acquired in 1999, followed by the acquisition of competitor FAG Kugelfischer in 2001. Sales and headcount tripled in the space of one decade. Operationally executed by a trusted management team, the shareholders transformed the medium-sized company with its origins in the mechanical sector into a technology group with global operations. There

"I personally know only few entrepreneurial or managerial personalities – be they men or women – who proceed in more rational, calculated and strategically foresighted ways than she does"

Prof. Dr. Wolfgang Reitzle about Maria-Elisabeth Schaeffler-Thumann

In 1963, Maria-Elisabeth Kurssa marries entrepreneur Georg Schaeffler and becomes the "First Lady" of the family-owned group of companies

were many observers who didn't expect such success to be achievable. Maria-Elisabeth Schaeffler-Thumann recalls: "Here was a widow with little expertise and a son working as an attorney in America; so, there wasn't a lot of confidence in us. But I was and still am obsessed with this company." This passion for the company, of which her husband had been a living example, inspired his heirs as well.

Family business preserved

Company and family were always a unit for Georg Schaeffler. Together with his brother, Wilhelm, he founded Industrie GmbH in Herzogenaurach in 1946. As early as in the first financial year, headcount grew to 150. A hand truck with side walls that were changeable as needed became the first mobility bestseller in post-war Germany. But the simple vehicle was just a temporary solution. From 1950 onward, the cage-guided needle roller bearing, a brilliant invention by Georg Schaeffler that would revolutionize motion and mobility – in automotive engineering as well as in general industry – enabled the company's rapid rise.

Georg Schaeffler was more than the technical head of his business. From day one, he was its social heart as well. He introduced company sports teams, company childcare facilities, boarding houses for vacationers and insurance policies with favorable premiums.

Maria-Elisabeth Schaeffler-Thumann fosters this part of his legacy with equal passion. "He wanted me to regard the company as part of our family, just like he did, so he explained to me the business, the products, introduced me to the workforce and encouraged me to go into the organization in order to learn by watching and listening," she says in looking back on her very personal 33 years of learning at Georg Schaeffler's side. Conferences of senior management and meetings of design engineers here, speeches addressing apprentices, length of service recognition of employees and parties with retirees there: Schaeffler's "First Lady" always establishes good rapport and strikes the right chord with the members of management and with employees on all levels and all over the world. She listens carefully, is truly empathetic but does not shy away from making painful decisions if they're important for the good of the company as a whole. That's why the workforce trusts her even in the most difficult of times.

Strong leadership in times of crisis

The bond between the shareholders and the workforce of the family-owned corporation also manifested itself during the course of Schaeffler's majority shareholding in Continental that started encountering severe turbulence in 2008 due to the

unexpected onset of the global financial crisis. The threat of the company folding was looming. “We were united in solidarity on the city hall square and I can still hear the shouts of ‘We are Schaeffler’ in my ear. This sense of cohesion of the big ‘Schaeffler family’ gave me a lot of strength,” says Maria-Elisabeth Schaeffler-Thumann as she recalls her most difficult phase as the company’s “director” and “pacemaker.” Working together with her son and shoulder to shoulder with the workforce and management, the effort of steering the corporation back into calmer waters proved successful.

For Dr. Ariane Reinhart, Member of the Executive Board for Human Resources and Director of Labor Relations at Continental, the Schaeffler shareholder’s empathy with and loyalty to employees are equal success factors as her courage, her determination and her perseverance: “Maria-Elisabeth Schaeffler-Thumann was and continues to always be a reliable guide in this respect, a matriarch in the best sense of the term. People feel equally valued and protected by her and therefore supported and validated.” The company and the family belong together inseparably. That’s the example set by the lives of the company’s founders, Wilhelm and Georg Schaeffler, and that’s how their heirs continue in their day.

An equal interest in technology and people: Maria-Elisabeth Schaeffler-Thumann seeks to engage in conversations with her employees

Still a family business after going public

In 2015, the Schaeffler Group went public. Once again, Maria-Elisabeth Schaeffler-Thumann stated clearly that “The Schaeffler Group will continue to be a family business going forward. As shareholders we assume responsibility for the development of our group of companies unchanged.” The fact that headcount since 1996 had more than quadrupled from around 20,000 to nearly 84,000 showed the company’s extremely successful development in the past 25 years.

Today, Schaeffler operates 75 production plants in more than 50 countries and is represented at some 200 locations in total. As an automotive supplier the company has become a driving force in the development of electric powertrains and with its industrial division has evolved into one of the leading suppliers of systems and bearing solutions in the wind power sector, among other things. Autonomous driving, digitalization and Industry 4.0 have long become important business segments. Year after year the automotive and industrial supplier registers some 2,000 patents – a number that’s hardly matched by any other company. As a result, Schaeffler AG is one of the world leaders in terms of inventing and developing components and systems for motion and mobility. Or, as a poster on Schaeffler’s premises installed underneath the shareholders’ office says: “We pioneer motion.”

Successful triumvirate: Shareholders Georg F. W. Schaeffler and Maria-Elisabeth Schaeffler-Thumann and CEO Klaus Rosenfeld (from left) floated the giant supplier company and led it into electric mobility and Industry 4.0

75 YEARS

of pioneering motion

It's one of the biggest success stories "Made in Germany": At the end of 2021, the globally operating automotive and industrial supplier Schaeffler celebrated its 75th anniversary. The pioneering spirit of the two founders, Dr. Wilhelm Schaeffler and Dr.-Ing. E. h. Georg Schaeffler, has been shaping the company ever since.

By Volker Paulun

The Schaeffler brothers laid the foundation for the corporation in 1946 by founding Industrie GmbH in Herzogenaurach. It marked the beginning of a company that, today, employs more than 83,900 people at some 200 locations in more than 50 countries. From 1950 onward, the cage-guided needle roller bearing, an ingenious invention by Dr.-Ing. E. h. Georg Schaeffler that revolutionized motion and mobility – in automotive engineering as well as in general industrial applications – enabled the company's rapid rise. Many other innovations followed – and will continue to do so.

"Schaeffler has always been characterized by its exceptional ability to innovate and its high level of social competence," says Professor Gregor Schöllgen, PhD. "The curiosity and focused forward look that already drove the two founders are still the great strengths of this tradition-conscious family-owned enterprise." The renowned historian systematically reviewed the company's history on the occasion of its 75th anniversary.

Georg F. W. Schaeffler, family shareholder and chairman of Schaeffler AG's supervisory board, emphasizes the significant role that the company's ability to innovate has been playing for its evolution into a global player as well: "A pioneering spirit has always been decisive for the success of the Schaeffler company. A high level of resilience and willingness to always use fundamental change as an opportunity are evident especially in challenging phases. As shareholders we are particularly aware of the fact that this decades-long success depends primarily on our engaged employees around the world and on our customers and suppliers."

With a forward-looking view, the Schaeffler Group has clearly positioned itself strategically with its Roadmap 2025. The roadmap consistently aligns the company and its three divisions with the transformation in ten customer sectors in order to continue to be the preferred technology partner of its customers, going forward. Sustainability and digitalization are central in this context, accompanied by five focus fields revolving around topics such as CO_2-efficient powertrains and renewable energies.

Klaus Rosenfeld, CEO of Schaeffler AG, comments: "As long as there is motion, there will be Schaeffler. At Schaeffler, innovation, quality, systems understanding and manufacturing excellence combine into a common strength. With this strength and the family-owned company's DNA we are perfectly prepared for the future."

Schaeffler's most important technological milestones from the past 75 years can be found on the inside pages of this fold-out.

Industry. Automotive. Automotive Afterma

Schaeffler's most important pioneering ach

1946

Wilhelm and Georg Schaeffler found Industrie GmbH in Herzogenaurach. **A simple hand truck** that becomes a top seller as a means of transportation in post-war Germany is an early mobility product.

1965

With their LuK brand, the Schaeffler brothers are the first to achieve mass production of **diaphragm spring clutches** in Europe. In 1967, Volkswagen starts to equip all new cars with diaphragm spring clutches. The diaphragm spring clutch is an innovative clutch in which a diaphragm spring instead of coil springs exert the contact pressure of the clutch linings.

1969

Digitization is up and running: In 1969, the new INA data center is the most advanced facility of its kind in the market.

1950

Georg Schaeffler files a patent application for his idea of the century: **the cage-guided needle roller bearing.** Later in the year, the step from the prototype to the product that's ready for mass production is achieved. The compact and powerful needle bearings are used in automotive engineering as well as in general mechanical and transmission engineering. In electric mobility, needle bearings are indispensable for the operation of numerous electrified transmissions.

1977

Schaeffler launches its first **rotary table bearing.** With an extensive portfolio of bearings and torque motors, Schaeffler subsequently develops an outstanding position in the market for driven rotary axes and rotary tables. In 1999, Schaeffler starts equipping rotary axis bearings also with a bearing-integrated measuring system (pictured).

Mid-1950s

INA transfers the idea of the cage-guided needle roller bearing from rotary to linear motion and thereby lays the foundation for the **Linear Technology business unit.**

1978

Schaeffler Automotive Aftermarket, then still called AS Autoteile-Service, introduces **LuK RepSet –** the first complete solution for clutch repair in the independent spare parts market. In addition to the clutch, the repair kit includes all the accessory parts required for the repair in a box.

arket.

ievements of the past 75 years at a glance.

1985

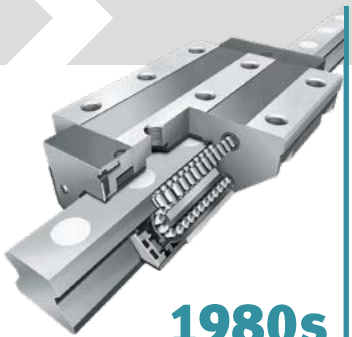
In 1985, LuK develops the **dual-mass flywheel** for fuel saving concepts using speed reduction of the gasoline engine to production level. In addition, the innovative comfort-enhancing system establishes itself as a vital component for new direct-injection and turbocharged diesel engines that start ringing in the diesel boom in 1989.

1994

Schaeffler brands contribute to the success of **space projects** as well. In 1994, FAG equips the high-pressure pumps for the Space Shuttle's rocket engine with novel bearings.

1995

Schaeffler Automotive Aftermarket launches the **technology hotline** to respond directly to questions from garages. In addition, the aftermarket specialists conduct customized technical training programs and provide information, repair manuals and installation instructions. Currently, more than 65 trainers worldwide provide training to more than 40,000 participants in 22 languages.

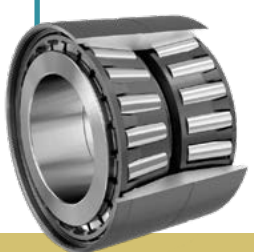


1980s

Starting in the 1980s, Schaeffler, with its **recirculating roller bearings,** sets the benchmark for highest rigidity, load bearing capacity, precision and reliability, especially in the machine tool sector. Among the profiled rail guides, the six-row recirculating ball bearings represent the ball-based guides with the highest load bearing capacity and rigidity.

1991

Schaeffler starts fielding mass-produced **TAROL (Tapered Roller Bearing) wheelset bearings** specifically equipped with plastic cages for use in high-speed trains. The LuK brand's more than 100 years of experience in the rail sector make Schaeffler a reliable partner when it comes to bearing and system solutions for rail vehicles. Wheelset bearings, traction motors, transmission bearings as well as mechatronic modules for digitized monitoring and optimized maintenance are all part of Schaeffler's portfolio.



2000

The turn of the millennium sees the inauguration of the Millennium Wheel. With a height of 135 meters (443 feet), it is **the tallest Ferris wheel in the world** at the time. The attraction in the UK capital, aka the "London Eye," has a circumference of 424 meters (1,391 feet) and a total weight of 2,100 metric tons (2,315 short tons). Two spherical roller bearings from FAG with a weight of several tons ensure smooth spinning.

1987

At the Herzogenaurach location, Schaeffler appoints its **first environmental protection representative** and starts publishing an annual environmental protection report. However, INA has previously started taking initial environmental protection actions as far back as in the 1970s. At that time, the construction of an emulsion splitting plant and the appointment of a waste management representative are among the innovations.

2009

The fully variable electrohydraulic **valve control system UniAir** hits the market. UniAir controls the engine's valves as needed and enables nearly any desired variation of valve lift. As a result, significant consumption and emission reductions can be achieved, plus clearly enhanced torque curves.

2011

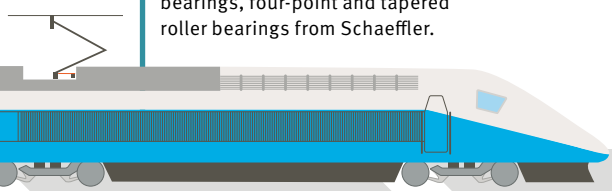
Schaeffler commissions the then most powerful **large-bearing test rig** in the world. At the Schweinfurt location, "Astraios" tests bearings with a weight of up to 15 metric tons (16.6 short tons) and an outer diameter of 3.5 meters (11.5 feet) of the kind that are used in wind turbines for example.

2017

Schaeffler Automotive Aftermarket offers INA FEAD KIT, the first **repair solution for 48-volt hybrid electric vehicles,** and is working on further solutions in the areas of powertrain and chassis systems for electric vehicles. These products are intended to open the door to the growing e-mobility business also for independent garages.

2007

The French TGV V150 high-speed train sets a **new speed record:** 574.8 km/h (357.2 mph). Also on board are cylinder roller bearings, four-point and tapered roller bearings from Schaeffler.



2005

Schaeffler Automotive Aftermarket launches **REPXPERT,** its online garage portal that still exists today. In October 2021, the third generation of the portal, which by now is accessed by some 200,000 users from 36 country portals in 16 languages, went online.

2008

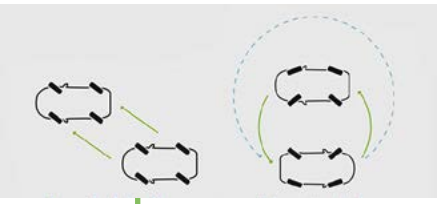
Schaeffler lands on **Mars for the first time –** in the form of precision bearings from Schaeffler's U.S. subsidiary The Barden Corporation that articulate the robotic arm of the Phoenix Mars probe.

2016

The new Panama Canal is inaugurated. **Schaeffler supplies more than 3,400 roller bearings for gate technology** and water management of the most important shortcut of the route between the Atlantic and the Pacific.

2014

As a pioneer from day one, Schaeffler competes in the new **Formula E electric racing series** and wins the inaugural race with Lucas di Grassi right off the bat. In the following years, the Audi Sport ABT Schaeffler team clinches one drivers' and one teams' title, respectively.



2019

At the International Motor Show Germany (IAA), Schaeffler presents the **mechatronic rear-axle steering system.** It enhances both ride comfort and safety and can display its advantages particularly in the context of urbanization. Steering in the direction that's opposite to front steering reduces the turning circle and increases maneuverability – which, for example, significantly simplifies the search for parking spaces in the city.

2020

ETC (Engine, Transmission, Chassis) is rolled out as the first manufacturer-managed digital **supply chain commerce platform** in the independent automotive aftermarket in China. The platform connects upstream and downstream areas within the supply chain and coordinates the needs of suppliers and dealerships.

2021

2021

As an environmental pioneer, the Schaeffler Group is named one of the **UN's 50 Sustainability & Climate Leaders** worldwide.

2021

Another example of Schaeffler's capabilities: The **Free Drive** bike-by-wire system for e-bikes requires no mechanical connection between the crankset and driven axle.

2017

Schaeffler combines an electric motor and an automated disconnect clutch into a **P2 hybrid module** with integrated torque converter. Due to its compact design, the module can be used on different vehicle platforms and is installed between the IC engine and transmission.

2020

Schaeffler extends its offering for Industry 4.0 by the **OPTIME IoT solution.** The condition monitoring system monitors machines around the clock – across the board, efficiently and cost-effectively.

2021

In an exhibition billed as "On Track to Sustainable Mobility," Schaeffler presents its vision of sustainable mobility at IAA Mobility. In addition to innovative new products such as **3in1 e-axle systems, thermal management** and **800-volt power electronics,** the company unveils a modular **Rolling Chassis.**

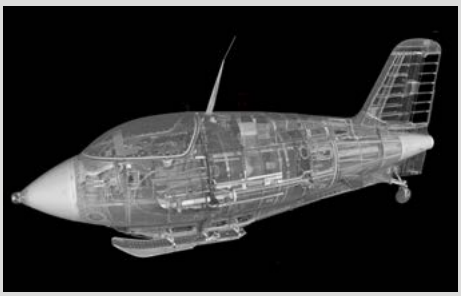
With the XXL-CT system co-developed by Dr. Michael Böhnel (l.) and Nils Reims from Fraunhofer Institute for Integrated Circuits IIS very large objects can be X-rayed and, thanks to high-speed cameras, even in motion

The universal inspectors

X-rays, as any child knows, are used to see inside the body. That thanks to new high-tech computed tomography the technology plays an important role not only in medicine but increasingly in industry too is a less known fact. Without Wilhelm Conrad Röntgen's pioneering achievement more than 100 years ago, none of this would have been conceivable.

Messerschmitt Me 163 interceptor aircraft

Thanks to state-of-the-art X-ray technology Fraunhofer research scientists have created **the digital twin of a rocket-powered fighter aircraft** from the Second World War. The images from the interior of a Messerschmitt Me163 provided new findings about the aircraft that the Nazis had touted as a "miracle weapon" but which it definitely wasn't. Instead, due to its high-risk design, it resembled a flying time bomb, says Fraunhofer X-ray expert Michael Salamon, because the pilot was sitting directly between two fuel tanks.



By Björn Carstens

Whenever something is named after someone the naming has typically been preceded by a historic event, like the one on November 8, 1895 when Wilhelm Conrad Röntgen in the University of Würzburg's Institute of Physics was experimenting with a cathode ray tube. The "radiant" accidental discovery he made on that day went on to be regarded as the discovery of the rays that have been named after him in many languages and that he himself called X-rays – a pioneering feat that reverberates to this day. A few weeks later, Röntgen managed to take the world-famous picture of his wife's hand clearly showing her bones and wedding ring. For this image to be produced, she had to sit still for more than 30 minutes.

Except for the fact that patients, today, typically have to stay put for just a few seconds, the technology developed by Röntgen is still being used nearly unchanged even 125 years later, albeit in far more settings than just hospitals and doctor's offices.

From 2D to 3D

Since the mid-nineteen-nineties, huge X-ray systems (58 meters / 190 feet long, 25 meters /

Pioneer Wilhelm Conrad Röntgen: a life devoted to science

1845: Birth in Lennep (Germany). Wilhelm Conrad Röntgen grows up in a wealthy family in Appeldoorn, the Netherlands.

1865: Röntgen attends university in Zurich without a high school diploma after having been expelled from school for allegedly having refused to tell on a classmate. After just 3 years, he earns a mechanical engineering degree.

1869: Röntgen earns a PhD. His doctoral thesis is titled "Study about Gases."

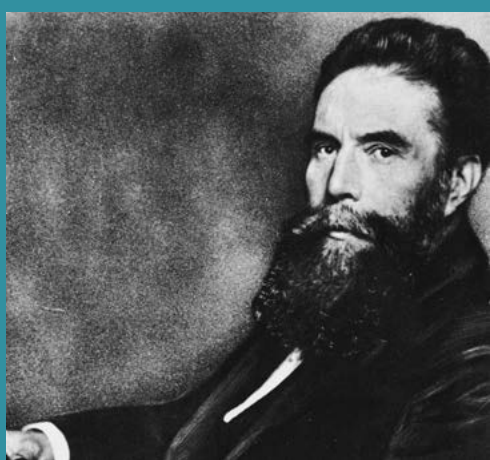
1872: Röntgen marries Bertha Ludwig (†1919) and joins the faculty of the University of Strasbourg where he qualifies for a professorship in experimental physics.

1896: During his only lecture about the X-rays he discovered in 1895, Röntgen, who shies away from publicity and by now has become director of the Institute of Physics in Würzburg, produces an X-ray image of one of the hands of anatomist Albert von Koelliker, who proposes to call the X-rays Röntgen rays.

1900: Röntgen does research work on physical properties of crystals at the Munich university.

1901: Röntgen is awarded the Nobel Prize in Physics and donates the prize money equating to 50,000 euros today to the University of Würzburg.

1923: Röntgen dies of colon cancer after having taught in Munich until 1920.



“X-ray technology is one of the most ingenious inventions from Germany”

Michael Salamon, Group Manager at Fraunhofer Development Center for X-Ray Technology EZRT, a branch of IIS

82 feet wide) at the Hamburg port have been peering into steel-walled ocean freight containers from all over the world – having revealed more than a billion untaxed cigarettes, several thousand kilograms of cocaine and nearly the same number of liters of faked perfumes – albeit still using the traditional two-dimensional X-ray method.

Industrial research on the other hand employs various techniques such as computed tomography (CT) that has been in use in medicine since the nineteen-seventies. It is a further development of Röntgen’s principle, in which hundreds of scans from various directions are used to create a three-dimensional image. Whether in material tests of vehicles, the analysis of metal alloys or the inspection of tools – the utilization of X-rays has become indispensable to quality assurance and the development of innovations.

The world’s largest CT scanner is located in Fürth

By now, objects of practically any size and shape are X-rayed. Researchers of Fraunhofer Institute for Integrated Circuits IIS in Fürth, located not far from Schaeffler’s headquarters in Herzogenaurach, have managed to develop a technology that can X-ray objects with a diameter of up to 3.20 meters (10.5 feet)

Electric cars after crash tests

The high-intensity X-rays make structures visible even in densely packed batteries. “Ideally, after a crash, no one will touch the battery of an electric vehicle because it’s never clear what damage the structure has suffered and what its effects will be. With our X-ray inspection, **we make crash analyses safer and more efficient**, and provide our industry partners with results they use to improve the safety standards for motorists significantly,” says Michael Salamon.

Musical instruments from the Middle Ages:

Especially in the case of historical instruments, it’s often unclear how they’ve been designed in inaccessible areas or if they’ve been damaged inside as a result of storage or long-term use. **However, disassembling them is often nearly impossible.** Computed tomography helps there, too. In the Musical Instrument Computed Tomography Examination Standard (MUSICES) project, Salamon’s colleagues represented more than 100 historically significant instruments three-dimensionally and even developed guidelines for scanning musical instruments.

0.1

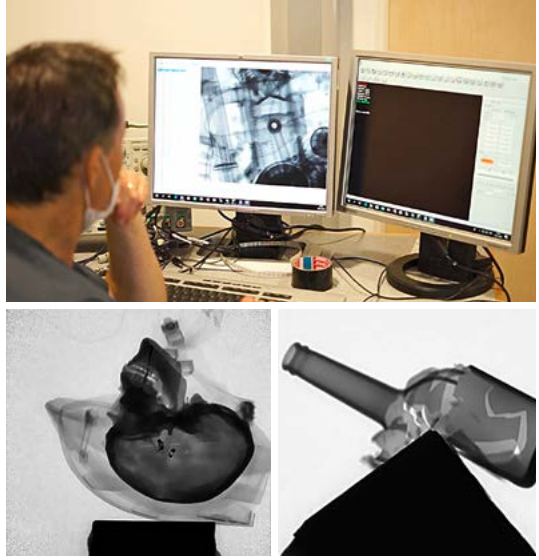
millimeters (0.004 inches)
can be made visible in
extreme cases.

9

megaelectron volts (MeV)
This is the energy of the linear accelerator that the Fraunhofer researchers use as an X-ray source – around 300 times as much as in medical X-ray diagnostics (30 KeV bis 150 KeV).

4 meters

(13 feet). That's the width of the line detector that captures the residual radiation passing the crashed car.



High-speed and X-ray image combined: The Fraunhofer research team can X-ray and analyze dynamic processes – such as a cylinder moving in an engine shown here (above), a bike helmet during a simulated crash (below left) or a bursting glass bottle – in every detail

The XXL-CT system essentially consists of a linear accelerator (l.), a high-precision turntable and a line detector with a width of four meters (13 feet, r.)

and a height of five meters (16.4 feet), and generate high-resolution 3D images. A special technology that records an object in parts enables scanning of even larger objects, which makes this scanner the currently largest CT system in the world.

As an X-ray source the researchers use a linear accelerator with nine megaelectron volts (MeV) – around 300 times as much as in medical X-ray diagnostics (30 KeV bis 150 KeV) – and combine it with a four-meter (13-feet) wide X-ray camera.

The XXL-scanner in Fürth can make structures visible that are literally as thin as a human hair: even solids with a thickness of 0.1 millimeters (0.004 inches) can be represented in extreme cases, and in the case of very large objects with diameters of several meters, structures with a thickness of about 0.5 millimeters (0.01 inches) are possible. The objects to be X-rayed rotate on a heavy-duty turntable. The camera and the radiation source scan the object synchronously in vertical movements line by line.

Dynamic interior view

And the development continues to make progress. The Fraunhofer research team is already able to

X-ray and analyze even dynamic processes in every detail: a combination of optical high-speed and X-ray imaging.

Taking crash tests as a case in point once more, engineers are desperately trying to answer the following questions: What exactly is happening in a vehicle's cabin at the time an impact occurs? Are the forces dissipated to various components as planned? In the MAVO fastX-crash project at EZRT, these questions are discussed, with the deformation of the vehicles being filmed with maximum accuracy by high-speed cameras. The special feature of this method is that the optical slow-motion and the X-ray process of taking more than 1,000 images per second are recorded synchronously, thus enabling a direct comparison. Image by image, the experts can compare the similarity between the calculations and the tests. Even a 4D CT – i.e., a time-resolved three-dimensional representation – can be implemented in this way.

A key component in this context is the X-ray detector absorbing the rays that are not absorbed by the destroyed vehicle. The researchers in Fürth increased the sensitivity of these detectors to the extent that even with customary industrial-standard X-ray sources at a rate of 1,000 images per second an image quality is achieved that enables an in-depth view of the interior. Where engineers used to apply putty in a complex process to analyze the deformations after a crash an X-ray film can now be produced: faster and more reliably, and in greater detail.

The author

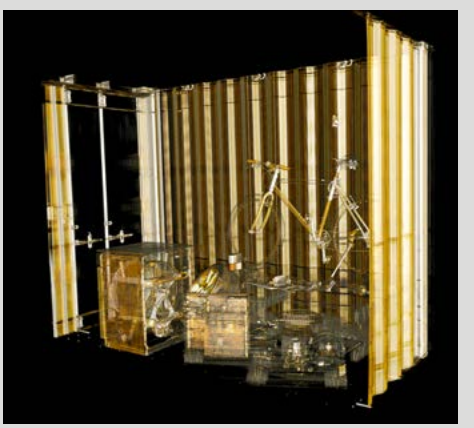
Having suffered various bone fractures in his life, our author **Björn Carstens** has had the dubious pleasure of coming into contact with Röntgen's scientific legacy on several occasions. While doing research for this article he was amazed to learn about the wide variety of things being X-rayed today besides patients.

Peruvian mummy

Except for its approximate age (11th to 15th century) and its origin little was known about the mummy prior to the scan. By using the 3D CT numerous grave goods (sea shells, bracelets) were identified behind dozens of cotton cloth layers. **Even a corn cob was discovered in the area of the mummy's head.** In the past, viewing such high-resolution data sets required costly industrial computers. Thanks to newly developed software the high-resolution data sets can now be viewed using an off-the-shelf notebook.

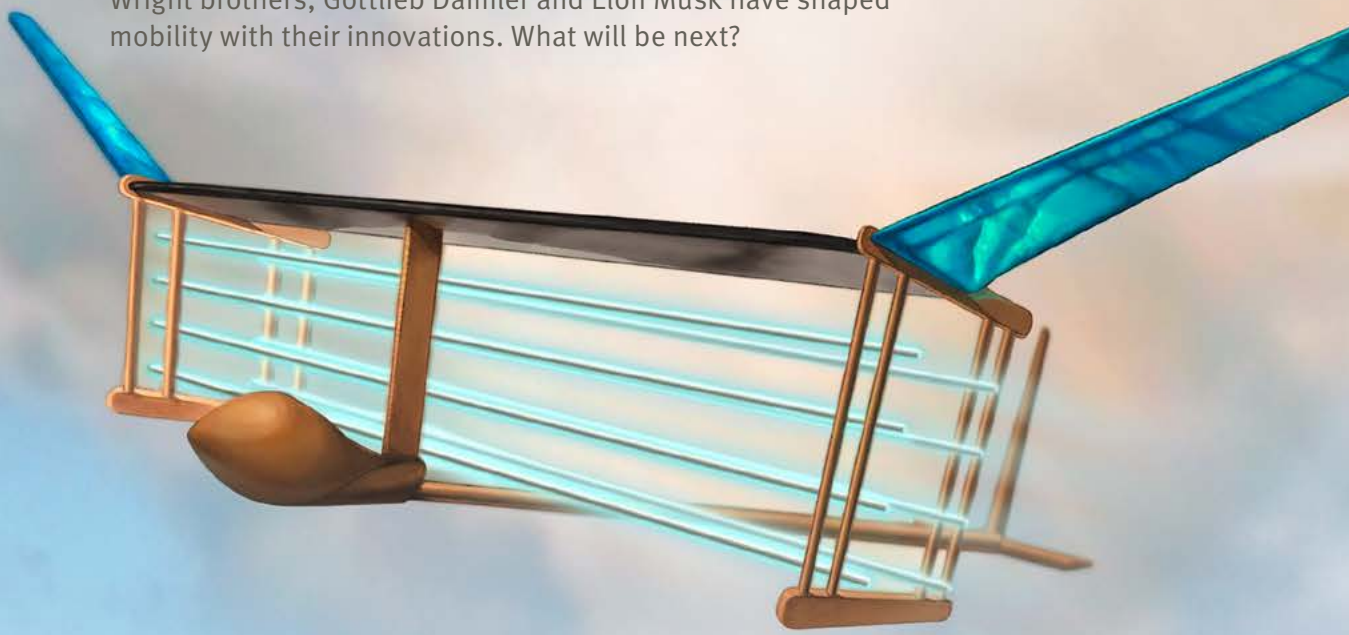
Freight containers

3D X-ray technology makes **even small objects inside containers clearly visible.** Especially for official security personnel searching freight containers for explosives or weapons as well as for customs officials looking for contraband, the technology from IIS can deliver added value.



In Motion

Onshore, offshore and airborne – pioneers like Karl Drais, the Wright brothers, Gottlieb Daimler and Elon Musk have shaped mobility with their innovations. What will be next?



Flying Star Trek-style

Who would have thought that the principle of ion thrusters operating with high voltage differences – that many of us are familiar with only from sci-fi movies – was described by the Austrian-German space pioneer Hermann Oberth as far back as in 1923. However, the first spacecraft powered by an ion thruster didn't speed through space until 1998. **In conditions of weightlessness, the propulsion system can score with its extremely high endurance** but for applications close to Earth its propulsion force has not been sufficient so far. U.S. researchers at the Massachusetts Institute of Technology (MIT) are now planning to "beam" the technology to Earth and have lifted an ultra-light plane with an ion thruster off the ground. Thrust is created by applying a very high positive charge of 20,000 volts at the wing front, causing electrons to be extracted from the nitrogen particles in the air. The ions generated in the process are attracted by a negative 20,000-volt charge at the wing curvature and accelerate rearward via the wings. This generates a wind that propels the aircraft. At the moment, though, the technology is still in a prototype stage. The flying object used in the experiment weighed only 2.5 kilograms (5.5 lbs.) and the maximum altitude reached in the first successful test flight of merely twelve seconds was barely half a meter (1.6 feet). **So, real-world operation is still a long way off** and even the U.S. researchers doubt that it will be possible to design ion engines capable of propelling passenger aircraft within the foreseeable future. While ion drive technology is unlikely to revolutionize aviation for quite some time, its use in drones might become a reality relatively soon.

“Everyone wants to go back to nature. But no one wants to do so on foot”

Werner Mitsch (1936–2009), German aphorist

Spun into space

The journey into space has kindled plenty of pioneering spirit, with visions having extended from balloons all the way to elevators. Ultimately, the rocket has remained the most commonly used means of transportation to outer space so far. The problem is that in the fight against the force of gravity huge amounts of fuel are burned. And even when burning hydrogen fuel steam is released into the atmosphere, which has an adverse effect on the climate too. By contrast, the approach pursued by SpinLaunch relies on centrifugal forces. **At the core of such a launch system is a huge electrically powered centrifuge whose 45-meter (148-feet) long arm rotates inside a vacuum chamber (pictured) –** until the projectile attached to a retaining arm including payload reaches a speed of more than 2,200 m/s / 7,200 ft/s (8,000 km/h / 5,000 mph). That’s when the projectile is released and propelled toward the sky. An initial launch from a 1:3-scale test facility has already been successful: the three-meter (10-feet) long projectile flew to an altitude of several kilometers, according to the operators. Even the SpinLaunch system cannot operate entirely without fuel, though: for the final thrust required to reach the target orbit, a conventional rocket engine has to be ignited. **Overall, however, the system is said to “burn” four times less energy and ten times less money** than a conventional rocket-powered space flight. Crewed flights, though, are not possible due to the extremely high centrifugal forces of more than 10,000 *g* in the launch system.

555.9 km/h (345.4 mph)

That’s the speed achieved by the single-engine propeller-powered aircraft “Spirit of Innovation” **marking a new speed record for electric aircraft.** The companies involved in the project are planning to use this high-powered plane to demonstrate the **potential of vertical urban electric mobility and of hybrid-electric commuter aircraft for short-haul flights.**

“Innovation of the year”

Schaeffler’s 2in1 e-axle was recognized as “Innovation of the year” by the “Golden Steering Wheel,” one of Europe’s most important automobile awards. **The 2in1 e-axle from Schaeffler integrates the reduction gear and the electric motor in one compact unit** and is characterized primarily by very high power density and excellent acoustic performance. In addition, it **can be used in various vehicle platforms – in both hybrid and fully electric applications.** Following its 2021 market launch in China, this e-axle will be used by a European vehicle manufacturer as well. Schaeffler is continually increasing the level of integration of electric axles: besides the electric motor and transmission, the 3in1 e-axle combines the power electronics unit in a single system. For this innovation, Schaeffler has already been awarded several customer contracts.

As if by magic

An electric race car without a driver barreling down the track and a car sharing provider steering its automobiles from an office. These are two projects that embody pioneering spirit as they stand for mobility of the future.

By Björn Carstens

Many of us are familiar with remote-controlled cars only from kids' rooms. They're mini racers operated by means of controllers. The DTM, Schaeffler and other partners have reimagined them on a larger scale – and for traveling at really high speeds. A remote-controlled XXL-size race car. Motorsport as an innovation lab. That's what fans got to watch as part of the supporting program of the 2021 DTM race at Spielberg, Austria. A car equipped with Space Drive drive-by-wire technology developed by Schaeffler, a redundant electronic interface for operating the steering system, gas and brake pedals, was barreling down the 4,000-meter (2.5-mile) circuit in Styria without a driver at the wheel, but driven from a seat in a state-of-the-art driving simulator.

180 km/h (112 mph)

was the top speed of the driverless race car.

1,200 hp

That's the power output of the fully electric DTM Electric Demo Car that Schaeffler previously presented in 2020 at the DTM round at the Hockenheimring. Then still with a driver at the wheel.

82 kilometers (51 miles) away from the race track, in Graz: that's where the driving simulator was located.

Scan the QR code to watch a video of the Remote Run in Spielberg.

5G technology ensured stable control of the car. Vehicle dynamics simulation software and software for tele-operated driving, camera systems and sensors made for realistic handling. Michael Resl, Director Competition & Technology of ITR, the DTM's umbrella organization, explains: "We take a car, a simulator and a driver. The rest is to ensure the best possible connection by glass fiber, 5G and radio signals, and to reduce the challenges posed by latency." The reduction of latency during data transmission to a level enabling remote control of race cars required state-of-the-art wireless technologies. At a speed of 180 km/h (112mph), even 20 milliseconds of connection latency correspond to the car having traveled a distance of one meter (3.3 feet).

Looking at three monitors instead of through a windshield

What Schaeffler and its partners have successfully tested in the high-speed arena obviously works at a more leisurely pace as well. Not on the race track in that case, but in everyday settings. That, at least, is the plan in Hamburg. Starting in early 2022, the Hanseatic city is going to venture the world's first project of integrating real tele-driving into urban transportation. Together with Vay, a Berlin-based tech start-up, the city intends to offer a novel mobility service without a driver in the car, at least some of the time. After having been ordered by means of an app, fully electric sharing cars are supposed to travel precisely to the client's location. As if by magic.

360-degree view on three monitors: The teledrivers from car-rental service Vay watch traffic as shown here during a test run

> **"This project will be transferred onto the road and into logistics"**
>
> **Matthias Zink, CEO Automotive Technologies, Schaeffler AG**

Instead of behind the wheel, specially trained, certified tele-drivers from Vay will be sitting in front of three monitors in an office, keeping an eye on traffic by means of mobile communications and cameras. They'll steer the car to the client's location completely on its own – without any human backup inside. When the client gets into the car, he or she will take charge. At the end of the client's trip, the office-bound tele-drivers will resume control of the vehicle and drive it to the next client's location. This eliminates the tedious and often inefficient search for parking places. Service personnel will recharge the cars' batteries, like in the case of other carsharing providers.

Approval is imminent

The system is equipped with end-to-end redundancies, according to company information. It also uses several 4G mobile communications networks ensuring the safety of the service and that of other traffic participants at all times, says Vay. For two years, the cars have been traveling the streets of Berlin in test operations – albeit still with a safety driver in the seat there. And Vay will presumably start its operation in Hamburg, in the test area of Bergedorf, a district on the outskirts of Hamburg, with a driver at the wheel as well. However, the actual objective, says Dennis Krämer, the press spokesman of the Hamburg Transportation Authority, is for Vay to be operating without drivers in Bergedorf in 2022. The approval process, he adds, is on a promising track.

Tele-driving, Vay admits, is a transitional technology – one in which humans and machines collaborate. While completely autonomous driving is the goal, a few more years will pass before computers will be taking full control, according to the company.

“A craving for new challenges”

Jutta Kleinschmidt is the first and, so far, only woman to have won the Dakar Rally, the biggest “horsepower marathon” in the desert. An interview with a motorsport legend about motivation, limits, pioneering spirit and the Moon as a travel destination.

Comeback: In 2021, Jutta Kleinschmidt contested the inaugural season of the Extreme E electric offroad racing series

Interview: Leopold Wieland

Pioneering spirit is the focus topic of this issue of "tomorrow." Can you capture this "spirit" for us in just a few words?
For me, pioneering spirit means the human pursuit of new challenges, not of greater success and wealth.

Does this spirit tend to be more feminine or masculine?
It's neither. It's related to individuals, not to gender.

When did you first become aware of your own pioneering spirit?
It's been there right from the beginning. I've always had a strong interest in new things for as long as I can remember – especially in technology and adventures.

If, unlike in your case, a person doesn't have a pioneering spirit right off the bat, is it something that can be learned?
I'd say it probably can't. But I do believe that every human being has a sense of curiosity and a pioneering spirit. It's just that both of these need to be awakened and practiced over and over. If you follow your pioneering spirit, you can, naturally, develop all your inspiration and motivation and achieve your goals.

To attend physics classes, you went to a boys' school as a child with special permission. Did you already feel like you were a pioneer back then?
I didn't feel like I was a pioneer although, obviously, that's what I was. I wanted to take physics classes at all cost. My interest in that was simply greater than in anything else. That's why I fought for it and followed through with it. The boys immediately accepted me as the only girl and even elected me as class representative and head girl. I wasn't the odd one out, quite the opposite was true.

How did you get into endurance rallying, where you made motorsport history particularly by having won the Dakar Rally in 2001 as the first and, so far, only woman?
I've primarily been driven by my adventurousness, my love of new technologies and of competition. I found this combination in cross-country endurance rallies – first on motorcycles and then in cars.

How do you like this role as a trailblazer and role model that across your biography you've now had for more than twenty years also for young women?

The queen of the desert

Born in Cologne in 1962, Jutta Kleinschmidt grew up in Berchtesgaden. Her motto: **I'd rather have a tree house than a doll house.** After successful completion of her degree program in physics (1986–1992) she joined BMW's motorcycle development team as a graduate engineer. Concurrently, in 1987, she contested her first cross-country endurance rally on a motorcycle. In 1992, Kleinschmidt became a professional race driver and switched to rally cars in 1994. **2001 saw her claim her greatest success: as the first and, so far, only woman she won the Dakar Rally.** The partner for the powertrain of her Mitsubishi Pajero was Schaeffler's LuK brand. From 2002 to 2006, she was a Volkswagen works driver and as a developer one of the supporting pillars of the brand's Dakar project, in which LuK was a partner as well. **In 2005, Kleinschmidt made motorsport history once again on clinching the first podium finish, in third place, of a diesel-powered vehicle in the iconic event.** 2007 saw her contest her last Dakar, in a BMW, followed by sporadic participations in motorsports. Kleinschmidt went on to increasingly appear as a successful keynote speaker and, since 2019, has been President of the FIA's Cross Country Rally Commission. In 2021, the German celebrated **a surprising comeback in the Extreme E fully electric offroad racing series.** On the ABT CUPRA XE team, she took turns at the wheel of the e-CUPRA ABT XE1 with Mattias Ekström – with Schaeffler on board again as a team partner.

Premiere in 1987, a pro since 1992: Adventurousness and a fascination with technology and competition enticed Kleinschmidt to get into motorsports

Greatest triumph: In 2001, Kleinschmidt with co-driver Andreas Schulz won the Dakar Rally. Partnering with the team was Schaeffler's LuK brand

In the 2005 Dakar Rally, Kleinschmidt clinched the first podium finish for a diesel-powered vehicle in the VW Race Touareg, finishing third. LuK was on board again

This role has never been my goal. I've acquired it as a result of what I've been doing and have achieved. Obviously, it's positive and rewarding for me to motivate especially women and girls to get into technology and into motorsports, to pursue their dreams and to make them a reality.

Did you personally have any female role models like the first female race drivers Clärenore Stinnes and Pat Moss or aviator Elly Beinhorn?

I've never had a single role model but have watched and learned all the things that help me realize my dreams and goals from a number of highly accomplished and gifted people.

As an engineer and racer, did you want to prove something primarily to yourself or to others?

It was primarily about me, but not about proving something. It was about testing my limits and also about pushing the envelope. I wanted to find out what I was really able to achieve. Especially in the male-dominated world of motorsports I was also motivated by asking myself: why should I, as a woman, not be able to do and achieve this? I was not deterred by the fact that there were only few and only few very successful women in motorsports. I wanted to try that out for myself and then decide for myself whether or not I was capable of racing.

As a racer, where did you deliberately push the envelope?

Those were physical limits primarily. Endurance rallies are super-strenuous. There were a number of events before which it was hard to imagine that the upcoming strains could be handled. Even so, I always managed to do it somehow. And in that way, I not only found out what is physically possible but also what you can mentally achieve in super-strenuous situations that, as a result, can also be super-nerve-racking at times. You only get to really know yourself and others when you reach and push your limits.

Pure pioneering spirit: In the early years, Kleinschmidt would prepare her Enduros in her kitchen at home

Venturous people inevitably take risks. What does your personal risk management look like?
I've always tried to get as close as possible to defined limits. In rallying, for instance, I always asked: what are the capabilities of my car, what potential does the route have? In that context, I always used a very calculated approach. Obviously, I've also misjudged situations, which resulted in occasional crashes.

Did success satisfy the motorsports pioneer Jutta Kleinschmidt or did it make her hungrier for more?
Whenever I'm successful I don't need to repeat that success. I always set myself new limits, new goals. I have a craving for new challenges – not only in motorsports.

"Obviously, it's positive and rewarding for me to motivate especially women and girls to get into technology and into motorsports, to pursue their dreams and to make them a reality"

Jutta Kleinschmidt

Most recent success: podium celebrations in the fall of 2021 by Kleinschmidt, teammate Mattias Ekström and Team ABT CUPRA in the Extreme E racing series

In your many desert rallies, what have you learned for life?
Not to take all the minor problems at home so seriously anymore. Today, whenever I get upset about trivial issues of everyday life or drive myself crazy because of them, I consciously ask myself: now, how important is that to me, really? In most cases, I realize that it's not that important, that I'm just making a mountain out of a molehill. But motorsports have also taught me to more intensively enjoy all the small things – chilling out, watching TV and, above all, the beauty of nature, be it in the desert, on the oceanfront, in the mountains or just on the side of a road.

You're now working as a frequently booked speaker as well. One of your keynote topics is "Achieving success with mental strength." How can a person prevent doubting themselves? Or can self-doubts even be helpful at times?
That's a very exciting subject. I, for one, am very self-critical. That's both good and bad. The good part about it is that because of this trait I prepare myself for my tasks really well. The bad part about it is that self-doubts keep haunting me. That makes external and internal preparation all the more

"Immensely impressed": FIA official Kleinschmidt in 2022 visited Audi's Dakar team, including drivers Sainz and Peterhansel (from left), together with FIA President and ex-rally driver Mohammed Ben Sulayem

important. That has always been decisive for me in motorsports. That's why I did more physical training and tried to understand and know the technology of my car really well. I've worked out advantages in my racing career particularly by being perfectly prepared. That helped me gain the necessary mental strength in competitions. Another thing that always helped me a lot was to analyze the causes of my mistakes and the resulting self-doubts. This empowered me to systematically reduce my weak areas, strengthen my self-awareness and become better and better.

As an experienced engineer in the development of production and race cars, which pioneering feats in the history of mobility impress you?
The name of Bertha Benz comes to mind in this context. In 1888, she was the first person to venture driving a longer distance in a new invention, the automobile. She secretly grabbed her two sons and took off with them in the patented motor car developed by her husband, Carl. In doing so, she caused the automobile to finally become socially accepted. Today, Elon Musk achieves pioneering feats in a class of their own with Tesla. At first, nobody took him seriously and now every automaker is producing electric cars. In terms of electric mobility, the new Audi project impressed me immensely at the last Dakar Rally because this all-new and complex fully electric powertrain system using an internal combustion engine to drive a generator that charges the battery worked perfectly in its world premiere. I'm absolutely delighted that this pioneering achievement functioned in the toughest of all competitions.

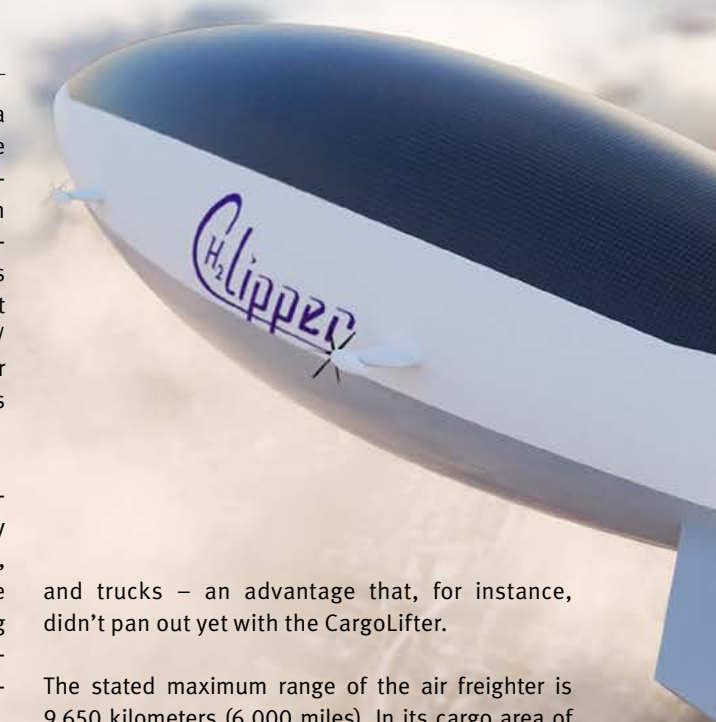
For you, the greatest pioneering feat of all in mobility is …
… the first Moon landing. What the NASA engineers achieved there in terms of technology 50 years ago, the risks that they and the astronauts dared to take, is truly awesome. All those control technologies using computers as we know them today were at best dreams at the time.

Space holds a great fascination for you. You would have liked becoming an astronaut after your racing career but had already passed the age limit. Plus, we've read that you could imagine spending the last day of your life on the Moon. Why?
I had the privilege of being able to actually experience many of the challenges I'd been dreaming of. As a result, I got to see some of the most wonderful places in the world that other people never get to visit. But this one, really special, place is still missing in my collection. Being able to look at our Earth as a globe from a spot that's far out in space just before my own life ends – that would be a unique final pleasure. But before that I still have quite a few other plans …

A comeback for airships?

In 1894, Count Ferdinand von Zeppelin obtained a patent for a “steerable airship-train.” The name of the aviation pioneer became a synonym for the flying cigars that had their heyday in the nineteen-thirties. Many comeback attempts since then have failed. Now a new airship project is getting off the ground: the H_2 Clipper relying on hydrogen technology.

By Volker Paulun



Airships hauling heavy cargo … doesn’t that ring a bell? Yes, it does, because around the turn of the millennium a German company called CargoLifter was planning to transform the transportation sector with an airship for heavy loads. But CargoLifter went bust even before the first dirigible was airborne. Its huge hangar (360 meters / 1,180 feet long, 210 meters / 630 feet wide and 107 meters / 350 feet tall) was repurposed into a tropical water park. Similar airship projects got stuck as early as in the initial idea or planning stages.

Now H_2 Clipper, a company from California, is venturing another attempt. More recent 21st century technological advances in the areas of materials, engineering practices and computers are to enable efficient and, above all, safe operation, according to statements released by the company. The research and concept design phases for the H_2 Clipper, it says, have been completed.

Focus on hydrogen

As the name suggests, the idea is centered on the advantages of hydrogen. The H_2 Clipper is not only supposed to be powered by a fuel cell using green hydrogen but might also be able to assume a key role in delivering green hydrogen – around ten times faster than a ship thanks to a cruising speed of up to 280 km/h (175 mph). Due to its use of hydrogen, the H_2 Clipper scores with its carbon-free propulsion compared to ships, aircraft and trucks – an advantage that, for instance, didn’t pan out yet with the CargoLifter.

The stated maximum range of the air freighter is 9,650 kilometers (6,000 miles). In its cargo area of over 7,530 cubic meters (265,000 cubic feet), it can carry a payload of up to 150 metric tons (165 short tons – eight to ten times more than a conventional cargo jet). Amounting to a quarter of classic air cargo, the shipping costs of 0.177 to 0.247 U.S. dollars per ton-mile, however, are above those of truck (0.12), rail (0.04) and maritime (0.01) transportation.

Time will tell whether or not these key performance data and other general conditions will suffice to lift the idea of an airship up into the sky again.

Airship ferry service

Hybrid Air Vehicles (HAV), a UK company, **is planning to produce "Airlander 10" passenger airships by 2025 at the latest.** Initially, five routes are to be served by these flying high-speed ferries: Barcelona–Palma de Mallorca (4.5 hours of travel time), Oslo–Stockholm (6.5), Liverpool–Belfast (5.5) and Seattle–Vancouver (4). Ocean Sky Cruises, a Swedish luxury travel company, is planning to use "Airlander 10" for airship cruises across the North Pole. 100 people are said to find comfortable on-board accommodation with splendid views. HAV offers three alternative propulsion systems: a traditional internal combustion (IC) engine, a hybrid system and an all-electric version. Compared to aircraft, even the IC engine is supposed to emit 75 percent less CO_2.

Travel with stunning views: the cabin of the "Airlander 10"

Think Green

Pioneers used to explore the world. Today, it takes pioneering work to protect the world.

Volts ahoy!

Coal, oil, gas: Tons and tons of fossil fuels are being shipped across the oceans, but what about electric current? PowerX intends to do exactly that and has commissioned the **first power transfer vessel to be built**. It's scheduled to start its service in 2025. The Power ARK 100 trimaran with a length of 100 meters (328 feet) is said to achieve a range of 300 kilometers (186 miles) with its electric propulsion system. For longer distances, a hybrid version with an additional biodiesel engine is planned as well. The electricity to be transferred will be stored in 100 grid-scale batteries with a capacity of 220 MWh, which, according to PowerX, is sufficient to **supply around 22,000 households with electric power for one day.** Plans exist for larger versions (150 meters and 220 meters / 492 and 722 feet) and even for a battery factory dedicated to equipping the vessels with the required storage cells. The battery ships are intended to transport ashore electric power from wind turbines floating in the sea far away from the coast (see also page 46). In the case of such systems, which are a prerequisite for operating wind farms in countries with deep coastal waters like Norway and Japan, transferring electric power by battery ships is **less expensive and better for the environment than the laying of subsea cables,** according to PowerX.

7.5 cm (3 in)

That's how thick the steel walls of the "Earth's Black Box" are. Like the black box of an aircraft the **scientific monument** on the Australian island of Tasmania (to be completed at the beginning of 2022) is intended to record data to document what has led to the crash – albeit not of an aircraft but of our planet. Hopefully, this documentation will never be needed ...

Source: earthsblackbox.com

"If you jump into cold water, you dive into a sea of possibilities"

Finnish proverb

H_2Ocean

Can green hydrogen be produced from seawater? That's exactly what Project SEA2H2, in which Dutch startup Hydron Energy B.V. that has belonged to Schaeffler since the summer of 2021 has acquired a stake, aims to find out. The answer is: yes, it is! **However, the electrolyzers splitting water into oxygen and hydrogen require ultra-pure liquids as a prerequisite for doing so.** Therefore, seawater not only has to be desalinated but also purified and filtered in a complex process. That costs a lot of energy, which the treatment system developed by Schaeffler's startup obtains also from the waste heat of the electrolysis process. **In a test plant, Hydron has already demonstrated that its water treatment system works.** Now the components are to be optimized for industrial-scale application. The long-term goal is to produce green hydrogen with energy from offshore wind farms using this technology and to transfer it ashore in pipelines.

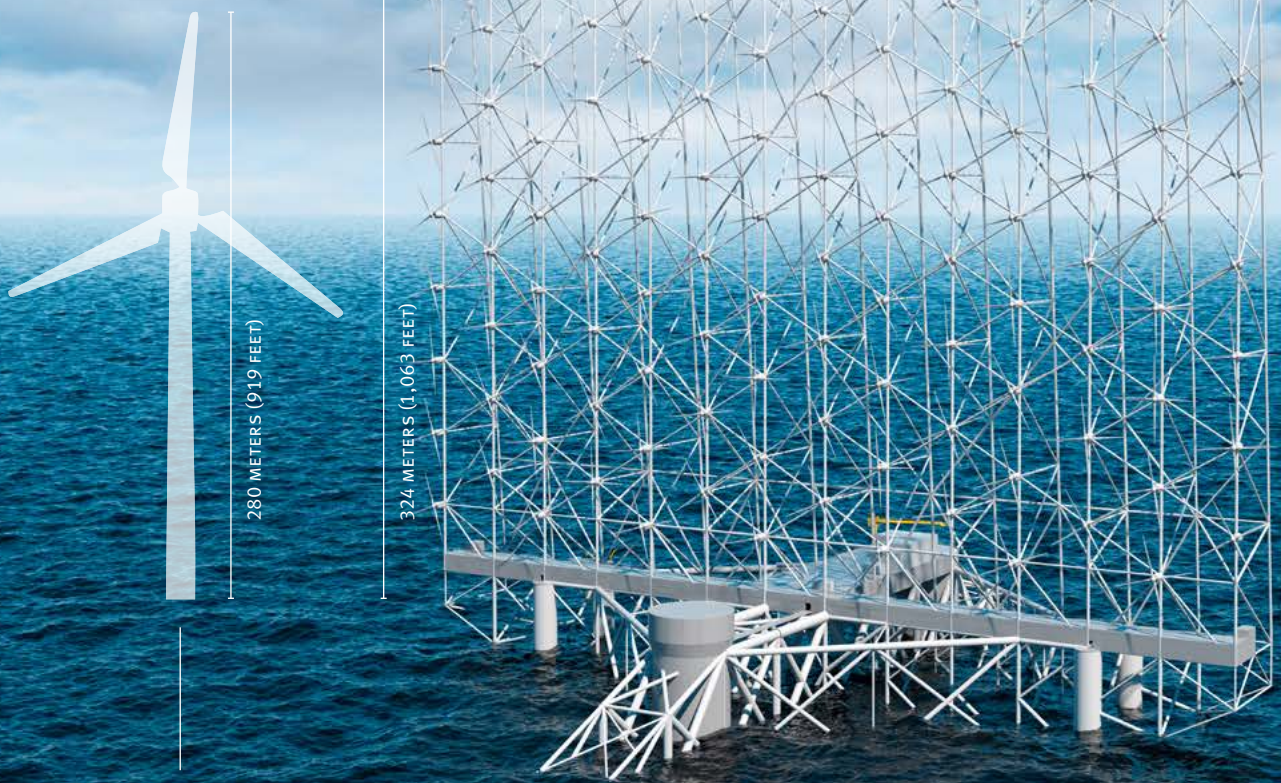
The pilot plant for producing hydrogen from seawater on the Dutch island of Texel. Featuring a similar design, this plant might also be used in offshore wind farms in just a few years from now

Smoke without sorrow

In the beginning there was fire – and then came the fine dust ... wood smoke contains tiny particles that are hazardous to human health. Finnish researchers have now developed a device that makes it possible to enjoy fireside evenings without a guilty conscience. **The high-temperature electric soot collector** (HiTESC) that has since been developed further by the Finnish startup Noeton and is planned to be launched by the end of 2022 consists of a high-voltage electrode that generates an electric field. **The particles settle on the surface of the electrode installed in the combustion chamber of the log-burning stove** where they oxidize at high temperatures and therefore no longer cause any harm. The device is operated from a 230-volt power outlet and consumes a moderate amount of 10 to 20 watts, according to the manufacturer.

Wind meets wall

Wind power generation reimagined: Instead of using increasingly larger rotors Wind Catching Systems headquartered in Norway relies on a large number of smaller ones. The pioneering project is a wall as tall as the Eiffel Tower with 126 small 1 MW-turbines that are supposed to supply enough offshore power for 80,000 households.



Danish industry leader Vestas' model V236-15.0 MW with a capacity of 15 MW and a height of 280 meters (919 feet) is currently the world's tallest wind turbine. One rotor blade measures a mammoth length of 115 meters (377 feet).

One Wind Catcher can produce roughly the same amount of electricity as five conventional 15-MW turbines. Site-dependent annual capacity is between 330 and 410 gigawatt hours, according to the manufacturer.

By Volker Paulun

The hunger for cheap green electricity is huge. By private households as well as by industry. A single gigantic chemical or steel plant requires almost as much electricity as an entire offshore wind farm can supply. However, suitable areas in shallow coastal waters such as the North and Baltic Seas in which such wind farms can be planted are rare in our oceans. But this is not the only reason why it makes sense to place wind farms at sea far off the coast, as the Norwegians are planning with their vertical wind turbine wall. It also makes sense because the wind there is stronger – and the electricity yield correspondingly greater.

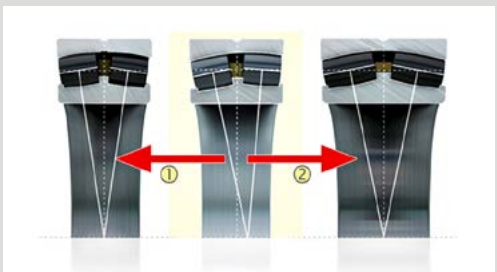
According to Wind Catching Systems, the 324-meter/1,063 feet-tall turbine wall offers additional advantages:

- Land use is 80 percent less than for conventional offshore farms
- The turbines can be produced onshore and after completion be towed to the site just like an oil rig
- A large number of smaller rotors can be produced and maintained at lower costs than a giant turbine. A hoist-based turbine installation system further simplifies maintenance, eliminating the need for special vessels or cranes
- Small rotors are less prone to wear than large ones. The manufacturer claims a service life of 50 years; conventional large wind turbines are designed to last 20 to 30 years
- The small rotors can be used even in extremely strong wind conditions and do not require complex folding mechanisms
- Overall, 80 percent higher efficiency than conventional offshore turbines

All of these advantages are supposed to enable offshore wind farm operators to produce power at a price that's competitive with other energy sources without requiring subsidies. Commissioning of the first Wind Catcher is targeted for 2024.

Same wind, more power

The main bearing is a key component in the drivetrain of a wind turbine. It not only supports the shaft that transmits torque from the rotor blades to the gearbox **but is also exposed to all the loads acting on the rotor hub.** With conventional, symmetric spherical roller bearings the high axial forces lead to an uneven internal load distribution between the two roller rows resulting in reduced performance, high wear and shorter service life. The central importance of this component motivated Schaeffler to optimize the design of its spherical roller bearings used there. The result was **the development of the asymmetric spherical roller bearing.** Its advantages are better distribution of the axial loads, 50 percent higher axial stiffness, reduced compression and axial shifting, less friction, wear and damage. Thanks to compatible installation dimensions operators of wind turbines can replace conventional with asymmetric spherical roller bearings without a major effort.



When turbine operators replace their symmetric bearings (1) with equally dimensioned asymmetric bearings (center) they will increase the capacity of their systems. Or they can replace their previously installed bearings (2) with smaller asymmetric bearings without capacity losses and save installation space

On the road toward a biobased economy

Microorganisms as turbo recyclers, mussels as innovation models or artificial muscles as actuators: Driven by a scientific pioneering spirit, biotechnology is gearing up for the battle against climate change.

By Volker Paulun

The cell clusters are moving around frantically in a petri dish. They're so-called Xenobots, artificially created from tissue and stem cells of the frog Xenopus laevis from which their name derives. With their C-like shape they're reminiscent of the video game character Pac-Man. The tiny creatures are propelled by extremely delicate cilia (tiny hair-like structures) that were implemented in the Xenobots by cell manipulation as well. During their seemingly chaotic ride the microorganisms gather stem cells that look like grains of sand on a sheet of glass. Soon after, cell clusters that increasingly resemble the original organisms start forming in front of their "mouths." The Xenobots are in the process of duplicating themselves. This already marks their third evolution after previously having learned to move and to repair themselves.

Xenobots were created by a team of biologists at Tufts University in Boston (USA) and computer scientists at the University of Vermont (UVM). A biotechnology collaboration that has just begun. "We want Xenobots to do useful work. Right now, we're giving them simple tasks, but, ultimately, we're aiming for a new kind of living tool that could, for example, clean up microplastics in the ocean or contaminants in soil," says UVM robotics expert Josh Bongard. In the foreseeable future, Xenobots are also supposed to help deliver medications directly to the places in the body where they're most effective or help detect and treat diseases.

Xenobots are a good example of visionary biotechnology – but by far not the only one. "The biologization of industry can lead to the same progress as digitalization does," Prof. Dr.-Ing. Tim Hosenfeldt, Senior Vice President, Corporate Research and Innovation & Central Technology at Schaeffler, is sure.

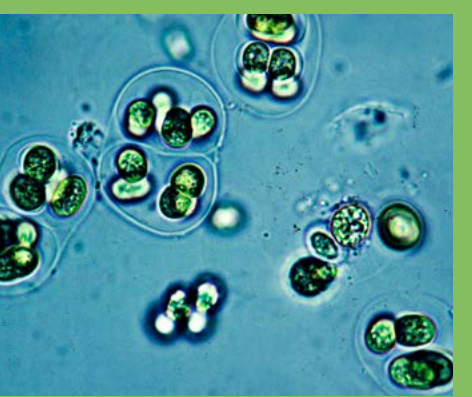
Even da Vinci used biotechnology

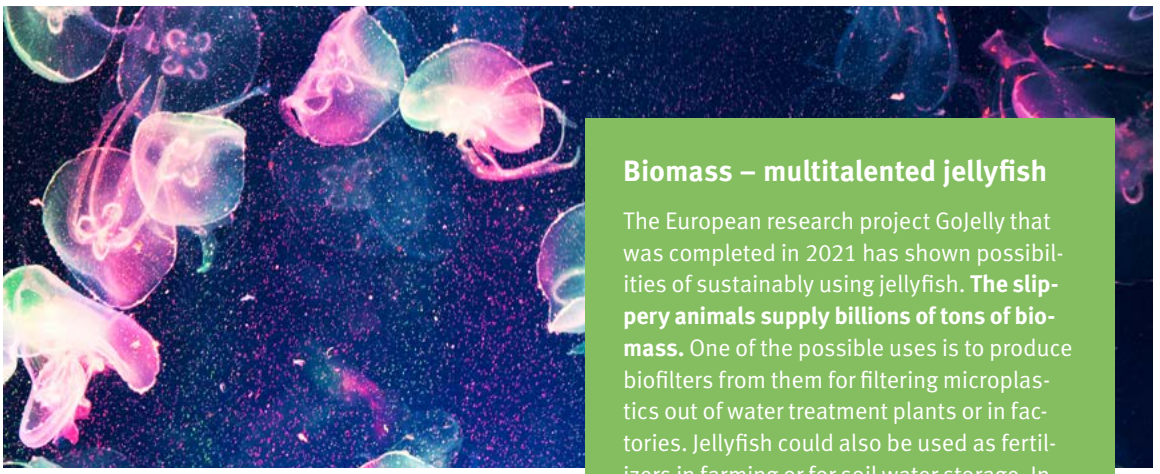
Although biotechnology may sound like science fiction, humans have been using it in production processes for a long time. An example that's thousands of years old is the utilization of yeasts in bread, beer and wine production. Today, experts refer to biointegration or frequently also to "white biotechnology" in the context of incorporating active biological components into technical processes and products.

A second field of biotechnology is bioinspiration or bionics, in other words copying of natural properties for technical products and processes. Leonardo da Vinci (1452–1519) – unsurprisingly – is regarded as the first bionics scientist. After having extensively studied the flight of birds, the universal genius designed flying devices, helicopters and parachutes. A farmer named Michael Kelly wanted to keep his livestock in check and copied a thornbush. In 1868, he registered a patent for his barbed wire – another example of early bionics. The first industrial robot named Unimate that was presented in 1959 bore an obvious resemblance to a human arm and was equally suitable

Biointegration – the perfect bioplastics?

Researchers at the University of Tübingen have modified the metabolic pathway of specific cyanobacteria, commonly known as blue-green algae, in such a way that they produce large quantities of the natural bioplastic polyhydroxybutyrate (PHB). **More than 80 percent of genetically manipulated blue-green algae consists of PHB plastics.** PHB has the major advantage of not only being producible from renewable raw materials or biogenic residues but also being naturally degradable – by bacteria, fungi or algae that may be modified as needed. The researchers in Tübingen are now planning to **optimize the utilization of bacteria further and to scale up the bacterial bioplastics factories for industrial use.**





Biomass – multitalented jellyfish

The European research project GoJelly that was completed in 2021 has shown possibilities of sustainably using jellyfish. **The slippery animals supply billions of tons of biomass.** One of the possible uses is to produce biofilters from them for filtering microplastics out of water treatment plants or in factories. Jellyfish could also be used as fertilizers in farming or for soil water storage. In addition, jellyfish might be included in people's diets to a clearly larger extent than is currently customary in many regions. **Some 30 species are fit for human consumption.**

Biomass – storing electricity in wood components

Some 50 million metric tons (55 million short tons) of lignin, a component of wood, are generated per year as a waste product in the paper industry – truly a sustainable treasure trove. The resin-like polymer can be used instead of petroleum-based materials to produce plastics, pharmaceuticals and paints. Lignin can also be used to **produce biobased organic electrolytes for so-called redox-flow batteries.** Schaeffler supports the CMBlu start-up in the development and industrialization of such an organic-flow battery. These batteries are scalable up to the gigawatt hour range and could become an important building block in the energy transition effort for purposes like storing green electricity and peak shaving. Organic lignin molecules are used in this context to chemically store and retrieve energy via a flow of ions. **The process exhibits long-term stability and is reversible.**

for multifunctional uses. Even today, buckling arm robots are still based on this bionic design principle. In surface technology, the lotus effect is a well-known bionics invention. The complex micro- and nanoscopic architecture of the lotus plant causes liquids and dirt particles to roll off the surface and has been copied thousands of times for products and applications.

Biointelligence is regarded as the third, important and most recent, field of biotechnology, in which technology, biology and information technology merge. Here biological elements can be controlled by data processing systems and incorporated into a technical system. Fingerprint activation, retina scanning and voice commands issued to artificial intelligence systems like Siri and Alexa are popular examples. And the previously described Xenobots are a biointelligent application as well.

Key technologies to combat climate change and curb resource consumption

"Nature is the highest form of self-organization that has been optimized throughout millions of years of evolution. Not to exploit this potential to master the pending challenges posed by climate change, population growth and resource consumption would be grossly negligent," warns Schaeffler's head of research, Tim Hosenfeldt. Everywhere in the world researchers are engaged in doing exactly that: integrating nature more efficiently in circular production processes and value

chains – from material extraction to material decomposition.

On a global scale, microorganisms and their enzymes, i. e., the complex protein molecules that accelerate biochemical reactions in all life forms, are the focus of attention. Progress achieved in genetic engineering opens up increasingly new opportunities for researchers to establish microbiological process chains, with the enzyme-based metabolism of microorganisms playing a key role in this context. And in the event that it doesn't fit (which is seldom the case) it will be arranged to fit: through systematic DNA modifications ("genome editing") the metabolisms of microorganisms are influenced or redesigned ("metabolic engineering").

The world's laboratories are developing microorganisms such as bacteria, fungi and algae that decompose plastics in soil and bodies of water or that can be incorporated into other recycling processes – up to and including those of radioactive or toxic substances. Equally important are "producing" organisms that help produce food, pharmaceuticals, chemicals, materials, and biofuels and biogases (see also examples provided alongside this article).

Such microbiological processes have another advantage: whereas conventional chemical processes require a lot of energy and, in some cases, toxic solvents, products can be produced under milder and more energy-efficient conditions using microorganisms because microbes grow in more eco-friendly aqueous solutions.

Transformation toward a biobased economy

The pressures on industry to act on the need to establish new processes using microorganisms is growing. Schaeffler's expert Hosenfeldt shares this sentiment: "Society and governments are calling for action regarding sustainability. The appropriate response to this is a biobased economy using renewable instead of fossil raw materials along the value chains of products, processes and services. Biointegration into processes and products is prospering thanks to progress in genetic engineering and is largely accepted. Many players work hand in hand and are market-driven. This has an accelerating effect as well."

Bionics – self-lubrication earthworm-style

The dirt-repellent, glide-enhancing lubricating layer of earthworms inspired researchers at the Leibniz Institute in Saarbrücken to develop a **plastic material that supplies itself with lubricant**. The material consists of a soft plastic inside of which silicone oil droplets are located as a lubricant. "When we put pressure on the material, the droplets change shape and migrate to the surface. The **silicone oil then spreads evenly on the surface** to a water- and dirt-repellent sliding layer," explains Jiaxi Cui, head of the institute's Switchable Microfluids research group. When the pressure decreases the droplets will reform. The scientists envision a wide variety of applications for the new material in industrial and biomedicine settings.

Universities have long begun to respond to this trend too by offering courses of study such as bionic engineering, biobased economics and industrial biotechnology.

If such a biobased economy intends to provide a basis for sustainable industrial value creation it also has to master the challenge of expanding the required production of biomass for energy-related and industrial purposes in ways that neither limit the production of food and animal feed nor destroy natural environments. In this

118 %

That's how much higher **global resource consumption** is compared to 30 years ago. By 2050, it's expected to double once more in the wake of the population growth to some 10 billion people worldwide.

Source: Fraunhofer Institute

99.9999 %

of the known bacteria are useful for humans and Earth. **Only about 600 bacteria (<0.0001 percent) cause diseases** in human beings.

Source: Leibnitz Institute

Approx. 8%

of all **fossil oils are used in the production of polymers**. It's assumed that this number might increase to 20% by 2050.

Source: biomarketinsights.com

context, biotechnology can make crucial contributions as well: by helping to use non-edible plants and plant components and by optimizing cultivable land of inferior quality. Biotechnical innovations are required to meet yet another challenge: large quantities of highly efficient enzymes and microorganisms have to be available at low costs to enable industrial-scale and economically feasible processing of renewable resources into a wide range of preliminary and intermediate products in so-called biorefineries.

In such a biobased economy even the greenhouse gas carbon dioxide can be used as a raw material in a sustainable circular economy. The CO_2EXIDE initiative is currently developing an electrochemical process using CO_2 removed from the atmosphere to produce ethylene oxide, which is a pre-product of polyester and polyamide production. If renewable energies were used, the resulting plastic materials would have a negative carbon footprint. Schaeffler supports the EU-funded project with its expertise in nano-structured coatings for the development of catalytic converters.

However, the carbon footprint is just one of the components in a sustainable circular economy. At least equally important is the question of what happens with products at the end of their useful

Biointegration – paints made from plant starch

More and more coatings and paints are made from sustainable natural products instead of being petroleum-based. Particularly popular is modified potato starch obtained as a waste product from food production. **Interior paints based on potato starch are already available in retail, and other indoor and outdoor applications are planned to follow.** Especially spectacular is a self-healing protective coating based on corn starch that researchers at the Leibnitz Institute for New Materials INM are developing. **When exposed to heat, it causes superficial micro-scratches to completely disappear within a matter of minutes.** To achieve the structure required for the coatings, the scientists strung ring-shaped derivatives of corn starch, so-called cyclodextrines, like pearls onto long-chain plastic molecules. Via a chemical reaction, the "pearl chains" are linked to one another to form an elastic net. When exposed to heat, the cyclodextrin beads migrate along the plastic string back into the scratch and thereby fill the existing gap.

life. Biobased plastics, for instance, are equally unsuitable for composting as their petroleum-based counterparts. Consequently, a need for biotechnological action also still exists in the context of such end-of-life considerations.

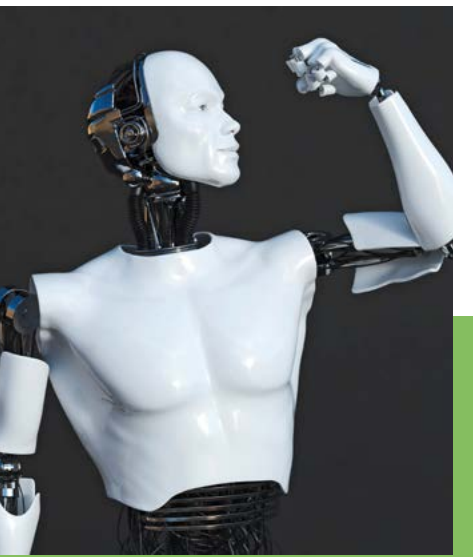
Copying nature

A bionics research project of the UnitCat Excellence Cluster in Berlin shows that the boundaries between the areas in biotechnology are permeable. The scientists were seeking to copy the protein glue of blue mussels, which is one of the strongest natural adhesives. They succeeded in doing so by using a biointegrative process. "To create these mussel proteins, we use intestinal bacteria, which we reprogrammed," explains Prof. Nediljko Budisa, a member of the project team. "They are like our chemical factory through which we produce the super glue." The protein adhesive could be used, for example, to fix broken bones or teeth in place – an option that many medical professionals have been waiting for.

Nature offers a cornucopia of ingenious functionalities that are worth copying. Be it fish gills as microplastics filters, floating ferns for friction-reduced surfaces, bamboo as a highly resilient lightweight-design champion or the good old hook-and-loop fastener that adopted its principle from burs (see also further examples provided alongside this article).

"Looking at nature pays off with regard to many of the tasks and problems we're confronted with today. In many cases, nature has already developed something that has prevailed in evolution and that we can adapt," says Prof. Dr.-Ing. Tim Hosenfeldt. "It's very exciting to see how nature optimally adapts to conditions and requirements of its surroundings. In doing so, it uses the available energy in very resource-efficient ways."

Concerning resource efficiency, Hosenfeldt provides an example from Schaeffler's practical experience: "Through bionic optimization of the housing design we managed to reduce the mass of a wheel bearing by 30 percent while retaining an identical load-bearing capacity." The principle of systematic omission adopted from nature not only saves resources in manufacturing but also while the product is in use. The bionic component was designed



Bionics – artificial muscles

In some applications, conventional actuators such as hydraulic and motorized systems reach their limits due to their weight or their slower response times. **Artificial muscles might become a powerful alternative in this case.** Researchers at the Massachusetts Institute for Technology in Cambridge have developed such a muscle by bonding two different polymers together to produce a fiber. When warmed up, the two materials expand at different speeds, the fiber coils up in a spiral shape and becomes shorter. Due to this motion, the artificial muscle can lift a weight amounting to more than 650 times its own. Bundling several of these fibers together can create a true powerhouse that can, for example, be used in robotics as well as in medicine. Researchers at Johannes Kepler University in Austria have developed a ring-shaped polymer muscle that can be contracted by means of electrical impulses. It can be used to vary the focal length of an elastomer lens within 260 ms between 22 and 550 mm (0.86 and 21.65 inches) – which equates to the focusing speed of the human eye. **Smartphone cameras or robotic eyes might be possible applications.**

Biointelligence – bites with bits and bytes

Especially in view of the rapidly growing world population, scientists are pinning great hopes also on biointelligent applications in food production – from smart farming solutions that, thanks to AI-controlled data analysis, increase crop yield while reducing the use of fertilizers, pesticides and water consumption **all the way to the production of artificial meat.** A utopian vision? Not really. California-based Memphis Meats is planning the market launch of meat that's cultivated in laboratories from animal cells in the next few years. One of the financiers in the background is Microsoft's founder, Bill Gates. Redefine Meat, an Israeli startup that's already supplying 3D-printed vegan "meat" to restaurants around the globe, is pursuing a different path. **The machines are supposed to be able to print up to 50 "steaks" per hour that,** thanks to additive manufacturing, are said not to differ from real meat in terms of taste or texture.

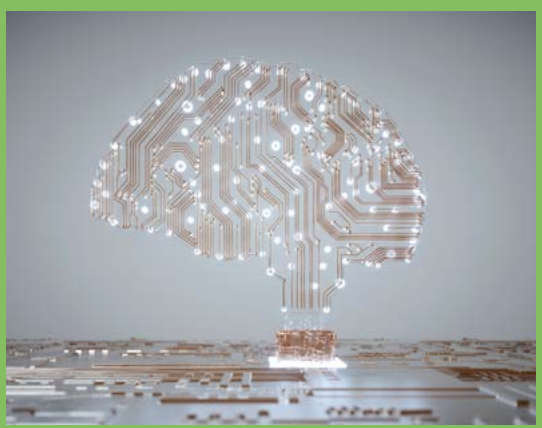
using artificial intelligence. Consequently, the design incorporated technology, biology and information technology – which takes us to the subject of biointelligence.

The dream of self-healing materials

The interaction of software, hardware and bioware opens the gate to many new fields of application, ranging from DNA-based data storage to bioprinting of tissue and biosensors to self-healing machines. Many of these applications are still in an experimental stage, such as DNA-based data storage where the information is not stored in rows of ones and zeros but in the form of DNA data strands that are formed from the basic biological building blocks guanine (G), thymine (T), cytosine (C) and adenine (A). Because these DNA storage strands are highly vulnerable, they require a protective encapsulation. Robert Grass and Wendelin Stark, professors of chemical engineering at ETH Zurich, have developed such an encapsulation from glass particles, for which they were recognized with the 2021 European Inventor Award. Grass estimates that about one exabyte of data (equating to one million terabytes) is stored in one gram (0.03 ounces) of glass-encapsulated DNA. If this biointelligent storage option were

Biointelligence – computers that think like brains

Current computers constantly push data back and forth between processors and memories. That costs a lot of time and energy. **The neuromorphic computers now being developed work differently.** Their chips are structured like the human brain and use highly connected artificial neurons and synapses that can process and store data in highly parallel ways. Even more important is the fact that neuromorphic computers also use the data to autonomously develop themselves further and to solve problems for which they were not specifically programmed. A look at the neuromorphic "Loihi" chip from Intel shows the potential: **it's already 1,000 times faster and 10,000 times more efficient than current microchips using a conventional architecture.** With computers like these, artificial intelligence can make great evolutionary strides – be it in navigating autonomous vehicles in confusing traffic scenarios, in human-machine coordination in the factories of tomorrow or in the field of human medicine as a substitute for human neural systems such as seeing and hearing. **However, it may still take a while for this to happen:** in 2020, computer scientists connected 768 Loihi chips to create a neuromorphic system. Its 100 million artificial neurons enabled the computing power of a mouse's brain. By comparison, the human brain contains nearly 90 billion neurons that are connected to each other by trillions of synapses.



usable in mass-compatible ways in the future, energy-guzzling server farms would be history.

And how realistic are self-repairing machines? Programmable "living materials" similar to the previously presented Xenobots might be a key in this context (as well as for many medical applications). "Unlike materials that we synthesize in the laboratory, living materials would have the capacity for self-healing, for adaptation to the environment and even for enhancing their performance during their utilization," explains Professor Aránzazu del Campo, Scientific Director at the Leibnitz Institute for New Materials INM.

As in many areas of biotechnology, there's still a long way to go. But to proceed on this pathway is inevitable in view of the challenges to be mastered due to climate change and population growth. Therefore, making use of nature to protect nature is simply logical. Or, as Charles Darvin once put it, "Anything that is against nature will not last in the long run."

"The interaction between software, hardware and bioware enables sustainable industrial value creation"

Prof. Dr.-Ing. Tim Hosenfeldt, Senior Vice President, Corporate Reseach and Innovation & Central Technology at Schaeffler

Digital

Pioneers wanted: Terra incognita that's worth exploring exists even in digital worlds.

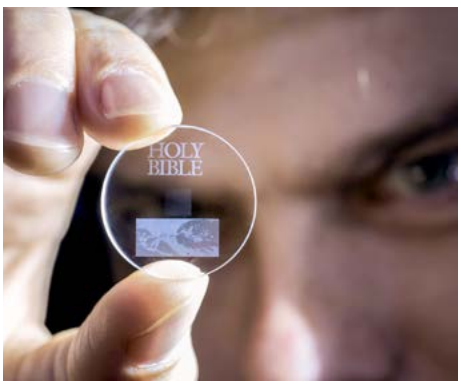
AI vs. genius

Artificial intelligence is a fast learner. A very fast learner. It's already able to write books, paint pictures, drive cars – and now even to finish composing complex symphonies of visionary musical geniuses? Clearly, AI has been demonstrating a pioneering spirit in a wide variety of fields – **but can it really complete something that musical genius Ludwig van Beethoven failed to do himself 195 years ago,** that is finalizing two movements of his unfinished "Tenth" by means of algorithms? A team of musicologists, composers and IT experts took on the challenge and fed the AI with sketches from Beethoven, with his symphonies and with sheet music from his contemporaries, amounting to some 10,000 musical pieces. The AI continued the composition in hundreds of versions, the expert team examined them and fed the most suitable compositions back into the AI – and the fine-tuning started all over. After two years of computing work and more than two million written notes, "Beethoven X – The AI Project," was ready to be performed. **The reviews were ambivalent.** Composer Walter Werzowa, who supported the project, said, "AI took in the essence of Beethoven's feelings." By contrast, conductor Dirk Kaftan said after the premiere, "Well, to put it in a nutshell: that's not a Beethoven." What he and other critics felt was missing was the element of surprise, something that, at the end of the day, only a genius of Beethoven's caliber can put on paper.

181.3

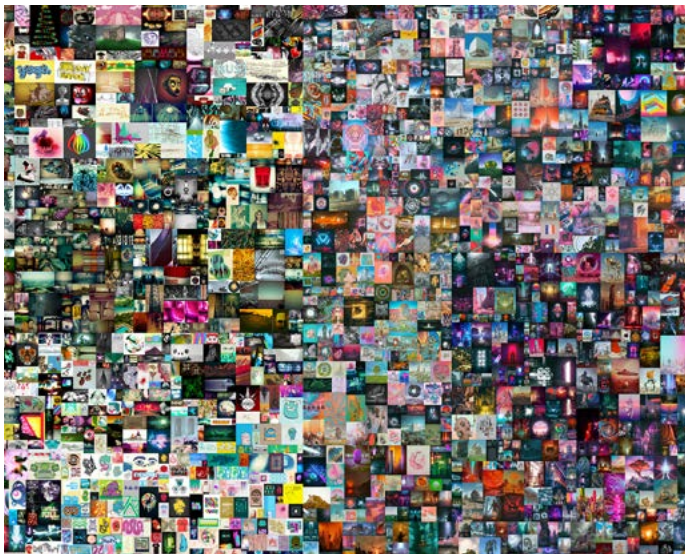
million years is the time it would currently take to **download all the information that's stored on the internet.** As the basis for their calculation, big data experts used a data volume of 33 zettabytes (33 sextillion bytes) and a download rate of 46 MB/s.

Source: Unicorn Insights



Transparent wonder disc

In the world of data storage, many smart minds have done pioneering work. The Mesopotamians with their clay tablets, Gutenberg with his book printing and Zuse with his punched tape. Our digitized world, however, consists of zillions of data points that need to be harnessed. Researchers at the University of Southampton have developed a high-speed method using infrared lasers for storing huge amounts of information for billions of years on 5D storage disks made of robust silica glass. **An area the size of a CD is supposed to accommodate up to 500 terabytes –** the digital library of all the books ever written in the world has a size of only about 400 terabytes. How can that work? The engraved data points are tiny nanostructures not only featuring the known three spatial dimensions (length, width, height) but also two additional, optical dimensions – hence the name 5D data storage. **Due to the interaction of light in the 4th and 5th dimensions, significantly more information can be stored and read.**



Digital and original

In spring of 2021, Christie's auctioned the digital opus "Everydays: The First 5000 Days" (pictured above) by American artist Beeple. 353 bids were received and the hammer hit the block at 69.35 million U.S. dollars – a huge amount of money, especially since digital art can be reproduced with just few mouse clicks. However, **a counterfeit-proof digital signature in the form of a non-fungible token (NFT)** ensures that there's just one original. Its authenticity is backed up by means of the Ethereum cryptocurrency blockchain. The auction that generated plenty of publicity triggered a veritable NFT hype. By now, several NFT e-commerce platforms have emerged for a wide variety of products extending from video clips to collectors' cards. Twitter's founder **Jack Dorsey sold his first-ever tweet as an NFT-signed original for 2.5 million dollars.**

"UNIX is basically a simple operating system, but you have to be a genius to understand this simplicity"

Dennis Ritchie (1941–2011),
Developer of the UNIX operating system and author of the corresponding manual

What is smart about the smart city?

The city in an all-new role: as a producer of big data. Professor Gesa Ziemer, PhD, director of the global CityScienceLab, describes the wide range of opportunities resulting from this role.

By Prof. Dr. Gesa Ziemer

Around the world, cities are not only becoming more expansive but, above all, more densely populated as well, so that more and more people are living together in extremely crowded places. At the moment, there are more than 30 megacities in the world with a population in excess of ten million, according to the United Nations. Lagos, the Nigerian metropolis in which some 15 million people are living today, is expected to grow to 80 million by the end of the century. How can technologies help achieve good government and organization of the increasingly complex urban organism?

One response to this challenge – in the much smaller cities of Europe as well – says that digitalization might be able to ensure a smooth and better flow of many processes. Cities have become producers of big data. We not only have more data than ever before but also a wealth of interlinking opportunities. Today, the mass of available data makes it possible for us to access a wide variety of information in urban development contexts such as data pertaining to areas, buildings, the environment and mobility as well as social and economic data.

However, the existence of data alone is no guarantee for success yet. What we need is interactive tools such as data platforms, maps, apps and other forms of visualization enabling data to be interlinked and scenarios to be formed for future urban life. Thinking in terms of scenarios, with which data modeling can help us, is one of the key skills we need to learn more intensively. This is a manifestation of a mindset, creative and complex, scenarios can be developed in a playful manner and with the participation of many players.

Flexible modeling of forward-thinking scenarios

At CityScienceLab, we visualize data on interactive tables, among other things. On these tables called City Scopes, which are developed in collaboration with the MIT Media Lab in Cambridge (USA), future scenarios of a city can be modeled very vividly and flexibly. For instance, we can demonstrate what would happen if we reduced the streets for cars in a city in support of more bicycle paths. Using models, we serve as consultants to policymakers and work together with administrative bodies. In a political context, it's becoming increasingly important to present data in a way that can be understood by as many people as possible. That takes us back to the facts and away from populism and ideology, and makes it easier to talk about concrete solutions.

The intensity of such a new, adventurous urban data culture in the area of urban development varies in individual countries. That's why the development of new forms of collaboration using digital tools is one of our key research topics and action fields in the area of the digital city. In the city itself as well as among cities. Finland's capital Helsinki has assumed a pioneering role in the areas of data use, data transparency and networks. We have to make such treasure troves of experience accessible to cities that are less smart in order to benefit from them on a global scale. Whether or not a city is "smart" will decisively have to be measured against the question of whether or not digitalization benefits its people and promotes collaboration between a wide range of players.

"Especially those with the skills of crafting creative combinations and collaborating with machines in elegant ways are smart"

Prof. Dr. Gesa Ziemer

How do we define a smart city in the context of heavily growing cities? A brief look at the history of the term shows some initial mentions in the nineteen-eighties. The sociologist Manuel Castells described that, increasingly, cities should not be understood strictly as material entities anymore but as networks based on flowing movements of data, knowledge, information and goods. Approaches pursued on the part of industry in particular emphasize increased efficiency and smooth process flows that smart city technologies are supposed to provide for us, for instance through enhanced transportation planning. However, while urban developers attach great value to a smart city becoming more efficient and progressive by means of technical infrastructures, they also stress that it should be designed with more environmental and social sustainability in mind.

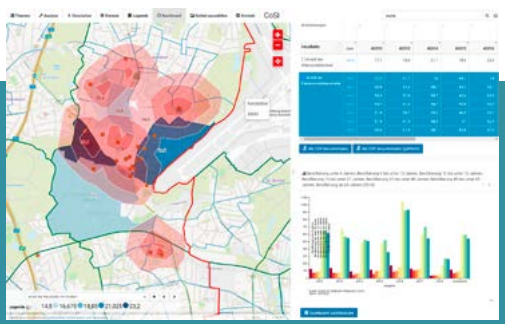
Our everyday urban life has long been shaped by digitalization: We use apps instead of analog maps; we rent bikes or cars from sharing or mobility-on-demand systems; we travel using digital booking systems that hardly require us to make travel plans in advance; our local governments are increasingly switching to digital services so that we don't need to visit a government office to fill out all official forms. Cities are equipped with sensors providing real-time data and residential buildings are increasingly constructed as smart buildings that measure the patterns of how we live. One of the biggest data generators is the mobility sector. A Tesla, today, is already primarily a data collector as well as – albeit just marginally – a means of transportation.

Urban development using digital twins

The construction industry, as well, is increasingly based on data, for instance when using Building Information Modeling (BIM) or Virtual Design and Construction (VDC). BIM describes a method enabling connected construction between the planning and execution stages of a building. All construction data can be captured, combined and modeled with software, which is intended to lead to better collaboration between the diverse disciplines. Today, there's talk of also linking data from the surroundings such as environmental, traffic and social data with building data so that construction deals not only with the building but also with the consequences of the buildings for its surroundings. This is summarized under the heading "from BIM to CIM," in other words City Information Modeling. These technologies are sub-aspects of digital twin technologies we've come to know from industrial manufacturing and that are now being transferred to cities. In the city's twin, urban development is supposed to be simulated and predicted before being implemented in the real world.

The art of smart combination

Which urban technologies have a pioneering character? Basically, innovation in this context is not so much about inventing something new but about combining in "smart ways" things that exist. Like no other organization, the city is well-suited for this purpose because huge treasure troves of data



Digital decision aid

The "Cockpit Social Infrastructure" (COSI) is an application example of smart data combinations. It serves as a digital decision aid for local government employees who are **now able to access data centrally from a web-based platform** instead of having to send individual queries to various government agencies as in the past. "That employees can independently combine data and make simple calculations in a decentralized way is an immense relief," says Prof. Gesa Ziemer. The data can be linked independently on a simple interface enabling predictions to be made. If apartments are being built in a particular neighborhood, how many childcare center slots, green areas or retail stores would be needed? If the coronavirus infection rates are particularly high in a neighborhood, where would be the best places for test centers? **COSI is a "living" project continually subjected to further development.**

Smart city application: Future scenarios of a city can be modeled very vividly and flexibly on so-called City Scopes

can be mined and recombined. Based on my daily experience – nationally in Hamburg as well as internationally in my work for the United Nations – I would highlight the following five areas:

- First, every city needs an urban and transparent data platform providing the basis for easy access to data. The pandemic has shown how important it is, also in situations of crisis, to have a solid data management system from which data can be visualized and combined quickly.
- Second, every democratic government must have co-creation systems with the help of which citizens can communicate with their governments. Citizens not only want to be informed but also be actively involved in planning processes.
- Third – especially in the mobility sector – sharing systems are in development. Mobility-on-demand systems combine cars, public transportation, bikes, ships or pedestrian paths to show us the most efficient route in terms of time and/or money – preferably in a single, centralized app.
- Fourth, there's a growing need for digital planning and construction tools for dynamic and interdisciplinary modeling of future urban scenarios.
- Fifth, around the world, prediction tools that are important for climate protection are in development. Here data pertaining to space, organization, physis, function and time are collected and modeled to enable predictions of future shock and stress moments for cities and regions such as storms and floods as well as political unrest.

Obviously, data security is an important issue concerning all of these items. In my view, controlling an entire city – from transportation to local government to hospitals and energy supply – from a single control center entails an extremely high risk. A horrific scenario would be for all hospitals to suddenly become dysfunctional because of something having been hacked. So, for all developments, corresponding backup systems preventing such scenarios have to be implemented. Generally, I'm in favor of decentralized data systems.

The question of who the data of a smart city belong to is another highly intriguing one. I feel that the city has to try to remain as independent as possible – even when working together with major technology corporations. After all, the city is responsible for providing services and information to its citizens that they need in life – and not to sell technologies. However, generally speaking, I see that all the parties involved can benefit from collaboration: the larger the volumes of public data combined with those of businesses, the more we're going to learn about our city, and the larger the number of new business models including startups that can emerge.

All approaches have in common that in spite of the major feats achieved by machines, they continue having to collaborate with people. Therefore, especially those with the skills of crafting creative combinations and collaborating with these machines in elegant ways in the future are smart.

More on the CityScienceLab at: **media.mit.edu**

The author

Gesa Ziemer, PhD, is professor of cultural theory at HafenCity University Hamburg, where she heads the CityScienceLab, a cooperative partnership with the MIT Media Lab in Cambridge/USA. Her research is focused on new forms of collaboration and urban publics in the cities of tomorrow. Gesa Ziemer is also a member of the German Science and Humanities Council and academic lead of the United Nations Technology Innovation Lab.

Delving into history with high tech

In the quest for traces of our ancestors, archeologists dig up Earth's past – and increasingly avail themselves of pioneering technologies in the process.

Geochemical soil analysis using lasers

Wherever humans settle they leave traces behind. Traces that can be detected in the soil even centuries later when all other remnants have long disappeared. State-of-the-art **spectroscopy laser guns (LIBS) provide on-site geochemical soil analyses** resulting in massive time savings. While a laboratory can perform 20 to 30 analyses per week, the on-site laser method enables hundreds to be performed per day.

Treasure hunting with Google Earth

Archaeologists used aerial photography long before the first satellites began to orbit Earth. But ever **since Google Maps and other satellite imagery services have been offering views of Earth for everyone, professional and amateur archaeologists have been enjoying all-new opportunities** to trace the past. American archaeologist Dr. Scott Madry, a Google Earth pioneer and mentor, provides an example from his practical experience to emphasize the potential of these aerial images: after looking for historic Roman sites in Burgundy, France, for 25 years using conventional methods and finding around 20 of them, he discovered more than 100 hundred on his computer at home using Google Earth.

Scanning the soil using Radar

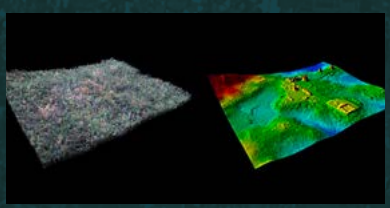
We've seen it in documentaries: excavations are truly Sisyphean tasks. In most cases, heavy-duty equipment cannot be used due to the risk of damaging potentially hidden treasures. Consequently, small shovels serve to scrape finds or fine brushes to expose them. **With a "ground-penetrating radar" (GPR) unit archaeologists are able to deeply penetrate soil** but not only that: in 2018, researchers discovered an airplane that was lost in 1942 – 91 meters (298 feet) below Greenland ice using GPR on board of a drone. These small remote-controlled aerial vehicles are used by archaeologists increasingly often too.

Perfect imaging of finds

3D scanners are less helpful in the quest for finds but do help in the subsequent analysis. The deeply penetrating systems, some of which can be used as portable ray guns at the excavation site, assist the scientists in **examining and imaging the finds down to molecular level without touching them and potentially damaging them** in the process. Not only CT scanners and X-rays are used for this purpose (see also page 26) but especially laser-based 3D scans costing only a fraction of a CT.

Peering underneath nature's green cloak

In 2021, the popular "National Geographic" science magazine enthusiastically titled an article: Laser Scans Reveal Maya "Megalopolis" Below Guatemalan Jungle. Researchers had discovered the ruins of a network of interconnected cities that were home to millions of people using **Lidar technology**, which stands for "light detection and ranging" and is also known from autonomous vehicles using laser Radar to scan their surroundings. Archaeologists fly over densely forested areas using the deeply penetrating tech eyes in their quest for hidden treasures. **The technology gathers millions of measured data points that a computer converts into detailed three-dimensional surface profiles (pictured left: original, pictured right: computer simulation).** As early as in 2013, researchers had discovered an ancient megalopolis near the Cambodian temple complex with the help of Lidar technology. Lidar cameras have also used been used for years to fly over the rain forest surrounding the Inka citadel Machu Picchu repeatedly "exposing" new building structures in the process.



Directly to your door!

Fearing neither storms nor shady characters: Messengers on horseback were true pioneers of conveying information. Today, high tech assists in high-speed deliveries. A journey through time covering postal history.

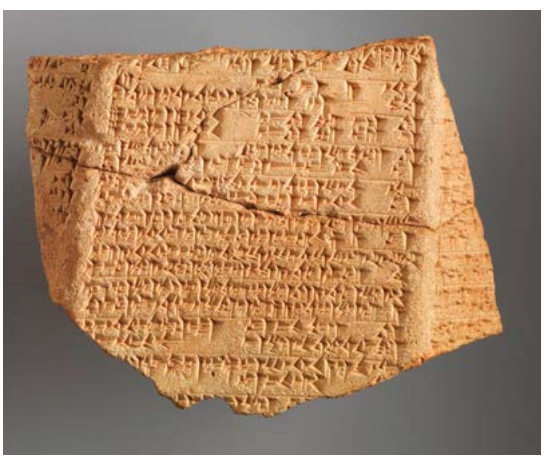
By Christoph Brix

3000 BC a couple of clever minds in Ancient Babylon notice that symbols can be scratched into clay tablets, enabling news to be transmitted word for word across even longer distances. A few centuries later, the pharaohs in Ancient Egypt will use extremely thin papyrus scrolls to send their written decrees to the remotest corners of their empire. The plant-based writing material has the advantage of being easier to write on, furlable and therefore facilitating transportation. In addition, the Egyptian god kings establish an initial form of postal operations using sailing boats on the Nile to carry important dispatches quickly across long distances at regular intervals.

The Chinese deserve credit as postal pioneers as well for having set up the first distribution network with relay stations around 1000 BC. In the 6th century BC, Cyrus' Persian empire uses a messenger relay system as well with horsemen riding from postal station to postal station. This system has been described in detail by the Greek historians Herodotus and Xenophon.

A fast flow of news is a key pillar of preserving power in the huge empires of antiquity, especially in the context of military operations. For faster transportation of the written message, the Romans under Emperor Augustus (63 BC to 14 AD) establish the cursus publicus – the first state-mandated postal system. Couriers on horseback carry letters from political and military leaders into all corners of the empire. Tired horses can be replaced every few miles at change stations.

The Babylonians used clay tablets like these to communicate many centuries before the birth of Christ



Postal services for everyone

For centuries, postal services remain a privilege of the wealthy and powerful. Letters become an increasingly important form of communication for merchants as well only in the 15th century when cheaper paper is introduced as a writing material. In the course of the following centuries, more and more private citizens make use of the opportunity to correspond with others by means of postal couriers.

The transportation of mail picks up pace with each technological evolution. Stagecoaches are replaced by trains and air mail accelerates deliveries further. Even rockets as couriers traveling at the speed of sound are used in experiments.

The faster and cheaper deliveries become, the larger the number of letters and parcels being dispatched. As a result, the distribution centers can't keep up with all the sorting work, not least due to technological progress failing to make inroads into the centers for a long time. Merely the simplest of tools such as sorting tables, racks and pockets facilitate the work until far beyond the first half of the 20th century.

Humans vs. machines

Only in the mid-nineteen-fifties, the U.S. Postal Service as a global trailblazer starts relying on assistance by machines for channeling the flows of mail. In 1956, the first semi-automatic mail sorting machine is put into service in Baltimore. A year later, on April 10, 1957, a Transorma Letter Sorting Machine starts operating at the Blair Post Office in the state of Maryland. Using the two-story behemoth with a height of nearly four meters (13 feet) from the Dutch manufacturer Werkspoor, five postal workers are able to sort up to 15,000 letters within the space of one hour – more than twice as many as previously by hand.

In 1857, the Butterfield Overland Mail Company was the first regular stagecoach service operating across the United States. The stagecoach from San Francisco arrived in St. Louis after 23 days and four hours carrying 12,000 letters and six passengers over 4,500 kilometers (2,800 miles). Robberies, the impending civil war and, ultimately, the triumph of the railroad led to the demise of the service as early as in 1861

1978 marks another milestone of progress when the first automatic mail sorting system with address recognition and video encoding is installed in Wiesbaden, Germany: a technology that will be subjected to continuous refinement in subsequent years. Today, all fully automatic large-scale sorting machines worldwide operate with text recognition programs. The seemingly simply process of sorting by now entails perfectly coordinated interaction of mechanical, optical and digital technologies.

In the pre-processing stage, mail items of various sizes are initially scanned and divided into two groups: can the machine read the address or not? If not, the mail item is segregated for manual data acquisition. Items with readable addresses are subsequently aligned, and recognized postage stamps automatically postmarked. Afterwards, the zip code is identified using OCR (Optical Character Recognition) software, and the letter forwarded on conveyor belts to the compartment for the matching destination: as fast as possible, because time is money and recipients would like to have their mail reach them within 24 to 48 hours.

Dizzying statistics

The volumes to be sorted are humongous. 430 million letters and parcels mailed per day make the United States the definite front runner in this context, with 90 percent of them accounting for marketing materials – a phenomenon all of us can

When sorting letters was done by hand: This photograph of the General Post Office in New York City was taken in 1936. Today, machines are doing the job, which could not be handled in any other way in view of millions of letters per day

arguably relate to considering the content of our own mailboxes. While the number of letters has remained on a constantly high level in nearly all industrial nations in recent years, the parcel delivery statistics have virtually been skyrocketing due to online shopping. Last year, 131 billion parcels were sent worldwide, according to the "Parcel Shipping Index" published by technology solutions provider Pitney Bowes. By comparison, the number of parcels shipped in 2014 was 43 billion.

Even though a couple of snug post offices may still exist here and there in the middle of nowhere, today's mail carriers are global players in the field of logistics. Simple postal routes have evolved into complex distribution networks. Outbound mail is collected in huge distribution centers and sorted for national and international dispatch.

Just looking at the statistics of UPS Worldport is a dizzying experience. In Louisville, Kentucky, the parcel service operates the world's largest parcel and distribution center in an area of 48 hectares (5.2 million square feet) (see right-hand page). The sorting hall alone measures 200,000 square meters (2,153 square feet). During the distribution process at Worldport a parcel comes into contact with human workers just twice: while being unloaded from an inbound container and while being loaded onto an outbound container. The statistics of DHL's site in Leipzig, which is an important hub of the world's leading logistics provider, are similarly impressive. Here 150,000 parcels per hour rush through a sorting system consisting of countless conveyor belts with a total length of 47 km (29 miles).

Schaeffler's SmartCheck online measuring system monitors the sorting machines at Royal Mail

656,000

traditional post offices employing 5.23 million people are still in existence worldwide.

Source: Postal Development Report 2020

Smart safety

It's easy to imagine what would happen if just one of the conveyor belts, just one of the switches, in one these high-tech distribution centers ground to a halt. An unforeseen defect would cause a massive number of parcels and letters to pile up. In the worst case, this would lead not only to negative headlines but also to financial penalties due to delayed deliveries.

To prevent such failures, machine operators replace components far ahead of having reached their wear limits just to be on the safe side. That costs money and resources. But as the saying goes: better safe than sorry. And, honestly, who can tell when a component will actually break down? The answer used to be: no one. Today, condition monitoring systems are available for exactly these types of predictions.

Royal Mail, the national postal service in the United Kingdom as well as a global player, for instance, relies on Schaeffler's SmartCheck to minimize the risk of cost-intensive failures. The online measuring system at Royal Mail monitors and analyzes the work processes of the carousel sorting machines at vulnerable points. As a result, not only unnecessary maintenance costs and spare parts worth 50,000 pounds sterling have been saved per year but the failure rate of important drive components has dropped significantly as well. This has resulted in fewer disruptions, a more fluid supply chain and satisfied customers. After all, nobody enjoys a long wait for an eagerly expected letter or parcel of merchandise they've ordered.

At UPS Worldport, the world's largest parcel center in the U.S. state of Kentucky, parcels are hauled on miles and miles of conveyor belts in the 200,000-square meter (2,153-square-feet) sorting hall while coming into human contact just twice

Approx. 300

aircraft movements per day take place at UPS Worldport.

33,245

conveyor belts haul the parcels on a total length of 250 km (155 miles).

416,000

parcels per hour, expandable to up to 487,000 parcels, can be sorted at UPS Worldport.

8

to 45 minutes is the time it takes a parcel to move from Worldport's inbound area to the appropriate outbound area.

Future Life

Demonstrating a pioneering spirit in a modern world means to not only develop new ideas but also, if not even more so, to be open-minded about them.

Robo, the check please

Whether it's due to staffing shortages or for cost reasons: service robots are gaining traction in the hotel and restaurant business. They push fully loaded trays through restaurants, take orders, carry bags to hotel rooms or do cleaning jobs. **In several American fast food chains, "Flippy" whirls around the deep fat fryer.** The one-armed robot doesn't mind heat or fat splashes, can work a 24/7 schedule, rarely "calls in sick" and has no leave entitlements, so the 3,000-U.S. dollar leasing rate soon pays off. Pudu Robotics from China is the world market leader in the field of so-called service robots. **Their latest top seller is called BellaBot.** Compared to the previous generation, the 1.5-meter (4.9-foot) tall delivery robot offers the advantage of clearly enhanced communication and interaction capabilities with human co-workers and patrons – not to mention its highly impressive show effect (at least for now). "Bella" detects obstacles of two centimeters (0.8 inches) in height and higher within a horizontal angle of 192.6 degrees and sells for about 20,000 euros.

Current from a garden fence

Garden fences are practical. They not only protect us from prying eyes but also against the wind. This wind could be used to generate electricity. At least that's what New York designer and inventor Joe Doucet thought who developed a **"kinetic wall" with vertical rotors** that are supposed to produce up to 400 watts of electric power per spinning unit. Critics, however, doubt whether the rotor blades with their rather small surfaces are able to develop adequate torque to drive generators with such capacity, especially at normal wind speeds. **Doucet is currently looking for partners** to transfer his "kinetic wall" from a CAD program into the real world at competitive prices and to thereby literally take the wind out of his critics' sails.

182 billion euros

That's the global sales volume in the **smart home market projected for 2026 –** twice as much as in 2021. The growth rate is supposed to be due mainly to the percentage of households using smart home applications doubling as well, from 12.3 to 25.2%.

Source: Statista

"The future has many names: For the weak, it means the unattainable. For the fearful, it means the unknown. For the courageous, it means opportunity"

Victor Hugo (1802–1885), French writer

Motorsport is becoming increasingly electric

"It's been a pleasure to discover the new technology": Nine-time World Champion Sébastien Loeb while testing the Hybrid-Ford for the WRC

The growing electrification of mobility is now increasingly reflected in motorsport. **More and more series are racing with fully or partially electric powertrains.** This is another field in which Schaeffler is a pioneer and gathering important know-how in the high-speed test laboratories for development and mass production supporting the mobility transformation process. The automotive and industrial supplier was involved in Formula E from the inaugural race in 2014 until the end of the 2021 season and is currently developing the powertrain system for electrification of the DTM. In addition, its fully owned subsidiary Compact Dynamics is supporting the World Rally Championship (WRC) on its way forward: in 2022, the electrification specialist started **supplying a 100-kW hybrid system** including the motor generator, control unit and a battery to all manufacturers involved in the "Rally1" top category.

A super laser as a lightning rod

In 1752, the pioneer and subsequent U.S. President Benjamin Franklin invented the lightning rod. Ever since then wires routed from the roof into the ground have been protecting people against the dreaded high-voltage lightning strikes. Now the long-serving lightning rod might be replaced by a high-tech successor: lasers that channel thunderbolts are intended to provide clearly better protection for sensitive industrial plants, power-plants or airports.

By Björn Carstens

Lightning strikes cause damage of several billion euros around the world each year. They lead to power outages and forest fires, they damage computer systems, and they can kill people and animals. Scientists assume that heavy thunderstorms will increase due to climate change.

Ever since 1752 when Benjamin Franklin was struck by his brain wave of experimenting with a metal kite people have known how to protect themselves against the destructive fury of thunderbolts. The experiment inspired the American inventor and statesman with the idea of equipping the roofs of buildings with long metal tips that would intercept the electrical discharges and conduct them into the ground. Lightning rods have been serving this purpose all over the world until today – even 270 years after the kite experiment.

Lightning "teased out" from the clouds

However, lightning rods are not always of help. Especially in the case of large buildings with sensitive technical systems such as airports and power-plants they do not provide adequate protection. Moreover, lightning rods may even trigger additional indirect effects such as electromagnetic interferences and voltage surges in equipment. That's why the EU launched the Laser Lightning Rod (LLR) project. The idea behind it is a laser gun "teasing out" lightning from the clouds, specifically channeling and diverting it from costly infrastructure in order to conduct it from there into the ground.

While the idea itself has been around for some time, no laser meeting its demands has existed up to now. The project requires a laser with one terawatt (one billion watts) of peak pulse power. For comparison: one of the most powerful laser pointers has a power output of 50 watts and a range of 40 kilometers (25 miles).

The LLR project partners at the University of Geneva and the laser specialists of the technology company Trumpf have been testing the laser system weighing five metric tons (5.5 short tons) on Mount Säntis in Switzerland since this summer. Per second, the super laser shoots 1,000 ultra-short laser pulses into the atmosphere, generating a seemingly infinitely long ionized channel, a so-called laser filament, in the direction of the clouds. This channel is said to provide a preferred pathway for lightning.

Eliminating the risks of thunderclouds

"The filaments trigger discharges, and the lightning follows the channels. So, in addition to triggering lightning, we can also cause it to discharge in a certain direction," says Prof. Jean-Pierre Wolf from the University of Geneva. As a result, the risk of thunderclouds can be eliminated in two ways: the laser either discharges the cloud until it's calm or it guides the lightning to a standard lightning conductor on the ground.

"If we use lasers in the right way, we could eliminate the damage caused by lightning strikes in the future"

Prof. Jean-Pierre Wolf, University of Geneva

Watch this video to see how exactly the laser channels thunderbolts.

Lightning hotspots

Using satellite data, a research team has identified the places on Earth with the highest incidence of lightning. The worldwide record is held by Lago de Maracaibo in Venezuela, where flashes of lightning on average occur in an area of one square kilometer (0.4 square miles) on 297 days a year. Africa is the front runner among continents, with 283 of the 500 top lightning hotspots located there.

Idea + X = success

Startups have a pioneering spirit deeply rooted in their DNA. The following examples show how an innovative startup scene develops clever ideas further so that they achieve success in the marketplace.

Traceless plastics

Startup: Traceless Materials (16 employees)

Founded in: 2020

Idea: Originally, she'd "merely" meant to move forward with her PhD work in process engineering but now Anne Lamp may be holding the game changer in the fight against the global flood of plastics in her hands: a granulate of agricultural waste generated, for instance, in the production of corn starch. From this base material the startup founder from Hamburg developed a natural **type of plastic material consisting of natural fibers,** a so-called biopolymer. Without chemical modification, without harmful additives and without solvents. According to an initial carbon footprint assessment, production and disposal of the plastic substitute cause up to 87 percent less CO_2 emissions than virgin plastics. Even so, the material is said to be tear-resistant, waterproof and suitable for multi-optional uses: as a wrap for food packaging, in the production of hard-plastic components or as coatings for cardboard. Lamp says: "Our technology is 'back to the roots.' Even the first plastics 100 years ago were natural materials." Cellophane, for instance, that's produced from cellulose and is fully degradable. "At some point in time, petrochemicals replaced all that and those technologies fell into oblivion," explains Lamp.

Aiming to curb the flood of plastics: Traceless founders Johanna Baare (l.) and Dr. Anne Lamp

2 to 9 weeks is the time it takes for the biomaterial from Traceless to become fully composted

Implementation: While she was still doing her research work, it occurred to Anne Lamp that **this idea called for thinking big.** Via a startup assistance program, she teamed up with strategy consultant Johanna Baare. Together, they founded Traceless Materials. The startup's approach is a holistic one. Like the product itself, the process to produce it is planned to be eco-friendly. The Traceless granulate is intended to be a direct alternative to the products that chemical corporations offer. The two founders have already raised several million euros in funding support and investors' money.

Hurdles: Hundreds of startups around the world have been experimenting with eco-friendly and petroleum-free plastics for years, and successfully so. The problem is that **the production costs of most alternatives are higher than those of the current, petroleum-based plastics.** In a highly price-sensitive competitive environment, that's a real pitfall. By contrast, Traceless is supposed to be competitive in terms of price in industrial-scale production. The basic prerequisite, says Lamp, is that, "To get there, we have to become really big really fast."

Next steps: The first big player to partner with has been found. Together with German mail order and e-commerce giant Otto, Traceless is working on a sustainable shipping bag. In addition, larger-scale production is planned to be launched this year. The pilot plant has already been established.

See a doctor from your sofa

Startup: Teleclinic (more than 100 employees)

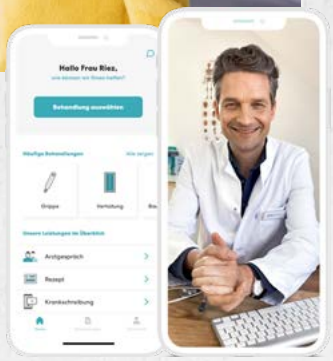
Founded in: 2015

Idea: Good-bye to the rampant presence of viruses in waiting rooms! Long before the pandemic struck, lawyer Katharina Jünger created a digital 24/7 video consultation service – the first one in Germany. At the mere age of 24, that made her a true pioneer. **As the daughter of physicians, she said she was used to receiving immediate medical attention whenever she needed it and wanted to provide this kind of access to everyone.**

Implementation: Together with a physician, she implemented the teledoctor app project. **The company earns a percentage of the physicians' treatment costs.**

Hurdles: Due to the fact that other countries like Sweden lifted the telemedicine ban earlier than Germany, **international competition is fierce.**

Next steps: With the help of a collaborative partnership with DocMorris online pharmacy, the startup aims to sell even more clients and doctors (currently several hundred) on the benefits of online treatment.



Teleclinic CEO Katharina Jünger (30, above) says: "70 percent of all treatments can take place through Teleclinic." More than 100,000 patients in Germany are using teledoctor apps like the one from Teleclinic

Feeder of the needy

Startup: Chowberry (more than 10 employees)

Founded in: 2014

Idea: Oscar Ekponimo remembers well what it felt like to be hungry. "Even as a child I said: **someday I'm going to make sure that others won't have to experience the same."** Nearly 20 years later, he kept his word. The professional software engineer developed an app that makes surplus food available to poor people in Nigeria. Here's how it works: retailers scan in their food products and reduce the price progressively as the best-before-date of the product comes closer. The system sends a message to needy customers and to charities.

Implementation: Ekponimo signed a large number of partnership agreements with NGOs and retailers: **"We help retailers reduce their food losses by 80 percent."**

Hurdles: Accessibility. **Many of his potential customers have no cellphone.**

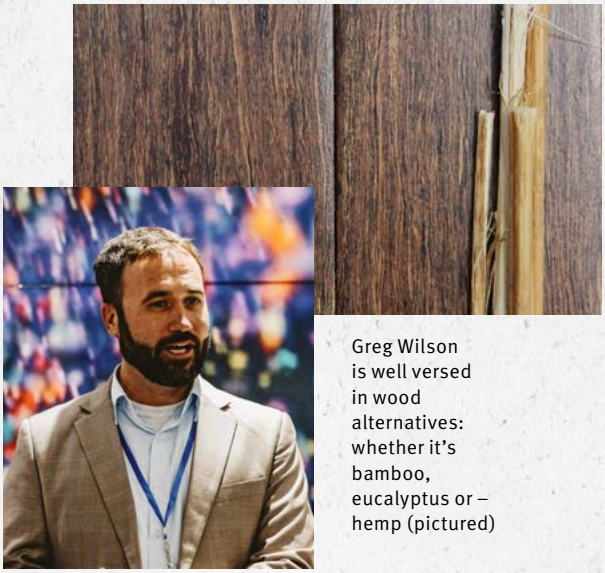
Next steps: Ekponimo is planning to supply up to 100,000 low-income households with food. **In the long term, the app is intended to fight global hunger.**

“Weed wood”

Startup: Fibonacci (more than 25 employees)

Founded in: 2018

Idea: For some young people, hemp is just a product to achieve a “higher state of consciousness” – but not for Greg Wilson, who even as a college student in search of eco-friendly alternatives to wood experimented with biomaterials. HempWood, as Wilson’s product consisting of crushed hemp fibers glued together with soy protein is called, is 100 percent biodegradable. **It looks like oak wood but is 20 percent more resistant and clearly more sustainable** because hemp grows back in just six months, he says.



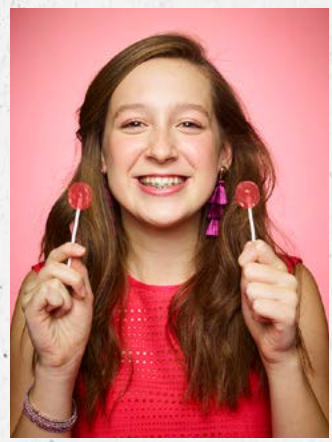
Greg Wilson is well versed in wood alternatives: whether it’s bamboo, eucalyptus or – hemp (pictured)

Implementation: Wilson obtained the necessary know-how to launch HempWood in 2019 from Murray State University (Kentucky/USA). To produce it, he established a manufacturing site in Kentucky, the heartland of American industrial hemp production. Fibonacci grows its hemp as close as possible to the factory to avoid CO_2 emissions caused by transportation.

Hurdles: The biggest hurdle disappeared in 2018 when industrial hemp production was legalized in the United States. The question of sustainability is debatable because **hemp cultivation requires large areas of land.** To avoid deforestation, only the fields for food crops are left for producing industrial hemp.

Next steps: By introducing new products, Fibonacci is planning **to replace as much precious oak wood as possible by “hemp wood.”**

Early starter



“Teenpreneurs” is the technical term for young entrepreneurs under 20. Mark Zuckerberg and Bill Gates are arguably among the most prominent ones. Both, at age 19, laid the foundation for their multi-billion-dollar corporations. Just like Estonian Markus Villig, who is currently Europe’s youngest Unicorn founder. He started Bolt, his e-scooter business, now worth billions of euros, at age 19 after just one semester of studying computer science. Age-wise, teen entrepreneur **Alina Morse (pictured)** – the 16-year-old ruler of the candy kingdom “Zolli Candy,” beats them all. The idea of her healthy lollipops shot into her child’s mind at the age of seven when she got on her daddy’s nerve, asking, “Why don’t we produce candy that’s good for my teeth?” She managed to find a factory to produce her sugar-free lollipops and, having started out with 3,750 U.S. dollars, the business is currently valued at 12 million U.S. dollars.

High-speed market research

Startup: Appinio (approx. 120 employees)

Founded in: 2014

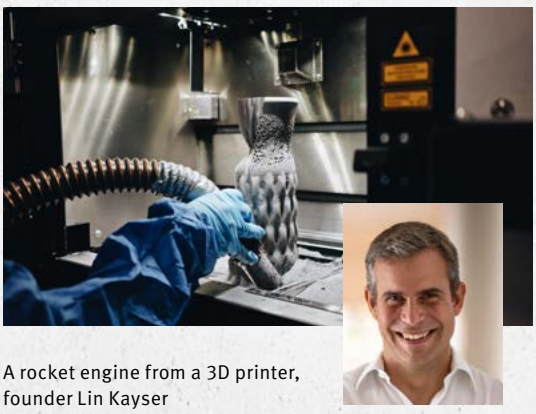
Idea: Two slow, too expensive, lack of data quality – Jonathan Kurfess wasn't a great believer in classic consumer surveys. **Instead, he wanted to create the world's fastest market research system –** a digital platform enabling its clients to address specific target groups within a very short period of time. The questions are sent directly to the app's users by push messages and the answers are returned within a few minutes or hours. Survey participants can collect points in a playful way and either donate them to social projects or convert them into vouchers.

Implementation: Not the iconic Silicon Valley garage but almost … Appinio was started in a storage room measuring eight square meters (86 square feet) located near the Hamburg port. After studying business administration, Kurfess founded Appinio together with an IT expert. Without a real product, without money. **"And without knowing how to run a business,"** the CEO recalled in a podcast. Then Lady Luck came in: liquor producer Jägermeister had a small budget to spare and awarded Appinio its first contract. Kurfess: "Fortunately, it panned out well."

Hurdles: Although Appinio by now has **a client base of more than 700 companies** and over half a million active users, the competition (Google, Facebook) is breathing down the company's neck.

Next steps: Appinio aspires to become the world's biggest consumer panel, a portal for consumers whose buying patterns are monitored.

Jonathan Kurfess: He founded Appinio while he was unemployed and six years later was voted into the Forbes "30 under 30" list of Europe's most successful young entrepreneurs



A rocket engine from a 3D printer, founder Lin Kayser

3D pioneers

Startup: Hyperganic (50 employees)

Founded in: 2017

Idea: An artificial intelligence system that designs objects fully automatically for 3D printing. **Designers only have to feed the AI with requirements to be met by the product and start the print run.** The idea evolved when serial entrepreneur Lin Kayser bought a 3D printer in 2012 – actually, for a totally different startup idea. "But then it dawned on me. When you think about molecular structures that can be moved algorithmically you can design anything that's physically possible and then issue it on an industrial printer."

Implementation: Good things come to those who wait. As far back as in 2014, Kayser's partner, Michael Gallo, who used to be a pioneer in digital image editing in the movie industry, developed the basic technology while Kayser traveled to countless centers for additive manufacturing around the world to explore their willingness to enter mass production. Kayser: "In the course of

time, we've developed the technology to a level allowing us to work together with third-party developers. **We prefer for our customers to develop their own applications using our platform and creating their own intellectual property."**

Hurdles: Aside from technological ones, the main challenge was to bring customers on board. Kayser: **"We had to prove that 3D printing can also work differently.** That objects can be designed by means of computer codes instead of manually editing them using CAD programs."

Next steps: The platform is planned to be presented to the general public at the end of 2022.

3 questions for ...

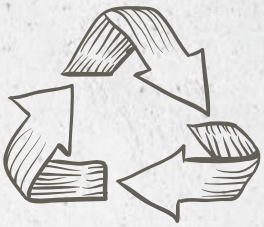
... Carsten Merklein, who is responsible for the development of novel manufacturing technologies at Schaeffler. The automotive and industrial supplier collaborates with numerous startups worldwide, including the Munich-based startup Hyperganic (see item on previous page).

What does the collaboration between a corporation and a young startup look like?
Carsten Merklein: It's creative and results-focused. It's fun to discuss technologies and solutions to problems without any constraints and to implement them quickly. As a corporation we benefit from out-of-the-box thinking in action. On the other hand, corporations can support startups in industrializing their products and provide input concerning product adjustments that may be needed.

In what stage of a startup does a connection with a core partner in industry deliver the greatest value? To what extent are innovation platforms like "Startup Autobahn" helpful?
As a corporation, the earlier you connect with a startup the more opportunities you'll have to shape things and the greater the chance to generate shared intellectual property and a unique selling proposition. However, in this context you mustn't measure a startup's way of working against your own standards and requirements or else the collaboration will fail. Innovation platforms are immensely helpful in finding the right startups for the problems you're working on yourself. The "casting" process they've gone through ensures that the level of maturity of the innovations is already measurable and not just "pie in the sky."

Know-how, manpower, investment – what are the key factors of leading an idea to success when a big player like Schaeffler collaborates with a young tech company?
All of these are essential prerequisites but to be successful you've got to be open-minded, prepared to deal with new solutions and convinced that the pathway that you've pursued will lead to success in spite of setbacks or resistance. On the other hand, you shouldn't continue to feed a dead horse – so, if it's not the right fit, it's just not the right fit.

Digital battery recycling



"By giving it a second life, the carbon footprint of a battery is reduced by up to 50 percent," says CEO Patrick Peter

Startup: Circunomics (11 employees)

Founded in: 2019

Idea: Electric cars have a problem: their batteries typically have to be replaced after a few years. Then what? Throw them away or recycle them? For founder Patrick Peter, that's not a question because **"old batteries are by no means ready for the scrapyard."** They contain recyclable raw materials or can be repurposed, for instance, to store energy at home. Consequently, Peter, an MBA graduate from Frankfurt, came up with the idea of a digital marketplace in which automakers, secondary users and recycling companies trade used batteries and so return them to the circular economy.

Implementation: Strategic partnerships in the mobility business and know-how – especially know-how. That's a pillar Circunomics relies on. Every team member contributes something. While one may have experience in the digital and automotive sector, another one may in the battery and energy industry or in the circular economy, such as founder Cesar Prados, who as a technical director previously developed blockchain solutions for the European Space Agency ESA. Such decentralized databases are crucial for the startup **because Circunomics works with digital battery twins** to analyze the condition and value of a battery using AI technology. To do so, the company uses information from automakers, charging station operators and suppliers.

Hurdles: Selling people on the vision of a sustainable battery value chain was arguably the biggest hurdle. "The challenge was to achieve a paradigm shift toward collaboration, because only through collaboration can an effective and profitable battery industry without unnecessary waste of resources be made a reality. **As a founder you need a lot of perseverance."**

Next steps: By 2025, the startup is planning to **broker 1.2 million batteries.** In a further step, by 2030, ten in-house recycling facilities are supposed to be established, in which batteries with a capacity of 10 GWh are to be made fit for a second life.

The founding trio of Cesar Prados, Sebastian Wolzak and Patrick Peter (from left) gives electric car batteries a second chance

Rafael Fietzek (r.) and Stéphane Foulard. “For automakers, the data result in major savings potential,” says Fietzek. Of up to four euros for wheels, for example. In mass production, that’s a fortune

Predictors of damage

Startup: Compredict (25 employees)

Founded in: 2018

Idea: Automakers like being able to plan. That was what the two aspiring mechanical engineers Stéphane Foulard and Rafael Fietzek experienced as early as in their student days. Accordingly, their startup has the mission of predicting how individual components in a vehicle are being stressed and when they can be expected to fail. How does that work? **Compredict establishes utilization profiles of vehicles, taps the umpteen sensors installed in a car and analyzes them by means of algorithms.**

Implementation: As early as while they were working on their PhDs at TU Darmstadt, Foulard and Fietzek studied digital solutions for online load monitoring. Thanks to an initial financing round the startup picked up momentum. **Absolute discretion is critical** because automakers don’t appreciate others peering under the hoods of their cars.

Hurdles: In addition to the fear of industrial espionage that is pursued aggressively in the automotive sector, the founders are faced with the **problem of finding highly skilled engineers.**

Next steps: So far, the service has been limited to B2B clients. The plan is to develop such a service for consumers as well.

Instant charger

StoreDot CEO Dr. Doron Myersdorf: “Our battery will help overcome the major barrier to EV ownership”

Startup: StoreDot (more than 100 employees)

Founded in: 2012

Idea: Mitigating the “range fear” that keeps many consumers from buying an electric car by means of a battery **that’s fully charged within the space of five minutes.**

Implementation: In May 2021, StoreDot signed a basic agreement for mass production with a Chinese producer. The extremely fast-charging batteries provide manufacturers with the major advantage of being suitable for production in existing manufacturing lines for lithium-ion batteries. StoreDot collaborates with global players in the automotive industry and has already raised several hundred million euros of venture capital.

Hurdles: Designing the battery content using novel electrolyte solutions and nanomaterials so that the battery will retain its capacity even after more than 1,000 charging cycles.

Next steps: Mass production for global vehicle manufacturers is planned to start in 2024.

Masthead

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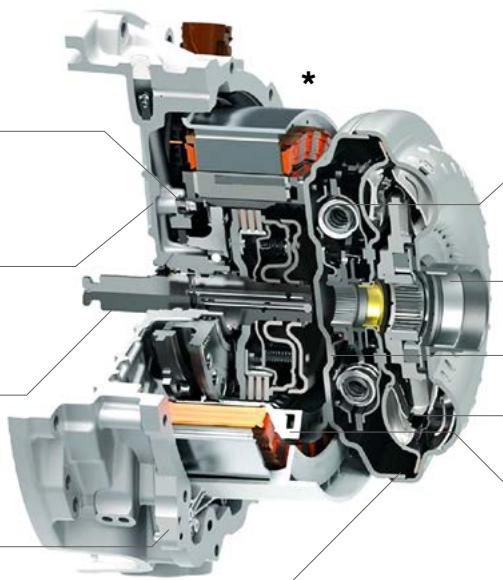

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* An Automotive News PACE Award winner: Thanks to its compact design, Schaeffler's hybrid module can be used on different vehicle platforms.

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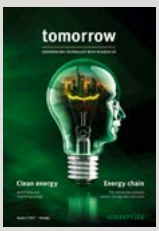

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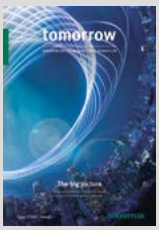

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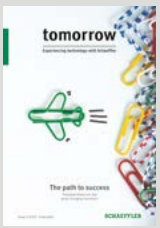

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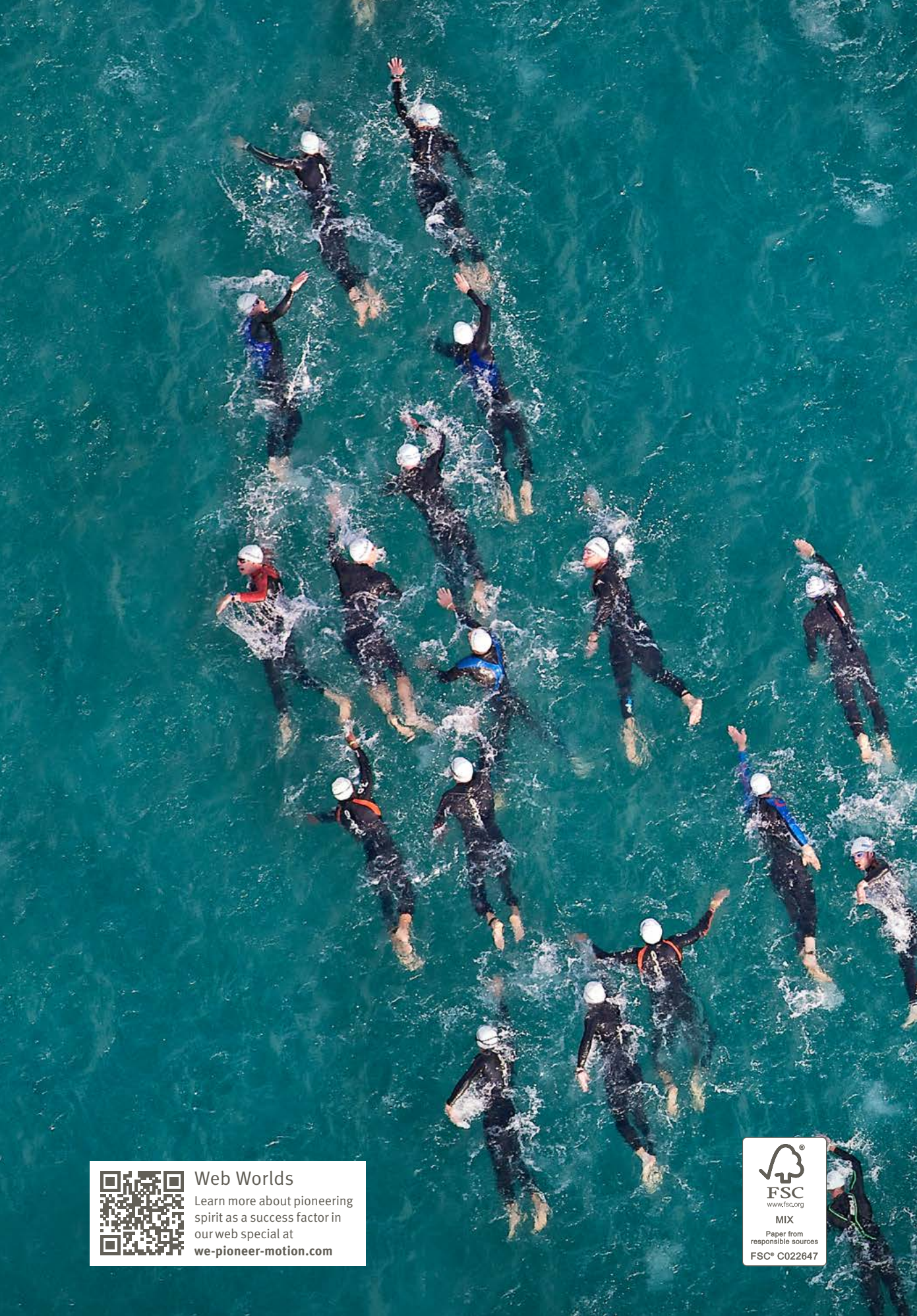

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