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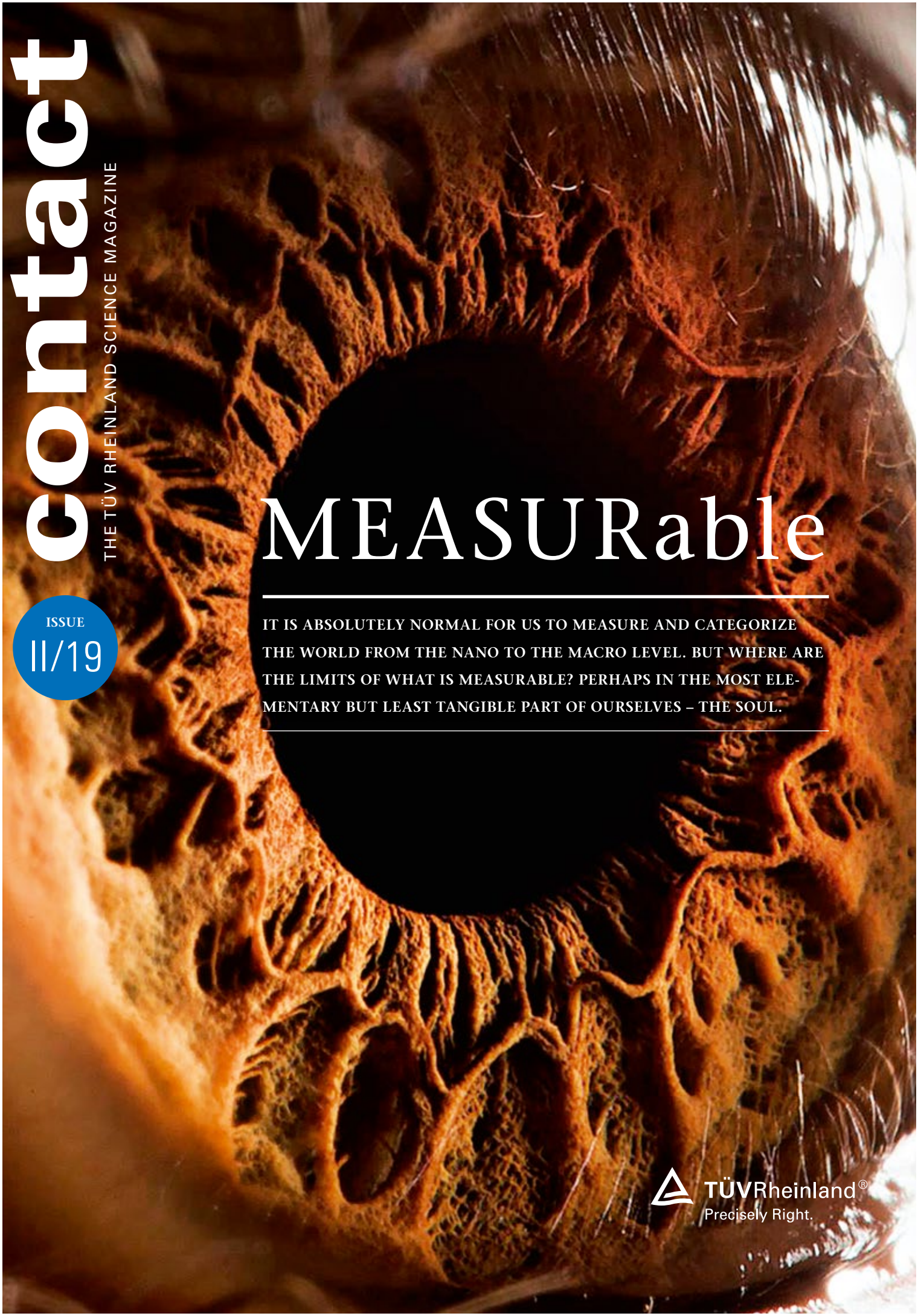

MEASURable

IT IS ABSOLUTELY NORMAL FOR US TO MEASURE AND CATEGORIZE THE WORLD FROM THE NANO TO THE MACRO LEVEL. BUT WHERE ARE THE LIMITS OF WHAT IS MEASURABLE? PERHAPS IN THE MOST ELEMENTARY BUT LEAST TANGIBLE PART OF OURSELVES – THE SOUL.

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03 **Dr. Michael Fübi: Is absolutely everything measurable?**
Measurement is a prerequisite for technical and social progress. But isn't it presumptuous to believe that we can measure and finally understand everything?

04 **Key life measurements**
Assistant Professor Dr. Axel Nothnagel, Geodetic Institute of the University of Bonn, examines the time data of the earth's rotation and explains why we always keep our orientation (p. 4).
Happiness researcher Professor Dr. Michaela Brohm-Badry is convinced that following a drastic experience, people are happier than before (p. 12).
Professor Dr. Volker Schürmann from the German Sport University Cologne finds it foolhardy to intervene medically in the human body to achieve equality of results in sport (p. 20).

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The human body can be fully measured. Advanced measurement methods allow us to see increasingly precise details. But what about human consciousness? Human dignity, happiness and education?

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Global air traffic is growing at an annual rate of five percent. This increase leads to problems. Airports and air traffic controllers are sometimes stretched to their limits.

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Thanks to smart medicine, the human body can be monitored around the clock and diagnoses can be made quickly and easily. But smart medicine does not replace a visit to the doctor.

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Modern headlamp systems have long been more than prescribed vehicle components. They have become an important design element for car manufacturers. And they are true light heroes.

34 **The fifth generation**
5G aims to connect the whole world and advance digitization. But what can 5G really do? Who benefits from the new standard? And what impact will it have?

immeasurable

EVERYONE HAS THEIR DESIRES, GOALS AND PROBLEMS AROUND WHICH THEIR LIFE REVOLVES. SOMETIMES WE THINK OF OURSELVES AS THE CENTER OF THE UNIVERSE. WE OFTEN FIRST BECOME AWARE OF JUST HOW PRESUMPTUOUS THIS VIEW OF OURSELVES IS WHEN WE MANAGE TO STEP BACK FROM OURSELVES.

In 2013, far in outer space, the Cassini space probe looked back from the shadow of the gas giant Saturn to its launch site, the earth. The photo shows us which place we occupy in the universe. From a distance of about 1.5 billion kilometers, the earth shrinks to a small, pale blue point. Our vulnerable home in infinite space – a spaceship for 7.5 billion astronauts.

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We Measure

AS AN ENGINEER AS WELL AS CEO OF TÜV RHEINLAND, I AM VERY FAMILIAR WITH GATHERING AND ANALYZING DATA AND FIGURES. AND AS A RULE, WHAT YOU MEASURE CAN BE IMPROVED – MEASURABLY. THIS IS ONE OF THE MAIN REASONS WHY PEOPLE HAVE ALWAYS COLLECTED DATA; WE MEASURE OURSELVES AND OUR ENVIRONMENT IN ORDER TO BE ABLE TO EVALUATE, ASSESS, CATEGORIZE AND ULTIMATELY IMPROVE EVERYTHING.

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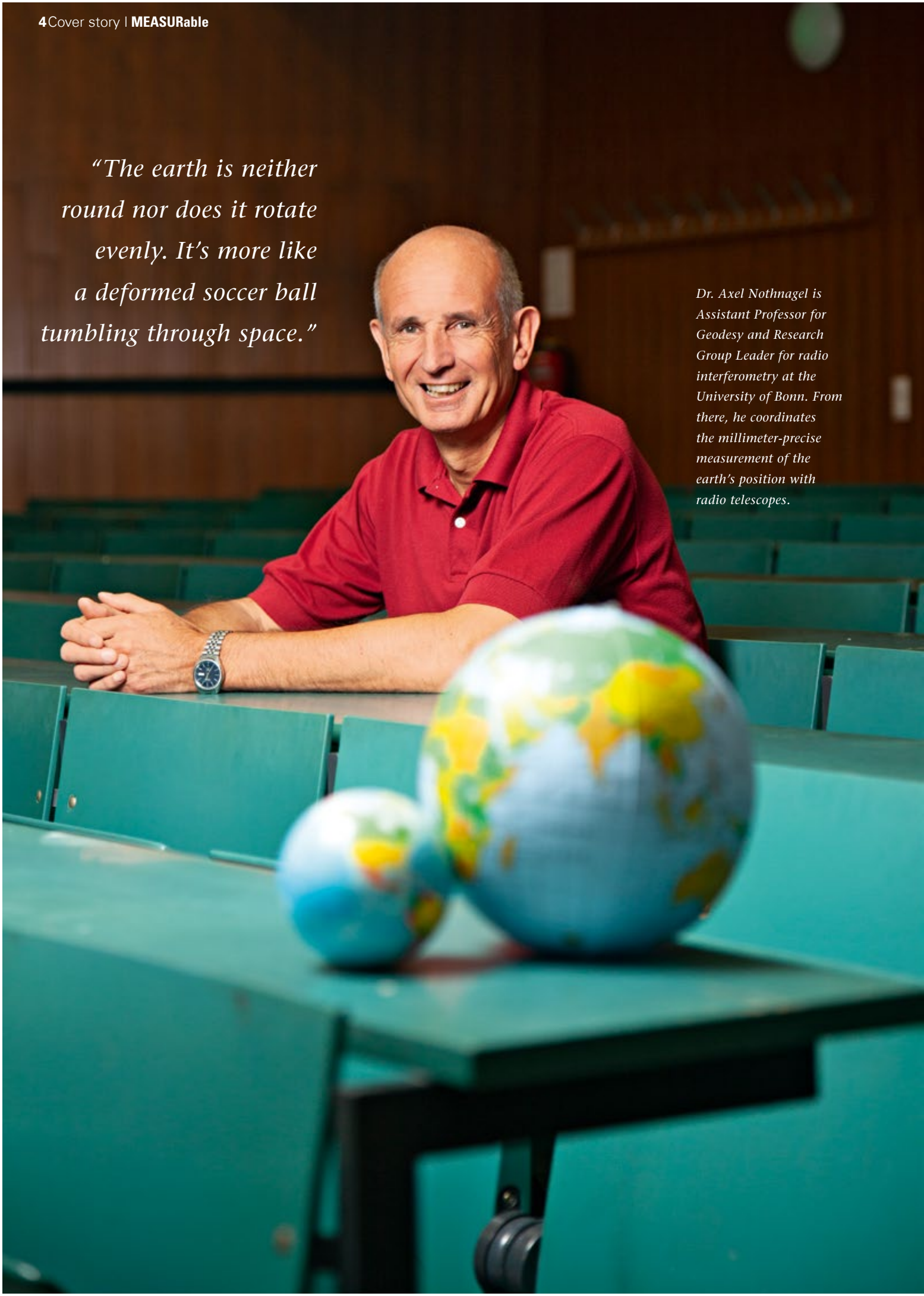
It is not a consequence of digitization that we collect and evaluate data to an unfathomable extent and thereby generate new knowledge and correlations. The urge to explore the unknown and give it a form, a name, has always offered mankind a way to overcome fear of the unknown. This is still how we learn today, in all areas of life. We discovered even the smallest elementary particles and photographed a black hole. The genome, the core of our lives, has been analyzed in all its components. Yet there are still many uncharted territories to be measured, explored and understood – the Amazon basin, the deep sea and the universe still hold many secrets in store. Today, digitization helps us to capture even larger amounts of data, to measure it even faster and more accurately, to analyze this data, to derive correlations and even to predict developments. These volumes of data are to make revolutionary things possible, such as autonomous driving, the transport of people and goods by drone or a thoroughly automated production and working environment in the "dark factory", where robots instead of humans are at work. New technologies are to save time, money and resources. Predictive maintenance, i.e. knowing when the elevator needs to be inspected and the road renewed, or when the bridge needs new steel girders, foreseeing the future from past data, is now possible thanks to digitization.

There is public debate as to whether it is wise for us to voluntarily "surrender" ourselves to unmanned flying machines or autonomous driving in the near future. Is this the right question? Or is it not rather a question of how we see ourselves in a global context, to what extent we are prepared to yield our human capabilities to the potential of technology? Man has to increasingly keep up with the speed of technological progress and learn to trust it. In the process, it is always about technology serving man and not the other way round. Studies show, for example, that the number of road traffic deaths could be drastically reduced by autonomous vehicles. Nevertheless, the acceptance of such systems is not yet widespread, even though we would all be the safer for it. Creating trust in new technologies and their safety – this has been TÜV Rheinland's core mission for over 140 years. That is why we have been measuring and testing from day one.

"Our society must continue to be able to rely on safe vehicles, industrial facilities and digital structures in the future. But we can only do that if we have the necessary data."

Dr.-Ing. Michael Fübi
Chief Executive Officer
TÜV Rheinland

"The earth is neither round nor does it rotate evenly. It's more like a deformed soccer ball tumbling through space."



Dr. Axel Nothnagel is Assistant Professor for Geodesy and Research Group Leader for radio interferometry at the University of Bonn. From there, he coordinates the millimeter-precise measurement of the earth's position with radio telescopes.

The Crazy Earth

OUR PLANET IS PRETTY OFF TRACK: SOMETIMES IT SPINS QUICKLY AND SOMETIMES SLOWLY, TWIRLING AROUND LIKE A GYROSCOPE. AND ITS SURFACE IS ALSO IN CONSTANT TURMOIL. BUT THANKS TO EARTH SURVEYORS LIKE DR. AXEL NOTHNAGEL, WE STILL KEEP OUR BEARINGS.

What is the shortest route to the next bike-sharing station? A glance at the company's app reveals the location and shows the fastest way to get there, thanks to satellite navigation. The fact that the route you travel by bike is also tracked by satellite is now standard. While the use of "navigation" functions has become a matter of course for us, the provision of this service is extremely complex. At an altitude of around 20,000 kilometers, almost 100 satellites from the Galileo (Europe), GPS (USA), Glonass (Russia) and Beidou (China) systems ensure that you can find your bike-sharing location, that ships take the shortest route on the world's oceans and that one day cars can drive autonomously through the city. In order for the navigation satellites to work reliably, however, they need precise information about the location of reference points on the earth's surface. This is the job of geodesist Dr. Axel Nothnagel from the University of Bonn. The expert in the field of earth surveying is head of the VLBI Service, an international network of research institutions, space agencies and radio telescopes that spans every continent of the world. "We create a grid of fixed points that is as accurate as possible in order to give the satellites orientation," says Nothnagel. This has to be done repeatedly, because to a certain extent our planet is constantly changing.

NOT SMOOTH AND UNIFORM

Sometimes the earth spins faster, sometimes slower, or more accurately: it wobbles. Due to wind and ocean currents, the length of the day can vary by up to one millisecond. At the equator, for example, the earth rotates 45 centimeters further during this time. In addition, the planet wobbles around its longitudinal axis like a slowing gyroscope. From the point of view of a geostationary satellite, the countries, coasts and oceans below it move back and forth up to 25 meters per year. Added to this is the movement of the earth's tectonic plates. Europe and America, for example, drift about two centimeters apart every year. Last but not least, the earth's surface is not as round and uniform as it appears from space. Without water cover and taking into account the masses and height differences, our planet is more like a shriveled, dented potato. All these effects together have a strong influence on determination of position on the earth. "If we didn't repeatedly measure and feed the satellites with current data, satellite navigation as we need it today for many applications would be impossible after a few weeks," says Axel Nothnagel.

QUASARS EMIT CRACKLING SOUNDS

Scientists' most important tool is the VLBI (Very Long Baseline Interferometry) measurement method, which gives the network its name. Twice a week, Nothnagel coordinates the measurement series of seven of the approximately 60 radio telescopes used worldwide for this purpose. They are the fixed points of the coordinate system. The giant bowls target radio sources in space in pairs, mostly quasars. These celestial bodies, two to eight billion light years away, emit crackling sounds and are ideal fixed points because of their great distance from earth. Because the telescopes are thousands of kilometers apart, the cosmic noise reaches them offset by fractions of a second. From this, high-performance computers calculate the distance between the telescopes to within two millimeters per thousand kilometers. These data in turn allow conclusions to be drawn about the current position and form of the earth – and help the satellites guide us reliably to the next bike-sharing station.

realignment

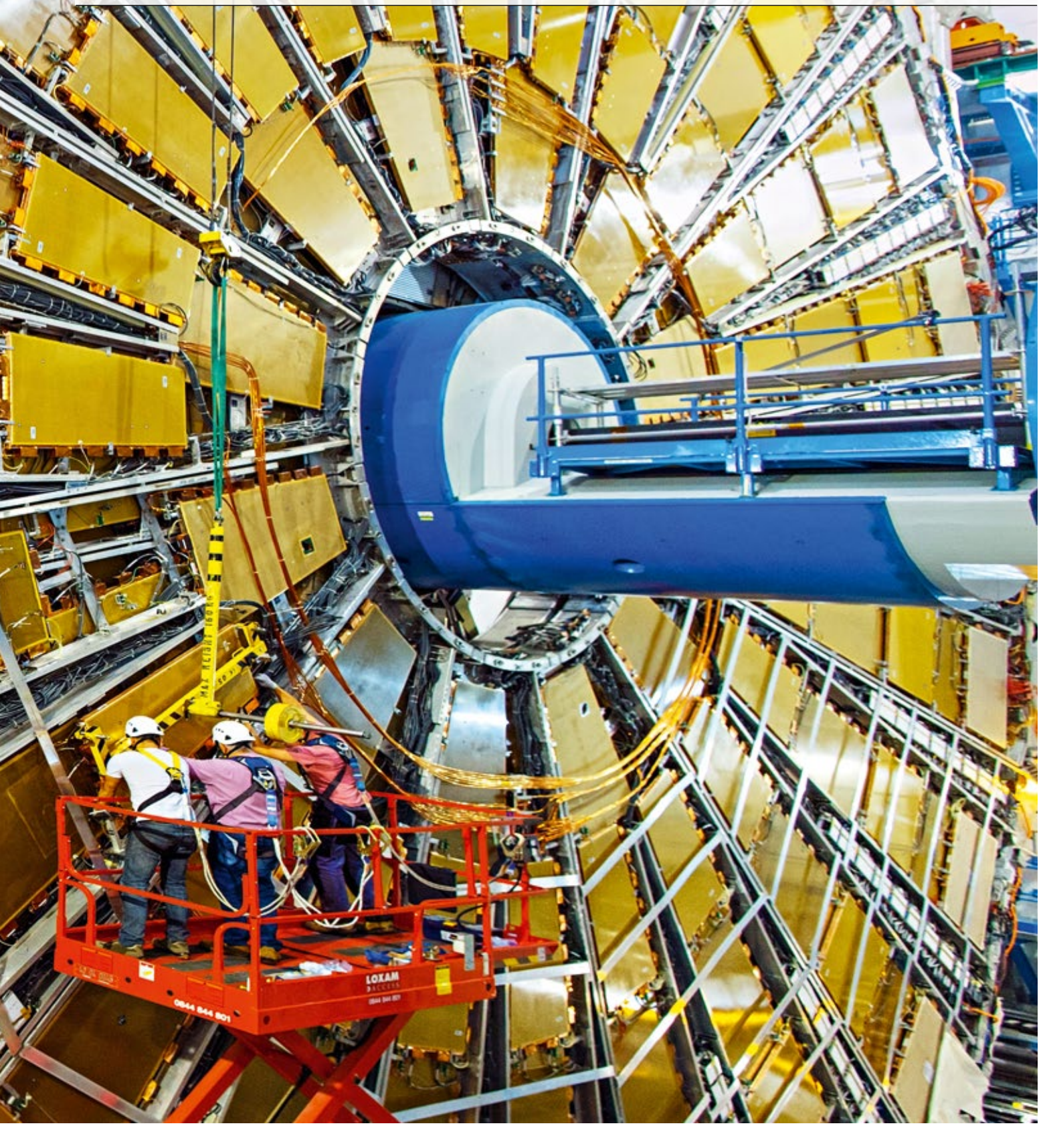
WHAT DOES THE LONG-TERM PROSPERITY OF A SOCIETY DEPEND ON? AND HOW IS PERSONAL WEALTH MEASURED? DIGITIZATION AND CLIMATE CHANGE ARE FUNDAMENTALLY CHANGING THE PARAMETERS THAT ANSWER THESE QUESTIONS FOR MANY PEOPLE. IT IS TIME FOR NEW GOALS.

Crude oil, natural gas, manganese, cobalt: the seabed is home to vast resources of raw materials. This awakens desires and holds potential for conflict. The UN Convention on the Law of the Sea only permits countries to exercise sovereignty over the "exclusive economic zone" and thus to exploit fishing grounds and raw materials within the 200 nautical mile belt zone off their coast. In addition, the oceans are defined as the "common heritage of mankind". Now, however, coastal nations and islands can extend their territory to a maximum of 350 nautical miles if their continental shelf extends this far under water. A new battle for the oceans has thus begun. With geological surveys, states want to prove that they have the largest possible share of the continental shelf. A UN commission of experts evaluates the data obtained from underwater drilling and radar measurements. Five countries bordering the Arctic Sea – Denmark, Canada, the USA, Norway and Russia – thus want to extend their sovereign rights towards the North Pole. More than ten percent of the world's oil is thought to be here. But the battle for economic supremacy on the seabed is not only fought with the weapons of science. For decades, six countries have been involved in a sometimes open military conflict over the small Spratley Islands in the South China Sea. Gas and oil deposits are believed to be here. The sea, the heritage of mankind: the dispute about it is in full swing.

Scientists from 85 nations and from 580 universities and research institutes have built the largest machine in human history for the search for what holds the world together at its core: the Large Hadron Collider (LHC). The ring-shaped particle accelerator with a circumference of 27 kilometers is located at a depth of around 100 meters below the European Organization for Nuclear Research CERN near Geneva. With four detectors like the huge ATLAS (45 meters long, 22 meters in diameter), the LHC captures the smallest components of our universe, the elementary particles. Two beams of protons or ions circulate in opposite directions in the LHC. When they collide in the detector at high energy, states such as directly after the Big Bang occur. The last missing elementary particle, the Higgs boson, was thus detected in 2012. This was rewarded with the Nobel Prize. The standard model of particle physics has now been experimentally proven. The problem is that only five percent of the universe can be described with this model – 95 percent is probably based on dark energy and dark matter. That's the theory. CERN is therefore continuing the search for our origin.

measured

MAN'S SCIENTIFIC CURIOSITY AND INNOVATIVE POWER ARE BOUNDLESS. WHETHER ON A MICRO OR MACRO SCALE, WE EXPLORE THE WORLD DOWN TO THE LAST DETAIL, UNDERSTAND MORE AND MORE, AND CONTINUALLY RESHAPE OUR LIVES. EVERYTHING WILL BE FINE IF THE DESIRE FOR PROGRESS SERVES EVERYONE.



decisive

WHY DO WE DO WHAT WE DO? WHY DO WE FEEL HOW WE FEEL? WE CANNOT DESCRIBE THE DECISIVE FORCES THAT GIVE OUR LIFE DIRECTION WITH INTELLECT AND REASON ALONE. WE ARE EMOTIONAL, IRRATIONAL AND COMPLEX. THE INDESCRIBABLE MAKES US EXCITING.

Life is beautiful! When the alpine summer in the Alps has passed without any deadly incidents for humans and animals, the herds are artistically decorated for the festive descent to the valley.

What is beautiful? And can beauty be measured? Research of attractiveness answers quite pragmatically: beauty is what the majority describes as beautiful. However, this democratic concept of beauty only reflects mass taste and neglects personal preferences. The individual notion of beauty develops in a more complex fashion. The influences of the environment, such as those of parents or the media, play a subordinate role, as does genetic predisposition. Even identical twins who grew up together judge the attractiveness of faces differently. Which features of a face we find attractive depends more on our own experiences and a multitude of subtle impressions. Nevertheless, there are universal criteria for beauty and attraction. Symmetrical and even features according to the golden ratio, for example, are generally regarded as the ideal of beauty on which most people can agree. But true beauty is not measurable, it is still in the eye of the beholder.

Dr. Michaela Brohm-Badry is Professor for Empirical Teaching-Learning Research at the University of Trier, President of the German Society for Positive Psychological Research and columnist for WirtschaftsWoche. Her research focuses on positive psychology, motivation and personality growth.

"We can largely control our behavior and our environment. Ultimately, the world is not one way or the other, our perspective on the world makes it one way or the other."

The Happy Five

ONLY WITH GREAT FORTUNE DOES MICHAELA BROHM-BADRY SURVIVE A BURST ANEURYSM – IN THE MIDST OF SELF-IMPOSED SOLITUDE. SINCE THEN, THE LEARNING RESEARCHER HAS DELVED INTO THE SUBJECT OF HAPPINESS. HER BOOK "DAS GUTE GLÜCK" ON ACHIEVING HAPPINESS SHOWS HOW WE CAN DO JUST THIS.

Professor, there are frequent rankings in which the happiest countries on earth are declared. But can happiness be measured at all?

In research, we do not talk about the fleeting state of "happiness", but about long-term well-being. We differentiate between subjectively perceived well-being and objective points. The most frequently quoted ranking is the UN World Happiness Report, which has been published annually since 2012 and covers around 150 countries. It attempts to combine objective and subjective aspects. The objective parameters are people's life expectancy, gross domestic product, labor market data and the social system. Subjective are the people's assessments of the objective conditions, their trust in the respective government and economic development, the perceived freedom of choice and other factors. The key here is the peoples' satisfaction.

How can happiness be measured?

Biomarkers are clear indicators: an excessively high cortisol level indicates negative stress, which can lead to burnout and depression in the long run. High neuronal activity in brain regions associated with pleasure, on the other hand, shows that the brain perceives pleasure. If the pain regions are active, this is not the case.

Positive psychology has found that you can influence your personal happiness: how happy we are depends on our behavior and our environment. Does that mean happiness can be learned?

In fact, about 50 percent seems to be genetically determined – mainly due to the neurotransmitter receptors in the brain, but 40 percent can be influenced by our behavior and another 10 percent depends on our environment. We can therefore control our behavior and our environment to a large extent. Ultimately, the world is not one way or the other, our perspective of the world makes it one way or the other. Negative people focus on what they reject in their lives. Happy people focus on what they love about their lives. And the freedom to be able to choose this perspective yourself is an inner freedom that exists irrespective of your life context.

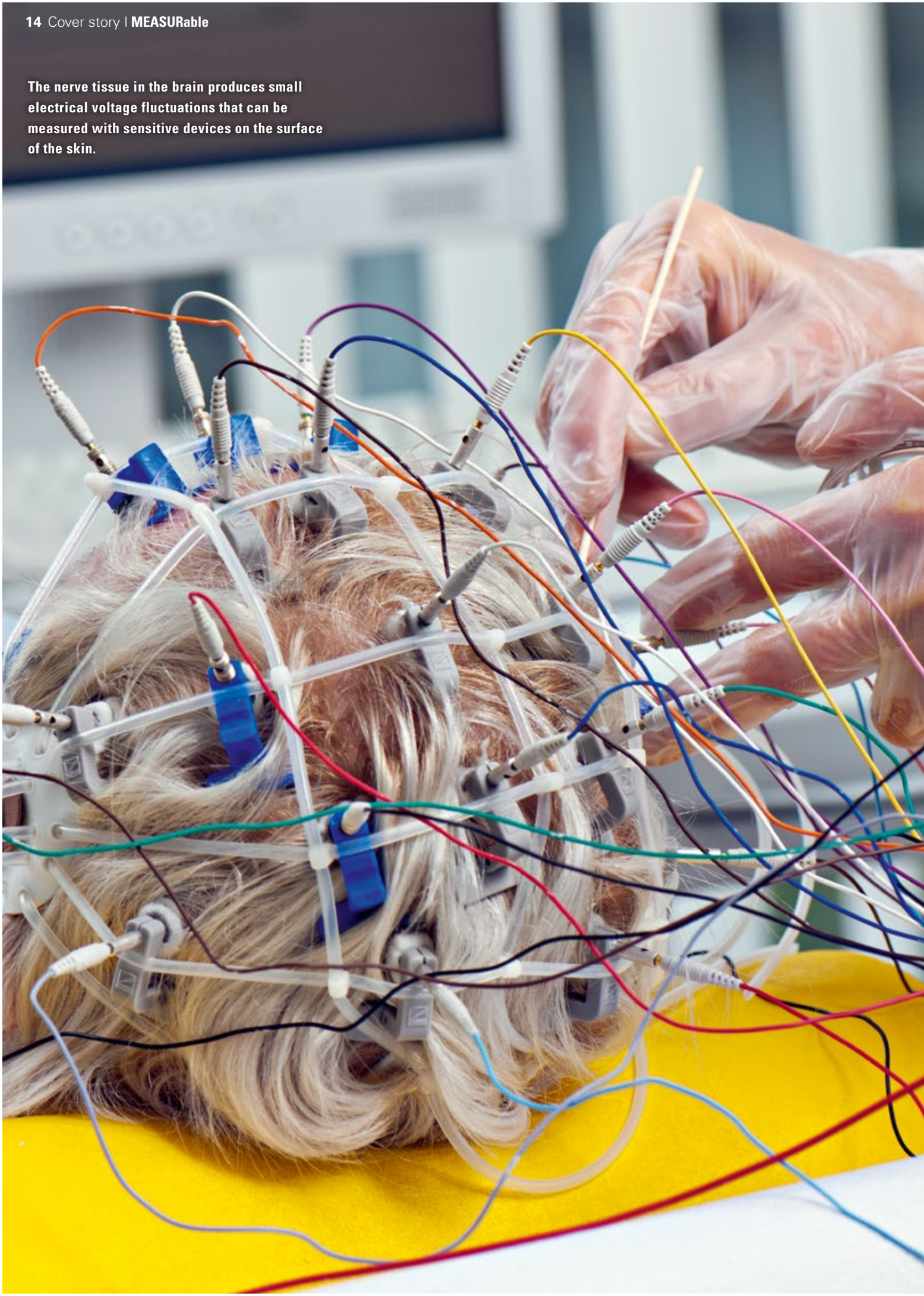
How can I focus on what is going well in my life, even if I feel like the world is just collapsing around me?

Negative feelings are as important as positive ones, but unfortunately most people have a "negativity bias" – a negative distortion that probably stems from our evolution. We then see a negative where it does not exist to ensure our survival in an emergency. Some indicators help us to get out of the downward spiral and have proven to be clearly helpful in research.

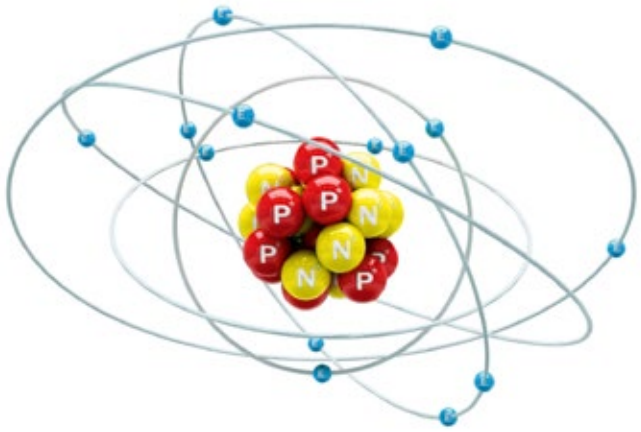
What are they?

From a scientific point of view we can say quite exactly what helps to be happier, because we know the "happy five" factors for life. These include positive feelings, such as hoping for the good, being grateful, curious and friendly, living lovingly; being committed to and motivated for something; building and maintaining good, deep, trusting relationships; finding meaning in life and acting in a way that makes us feel effective and successful. This often means really getting things done and not giving up in the midst of things.

The nerve tissue in the brain produces small electrical voltage fluctuations that can be measured with sensitive devices on the surface of the skin.



How heavy is a kilogram? Of late, the measure of all things is determined indirectly by the mass of a silicon atom.



Reaching the Limits of Measurement

EVERYTHING TODAY IS PRECISELY MEASURED, PROBED, AND ANALYZED. THE QUEST FOR DATA GENERATES KNOWLEDGE AND ENABLES PROGRESS. BUT THE PERVASIVE MEASUREMENT OF DATA CARRIES RISKS FOR OUR OPEN SOCIETY.

The image shows a nebulous, reddish glowing ring around a black dot in the middle of the murky darkness. It is a little blurry and looks rather unspectacular at first sight. And yet this image made the headlines on April 10, 2019 and enthralled millions of people. An international team of scientists had succeeded in taking the first photo of a black hole using eight radio telescopes. It was a sensational achievement. What researchers had only been able to describe mathematically up until then could finally be seen and measured by all. The black hole in the center of the M87 galaxy weighs 6.6 billion times the mass of the sun and is 55 million light years away from Earth. But what the photo tells us goes far beyond these impressive figures. For the first time, we are seeing a point at which space and time lose their meaning. If truth be told, this glimpse into a black hole takes us beyond the limits of our imagination, leaving us dazed and confused. Because no one really knows how it works. To understand it, you need a theory that reconciles quantum mechanics with gravity. But that theory doesn't exist. The data collected through the photo could one day lead to such a theory. This is why the image is so fascinating. People can see the limits of their world, and the limits of what can be measured, with their own eyes.

ALL THE MORE PRECISE

It is human to measure. We have always measured, scaled, and categorized the world. Measuring creates knowledge and security; it enables us to advance technologically and as a society. In turn, technological progress enables more precise measuring. It is a self-perpetuating process. And so we continually

expand our horizons. The Nebra sky disk was created around 4,000 years ago. It is the oldest known representation of the cosmos. People used it to measure the night sky, identify the seasons, and determine the best times for sowing and harvesting. Starting in 1730, discoverers used sextants to navigate the oceans, and land surveyors used them to gradually complete their map of the world. Geodesists like Dr. Axel Nothnagel measure the surface of our planet precisely to the millimeter (see interview page 4).

THE PERFECT KILOGRAM

Measurement technology is becoming more sophisticated and complex, allowing us to unearth the deepest secrets of the planet and everything that lives on it. We can capture elementary particles and measure black holes. Even the units of measurement themselves, the ones we use every day, were more accurately defined on World Metrology Day, May 20, 2019. "The way we measure the world concerns everyone. A silent revolution is taking place in the field of measurement," says Wolfgang M. Heckl, General Director of Deutsches Museum in Munich. Scientists were horrified by the previous units of measurement. They were too inaccurate, inconsistent, and man-made. In fact, a metal cylinder was the unit of mass for all things for 130 years. Metrology institutes compared their national kilo references to the so-called prototype kilogram, which is kept securely under three bell jars in a vault at the International Bureau of Weights and Measures (BIPM) in Paris. The cylinder is made of an alloy of 90 percent platinum and ten percent iridium, both of which are stable metals. Despite all precautions, nothing could be done to prevent the prototype kilogram from losing approximately half a microgram of mass per year. So far, it has lost more than 50 micrograms, which is about as much as a grain of salt. And the reason remains a mystery. This inaccuracy might not matter when weighing apples at the market. For people whose main occupation is to work with measurements and try to guarantee the consistency of measuring units all over the world, it is a huge disaster not unlike the chaos of measurement during the Middle Ages, when the unit of length – the foot – varied depending on the shoe size of the respective king. But for scientific experiments and technologies like satellite navigation, a clearly defined international unit of measurement is indispensable. Representatives from 60 countries therefore decided

In sport, fairness is the most important benchmark. The South African sprinter Caster Semenya is therefore supposed to artificially lower her high testosterone level and thus enable her rivals a fairer competition. Critics find this more than unfair and see a violation of Semenya's human dignity.

to introduce new, unchanging standard measurements for mass and weight based on constants in nature. The kilogram is based on the mass of a silicon atom. It is used to calculate precisely what a kilogram is. A perfect sphere of 21.52 quadrillion silicon atoms with a diameter of exactly 9.37 centimeters now serves as the new kilogram standard. Because the constants in nature apply everywhere, even in space, such a sphere can be accurately reproduced for a million euros a piece. One of the new prototype kilograms is on view at the Deutsches Museum. The kilogram is just one of several units of measurement that are now defined by constants in nature, such as the speed of light and the charge of an electron. The second (time), the meter (length), the ampere (electric current), the kelvin (temperature), the mole (amount of substance), and the candela (luminous intensity) were also redefined on May 20.

When is a person allowed to die? And who can decide this on what basis? Debates on euthanasia lead to ethical grey areas. Because the dignity and value of life cannot be measured in figures and data. And because every life has its own highest value.

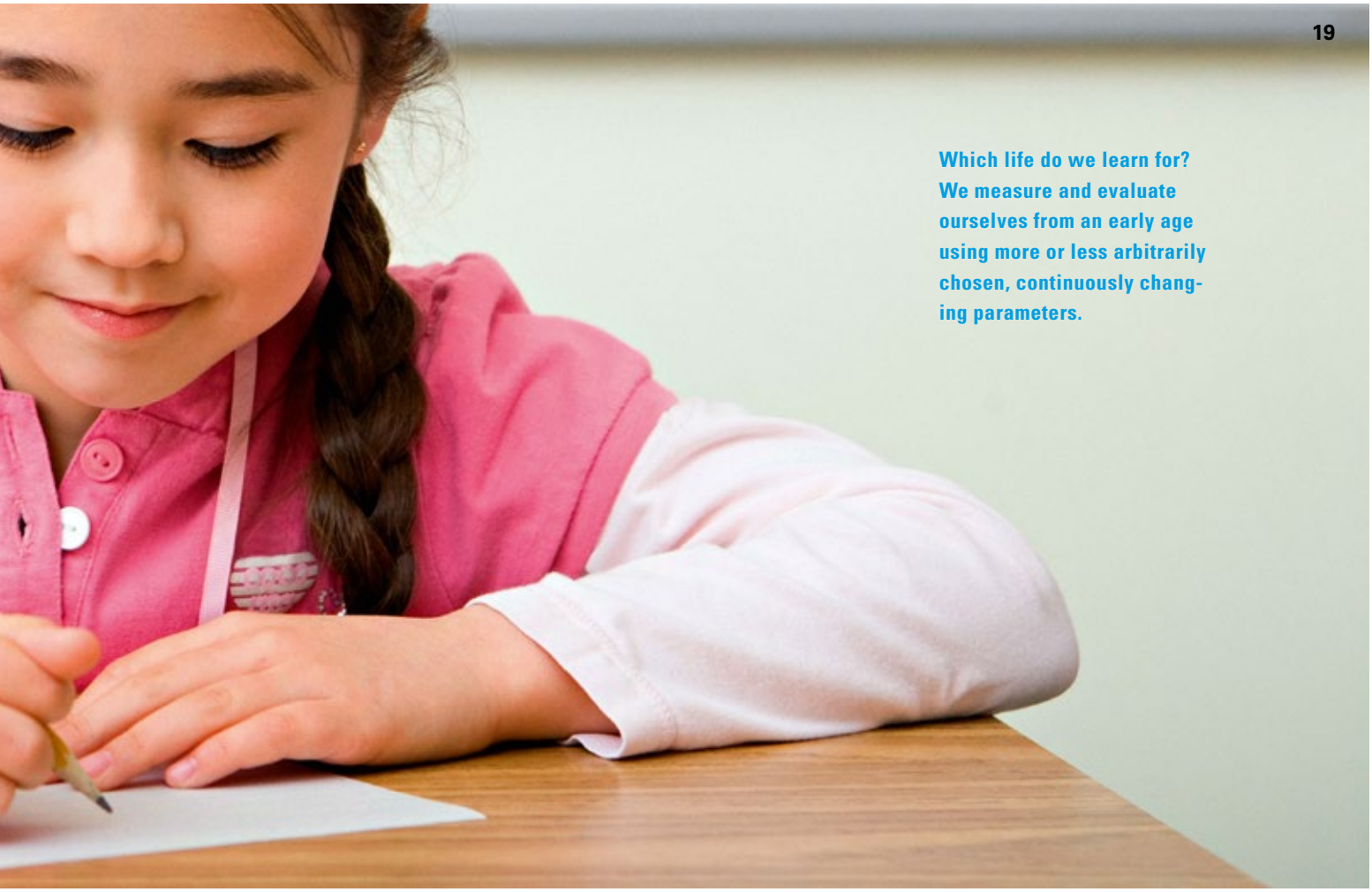
The way we measure the world has without a doubt reached a new level, and not just in science. The driver of this development is digitalization. According to a study conducted by market analysts at the International Data Corporation (IDC), there will be five times more digital data worldwide in 2025 than in 2018. We need a great deal of data in order to run applications such as autonomous driving, smart production processes, video streaming or customized online advertising. To generate this data, we measure, analyze, evaluate, and rate just about everything. We even measure ourselves with ever-increasing accuracy, both physically and sociologically. The smartphone is the ideal measuring device, and we all have one in our pocket. It creates movement and communication profiles and records purchase histories and physical activities – for our own use as well as for companies. The appetite for data, combined with pervasive quantification, has taken hold of our society, writes sociologist Steffen Mau in his book "The Metric Society." Mau believes that we are becoming "numerocrats" who increasingly perceive ourselves and our environment in terms of scores, likes, and rankings. This is to be expected in a society based on efficiency, transparency, and accountability. When performance

WE ARE BECOMING "NUMEROCRATS" WHO INCREASINGLY PERCEIVE THEMSELVES AND THEIR ENVIRONMENT IN TERMS OF SCORES, LIKES, AND RANKINGS.

targets and goals are agreed within a professional context, the outcome is monitored. Those working in quality management need to collect data, and so they must measure. Monitoring and evaluation are now a key part of any project work. We can acquire important knowledge about control by defining and measuring parameters; this helps optimize processes and address target groups more specifically, for example. As much as it makes sense to use performance measures to evaluate work in the private sector or in administration, it is all too tempting to reapply them to other areas in life.

TEMPTED BY FIGURES

Figures suggest clarity, accuracy, and neutrality. Quantifications reduce a complex reality to a few indicators, which is a strength and a weakness at the same time. As objective as figures may seem as a tool for evaluating individuals within their social framework, they are often not enough. "Values like fairness and dignity cannot be measured," says sports philosopher Volker Schürmann in an interview with "contact" (see page 20). Values are difficult to define using numerical parameters; they must always be worked out in a social discourse. It would be presumptuous to address social issues – such as those that involve the way we deal with unborn life, gene editing in human embryos or the right to assisted dying – solely based on key figures and indicators. Measured data can back up complex social and ethical decisions, but that is all. We are operating here under the illusion of measurability. Algorithms, Mau writes, do not show what is truly relevant and valuable, but only what is considered as such. For example, Mau claims that dating apps or fitness trackers linked to health insurance providers change the "quantifying assignment of status": People's attractiveness or lifestyle is made comparable and placed within a hierarchical relationship. The problem, writes Mau, is that scores generated in this way do not completely reflect real social contexts; instead, they produce a new order that – due to their supposed objectivity – puts pressure on social norms and political decisions. The one who controls quantification is the one holding the power, because he "can claim that status has been legitimately assigned to some while denying this legitimacy to others," explains Mau. In other words, the only ones who count are those who allow themselves to be measured. China's "social credit system" is an extreme example of what this can lead to. The state leadership intends to assign a score to all citizens, companies, and NGOs starting in late 2020. The score will be based on monitored factors such as criminal records, credit ratings, political opinions, and social media activity. The ranking within the scores will determine whether an individual can be granted access to state jobs and contracts or receive a visa to travel abroad.



Which life do we learn for? We measure and evaluate ourselves from an early age using more or less arbitrarily chosen, continuously changing parameters.

THE IMMEASURABLE SELF

We appear to have gone beyond the limits of what can be measured. Nothing can escape our curiosity. And yet there are places not only in distant outer space, such as the black hole, whose secrets remain hidden to us. There is also something within our inner self that defies all attempts to measure it: our consciousness. Scientists are still unable to answer the question of how human consciousness is empirically proven, and therefore measurable. So where is our consciousness, our soul, located? It is a question to which religions have always provided the answers and that philosophers and neuroscientists are pursuing today. The search for the self is not an easy endeavor. When we look inside the brain, we cannot find any structure that could be called the consciousness or the seat of the self. We can only measure the firing of neurons. "Consciousness is apparently the only phenomenon we know in science that is tied to a subjective inner perspective," says philosopher Thomas Metzinger. We are still far from being able to measure this subjectivity of the consciousness with objective research tools, says the author of the book "The Ego Tunnel – The Science of the Mind and the Myth of the Self: From Brain Research to the Ethics of Consciousness." Electrodes can be used to look inside the brain and measure the activity that occurs when we feel sensations such as pain. But what cannot be measured is the quality of the pain, the subjective value that we ascribe to the pain. The same applies to color and taste experiences. There is a lot of detailed knowledge about different forms of self-perception, but there is no unifying theory in which "all the little pieces of the puzzle come together as one picture," says Metzinger. Like the black hole, our consciousness lies beyond the limit of what is measurable. But with the power of our imagination, there is no reason why we cannot one day push the limits of our understanding even further.

IT IS SAID THAT THE EYES ARE THE WINDOW TO THE SOUL. IN FACT, WE CAN GAUGE THE INTENTIONS OF OUR COUNTERPART BY LOOKING INTO THEIR EYES.

Stay Fair

FAIRNESS IS THE MEASURE OF ALL THINGS IN SPORT. BUT TO CREATE EQUAL OPPORTUNITIES AT THE STARTING LINE IS AN ONGOING CHALLENGE FOR SPORTS POLICY, SAYS COLOGNE SPORTS PHILOSOPHER VOLKER SCHÜRMANN. IT'S ABOUT VALUES, TALENT AND HUMAN DIGNITY.

Mr. Schürmann, when is a sports competition fair?
When everyone has the same opportunity for an equal start and it has not been decided who will win beforehand. In essence, it's about a fair performance comparison.

In the case of the South African sprinter Caster Semenya, fairness seems to be in danger. Her high testosterone level is said to give her an advantage over her competitors. If she wants to continue, she has to undergo hormone therapy. Is that fair?
Fairness is the basic norm of sport. Just as dignity is the foundation of our constitution and of international law. Both are inviolable. What the Athletics Federation demands of Ms. Semenya and athletes in the same situation is incapacitating and inhuman. No one may prescribe interventions in the body without medical reason. In a truly complicated case, that is the only thing that is clear. There is no purpose that sanctifies discrimination.

The other runners could argue that they are disadvantaged.
Surely they are not happy to regularly lose to Ms. Semenya. In general, individual talent and differences in performance are part of the sport, otherwise everyone would cross the finish line together. But the extent of the differences must not be so great that they cannot be compensated in competition. Fairness therefore requires a definition of how these differences come about. Institutions must regulate this. That is why, for example, there are weight classes in boxing. Anything else is considered talent. So far, nobody has called for a maximum height for basketball players. Which individual parameters need to be regulated is historically in flux and also depends on the sport. In contrast to team sports, in individual sports, the individual's talent can hardly be compensated by tactics and team strength.

How can the Semenya case be solved?
Fortunately, no one doubts anymore that she is a woman or demands that she competes against men. Instead, the testosterone value is used as a parameter for permission to compete. This is, of course, a very technical way of looking at people. One tries to do justice to the fact that gender differences alone are not a performance-decisive characteristic. That is not wrong in itself. If one were to find the performance-decisive parameters for each sport, a classification beyond all gender boundaries would be possible. That would be fair. However, I consider it almost impossible to scientifically without a doubt determine such parameters in the field of tension between biology and sociology. At the Paralympics, we see how complex classification systems can become. These are and will remain sporting decisions.

What's the alternative?
There have always been athletes who were capable of extreme performance due to their physical condition. The swimmer Michael Phelps, the most successful Olympic athlete of all time, was able to use his big hands and feet like fins. No one ever saw a need for regulation and prohibited him from swimming. His special physique was considered a natural talent. And so one could also consider Caster Semenya as a special talent in sprinting – and that's it.

“Classifications are and will remain sports policy decisions that nature does not relieve us of.”

Prof. Dr. Volker Schürmann is Head of the Philosophy Department at the German Sports University in Cologne. He says: Fairness must be rewarded in a sports culture that again relies more on fair performance comparison than on uninhibited performance enhancement.

1 > STARTING POINT

Restricted Access

GLOBAL AIR TRAFFIC IS INCREASING EVERY YEAR BY FIVE PERCENT. THE NUMBER OF PASSENGER AIRCRAFTS IS EVEN SET TO DOUBLE BY 2035. TODAY THE AVIATION INDUSTRY IS ALREADY FACING THE ENORMOUS CHALLENGE OF COORDINATING AN EVER-INCREASING NUMBER OF AIRPLANES.

The skies are becoming more and more crowded. Full capacity is occasionally reached, particularly over the U.S. and Europe. This has led to ongoing discussions about how airspace should be organized and structured.

NUMBER OF WORLDWIDE AIR TRAVELERS IN 2018
4.3
BILLION

WORLDWIDE PASSENGER PLANE TAKEOFFS IN 2018
38
MILLION

RECORD HIGH IN ONE DAY ON JULY 13, 2018
205,468
FLIGHTS

AVERAGE NUMBER OF TAKEOFFS IN EUROPE
36,000
PER DAY

Source: ICAO, Flightradar24

As day breaks, the sky suddenly fills with countless flying objects, including massive jetliners, small drones, and everything in between. Worldwide civil air traffic has grown by 50 percent over the past 20 years. The result is essentially a rush hour in the sky, the worst of it over Europe, due to its geographical position and densely populated areas. An average of 36,000 passenger planes take off from here every day, most of them in the heart of the continent in cities like Paris, London, Amsterdam, Zurich, Frankfurt, Cologne, Munich, Düsseldorf or Berlin. With so many takeoffs, landings, and flyovers in Germany, the country is feeling the effects of the increasing volume of air traffic and is already coming up against its limits. For one thing, the airports are operating at full capacity. Frankfurt is one example, with around 100 takeoffs and landings per hour. The key priority is to get planes safely through the airspace, often at the expense of other factors such as punctuality.

CROSS-BORDER AIRSPACE

Ever since delays and cancellations at certain airports became the rule rather than the exception, much of the media has portrayed the situation as a "traffic jam in the sky." But the traffic jam isn't actually in the sky – it's on the taxiways. That's because the old system in which planes used to circle over the airport waiting for a landing strip to become available was eliminated in Europe 15 years ago. The only exception is London Heathrow. Instead, the planes remain on the ground when the airspace or the destination airport has reached full capacity. In this regard, the organization of European airspace has repeatedly come under fire. Critics say that Europe's "patchwork quilt" and the ensuing "zigzag flight paths" of the aircraft are the cause of inefficient air traffic and delays. This is due to inconsistent national regulations, which have resulted in 27 different air traffic control systems. Within this context, the Single European Sky (SES), a proposal to unify Europe's airspace, has been on the EU agenda since 2000. "Aviation has always been a global business. We work very closely together with our neighbors. For air traffic controllers, it is irrelevant whether they send an airplane over to a German or a French colleague. And all air traffic control systems are clearly capable of communicating with each other and with the planes," says Ute Otterbein, spokesperson for Deutsche Flugsicherung (DFS), the company in charge of air traffic control for Germany. What's more, the airspace is monitored independent of national borders. For example, the entire western part of Austria is monitored from Germany and Italy. Yet this doesn't lead to zigzag flight paths, according to Otterbein. "Flights in German airspace deviate from the great circle – the shortest path between the departure and the destination airports – by only 3.8 kilometers. That is shorter than the runway at the Frankfurt airport."

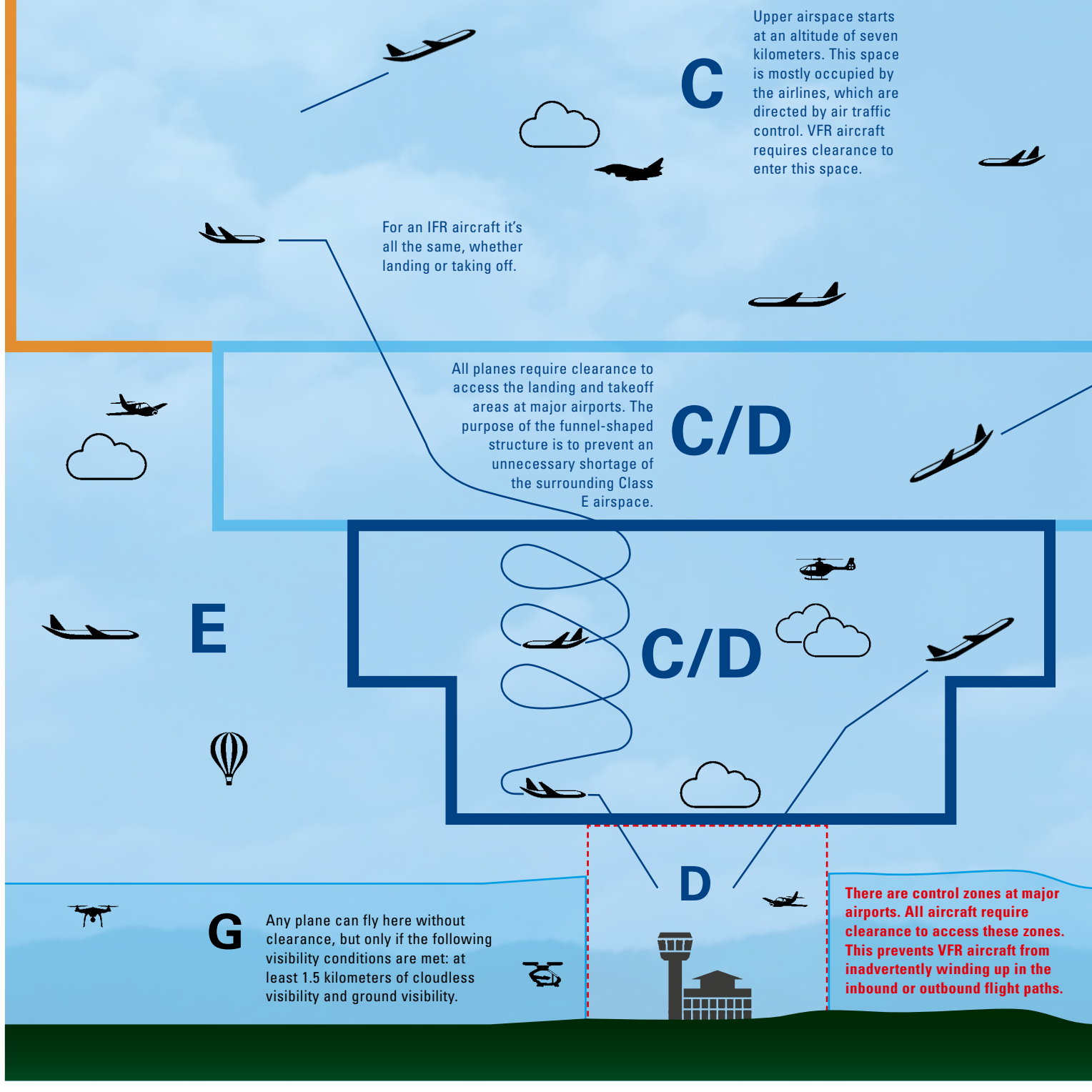
PLANNING VERSUS REALITY

Air traffic routing is the biggest priority in the skies. Air traffic controllers are mainly responsible for routing passenger planes worldwide. But staff shortages occur all too frequently. The reason behind this is that staff scheduling is not in line with the highly volatile nature of international air traffic, nor can it ever be. Tourism flows often shift from one season to the next. In the past several years, for instance, they have moved from Turkey to destinations in Spain. An unexpected onslaught of passengers can place huge demands on the local infrastructure and staff, resulting in massive delays. For security reasons, air traffic controllers only have clearance for one particular operating site, so it was also impossible to increase the staff on short notice. DFS is working on a number of technical solutions to better reconcile long-term staff scheduling and short-term traffic developments, including ways to improve the use of the already very limited airspace capacity (more details on page 28). However, solutions that help air traffic controllers do their job can never replace them entirely.

2 > STRUCTURE

Above and below the Clouds

AS A RULE, CIVIL AVIATION, SPORT FLYING, AND THE MILITARY SHARE THE AIRSPACE. TWO MAIN TYPES OF PILOTS COME UP AGAINST EACH OTHER IN THE SKIES: THOSE WHO FLY BY SIGHT AND THOSE WHO FLY BY INSTRUMENTS. THE AIRSPACE STRUCTURE IS GOVERNED BY A CLEAR SET OF RULES TO ENSURE THEIR COLLECTIVE SAFETY.



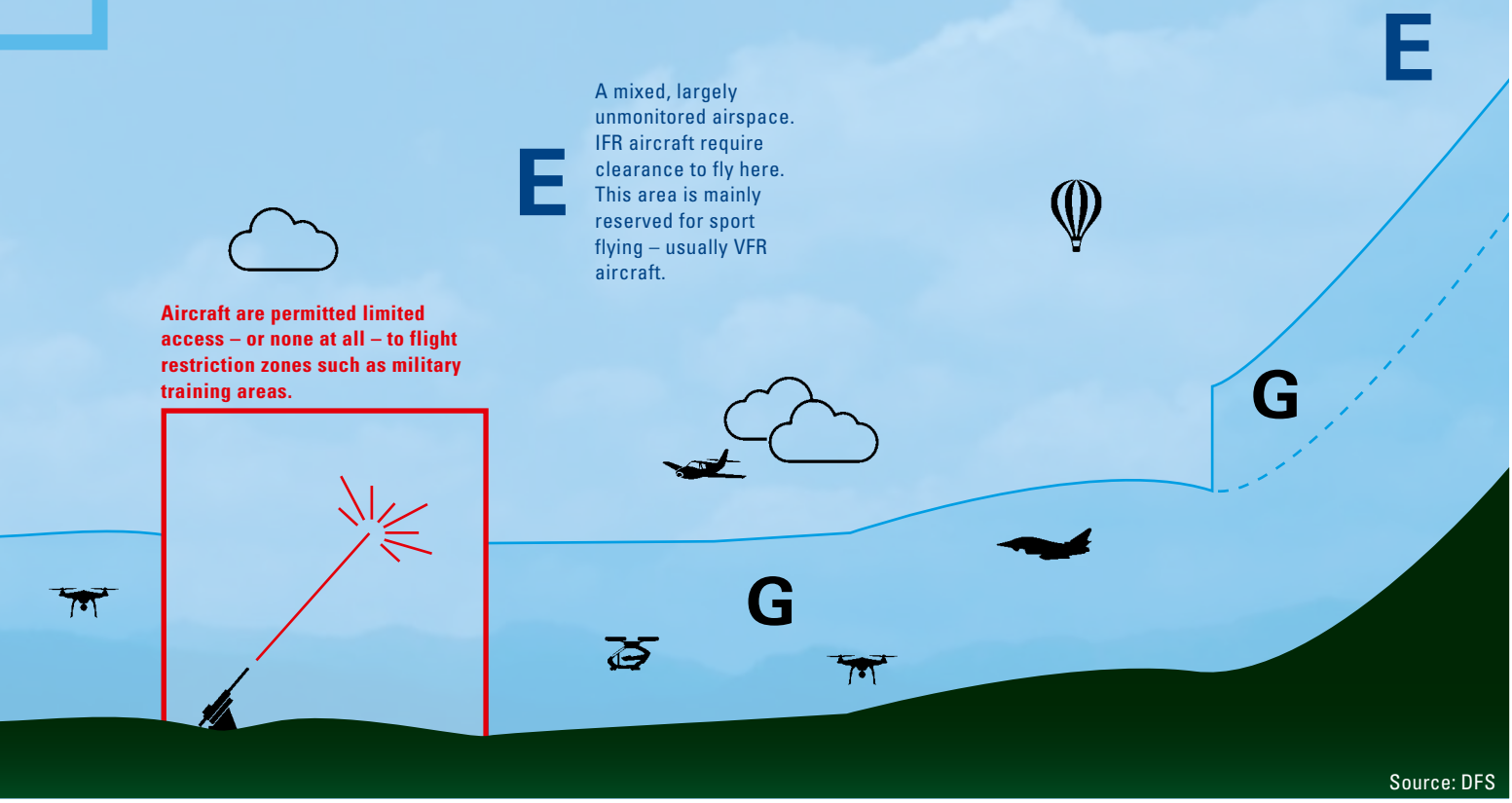
UNDERSTANDING OF AIRSPACE CLASSES ESSENTIAL FOR VFR AIRCRAFT

Large passenger planes are examples of aircraft operating under instrument flight rules (IFR). They are monitored and directed by air traffic controllers. An understanding of the airspace structure is essential for aircraft operating under visual flight rules (VFR). They need to know precisely which areas and altitudes require clearance from air traffic control. Moreover, the free airspace over densely populated areas with many large airports is growing scarce. Military training areas used for flight maneuvers also add to the situation. In Germany, these zones are not made available to civil air traffic when needed, while in other countries, they are permanently reserved for the military. This lack of flexibility in terms of access restricts free airspace even further in those countries. As a rule, each country defines its own airspace structure, but it must still adhere to the airspace classes specified by the International Civil Aviation Organization (ICAO). This diagram illustrates the airspace structure in Germany.

AIRSPACE CLASSES AND AIRSPACE ORGANIZATION

The International Civil Aviation Organization (ICAO) has defined standardized airspace classes. Overall, the Alpha (A), Bravo (B), Charlie (C), and Delta (D) classes are used for international general aviation, while VFR aircraft increasingly occupy the Echo (E), Fox (F), and Golf (G) airspace classes. This system enables secure flight guidance by providing air traffic control clearance at high altitudes. At lower altitudes, the airspace structure should also enable VFR aircrafts to access the airspace without air traffic control clearance anywhere it is safe to do so.

The national air traffic control organizations determine themselves the division of airspace into upper and lower airspace. In Germany, upper airspace starts at an altitude of 24,500 feet. There are different control centers for lower and upper airspace. They also handle different tasks. While inbound and outbound flight areas and many vertical movements are monitored in the lower airspace, there are large traffic flows in the upper airspace that move about without major changes in altitude.



Source: DFS

Autonomous Flying

SWARMS OF DRONES DELIVER PACKAGES AND PEOPLE ZIP THROUGH STREET CANYONS IN FLYING TAXIS. SCENES LIKE THIS ARE HARDLY CONCEIVABLE, EVEN IN A DISTANT FUTURE, ALTHOUGH AN AUTOPILOT SYSTEM FOR DRONES HAS ALREADY BEEN IN DEVELOPMENT SINCE 2014.

It was the Ski World Cup competition in Madonna Di Campiglio in December 2015. As Austrian skier Marcel Hirscher sped through the gates, a camera drone weighing approximately eight kilograms suddenly fell from the sky, missing Hirscher by mere centimeters. The incident shows just how dangerous drone accidents can be. But it also shows how complicated it is to operate these unmanned aerial vehicles. After all, the pilot had done everything correctly. He was flying his drone in the predefined corridor next to the course and operating it on the 2.4-gigahertz frequency commonly used in model flying. But due to the interference from the mobile networks and Wi-Fi hotspots of the many spectators, the drone's connection to the pilot was lost and it fell uncontrollably onto the piste. "A model flight that works on an open field doesn't always work in a crowded area. All ideas and concepts for an autopilot system for drones – and there are already a few – need to be rigorously tested," says Martin Sperber. Sperber is head of the Competence Center UAS (Unmanned Airflight Systems) at TÜV Rheinland and chairman of the DIN-UAS committee. The number of drones in Class G airspace close to the ground is continuing to rise, most of them flown by amateur pilots. However, the unmanned aerial vehicles are proving to be effective tools for various purposes in a wide range of sectors, such as growth monitoring and building inspection. In addition to testing service providers, there are now many commercial providers specialized in data collection and analysis.

RESEARCH IN MULTIPLE AREAS

The use of drones in Germany is only permitted if the pilot can see the drone without visual aids, which considerably limits their use. "There should be a European solution for this. Several committees are working on this issue. One of the projects is called Unmanned Aircraft System Traffic Management (UTM). It's in the early stages of development, so it's impossible to say exactly how it will work," says Sperber. Various research facilities have already come up with feasible systems. For example, drones could be equipped with a chip and controlled via existing mobile networks. Not only can aerial vehicles recognize each other in these networks, but they can also stay out of each other's way and automatically avoid flight restriction zones or obstacles. "But what about electromagnetic sensitivity? What about the product safety of drones? What about data privacy? These

Flight taxis for the masses – an unrealistic scenario in the distant future. Even these drones will probably be used for specific applications or marketing purposes.

OPERATIONAL AIMS OF UNMANNED AIRCRAFT SYSTEM TRAFFIC MANAGEMENT (UTM)

Martin Sperber (photo) gives some examples of how UTM might be deployed: "The aim is not to use drones on a large scale, but rather for specific purposes. For example, drones equipped with UTM could automatically circle over the city and monitor traffic. Medications or other loads could be delivered to areas that are difficult to access. Drones are now already used to conduct building inspections, which could be fully automated in the future. The helicopters and planes used today for dike protection, overhead line monitoring, and agricultural purposes would also become obsolete. Autonomous drones would be an energy and cost-saving alternative in many areas."

and many other questions must be kept in mind when developing an autopilot system. Vast research is being conducted in this area," explains Sperber.

HIGH COSTS AND LOW ACCEPTANCE

But even if they were equipped with a fully functional UTM, swarms of delivery drones or flying taxis would be far from landing on our doorstep. The implementation costs are only one aspect, since customers could hardly be expected to pay the price in higher delivery costs. The load capacity would also be severely restricted, which would only allow very lightweight packages to be delivered. Thermal lift in cities with strong, changing winds, an infinite number of emergency landing areas, and high energy costs are other barriers to the implementation of automated delivery logistics using drones on a large scale. Drones would also need protection from outside attacks in order to prevent criminals from hacking them, diverting them, and stealing valuable packages. The sound generated by countless drones would also be difficult to bear. "The cost-benefit analysis of such a scenario in urban areas would not hold water with the providers, nor with the public," says Sperber.

As the head of research at DFS, Jörg Buxbaum develops digital solutions with his team in order to help air traffic controllers and enable a more effective use of airspace.

Tetris in the Sky

HOW CAN AIR TRAFFIC BE MADE SAFER WHILE AIRSPACE BECOMES MORE AND MORE SCARCE? THE RESEARCH TEAM AT DFS IS WORKING ON THE ANSWER TO THIS QUESTION. ACCORDING TO JÖRG BUXBAUM, THE HEAD OF RESEARCH, AIR TRAFFIC CONTROLLERS ARE THE KEY.

Mr. Buxbaum, what are the fundamental criteria of your research?
It's hard to say with any certainty how air traffic is going to develop. This is why we need solutions that address as many scenarios as possible. In our view, the air traffic controllers are the key. We are researching solutions that will make their job easier and enable a more effective use of airspace. Thanks largely to assistance systems for air traffic controllers, we can now direct around 50 percent more airplanes safely through the air than we could 20 years ago.

What specifically are you researching at the moment?
We have come pretty far with language recognition. Air traffic controllers use radiotelephony to stay in constant contact with the pilots. If their instructions were to enter the system automatically, it would reduce the workload in approach areas by up to 30 percent. This has been confirmed in trials.

But that doesn't really improve matters in sectors with very heavy traffic. Once the airspace has reached full capacity, not much more can be done, right?
Yes, in principle. But the new assistance systems also allow us to create new capacities. With the "controller assistance tool," for example, we hope to be able to achieve a much higher capacity. When using this system, the air traffic controller can click on an airplane and immediately see which altitudes and directions are free of conflict. The system helps air traffic controllers in stressful situations. Hopefully, it will allow us to achieve a 20 percent increase in capacity in our airspace. There are plans to deploy it for the first time next year. There are also many upward and downward movements in this airspace. The problem with this is that an airplane doesn't gain altitude evenly. It is therefore relatively hard to predict the exact altitude the plane will reach after a given number of kilometers. So air traffic controllers have to include a certain corridor in their calculations. We fed a huge amount of data from past ascents into a neural network. This development tells the air traffic controller where the plane will be and when, while taking relevant parameters into account, such as the wind, the type of aircraft, the time of day, and the flight destination. We can then reduce the corridor that needs to be kept free from an altitude of around 3,000 meters to just 400 meters.

HUMAN CREATIVITY IS NEEDED IN ORDER TO SUCCESSFULLY MANAGE CRISIS SITUATIONS.

You are developing increasingly intelligent assistance systems. Is this the beginning of the end for air traffic controllers?
No. Air traffic controllers carry the responsibility. Assistance systems can help them do their job. But they can't rely blindly on them. The most important thing for air traffic controllers to do is to create a mental "picture" of the situation. In other words, where are the planes, which course are they on, and where do I want them to be a few minutes from now? If he loses the "picture," he loses control. Humans have one thing that technology doesn't. They can come up with creative solutions in extreme situations. This is a fundamental skill in air traffic control.

Smart health apps are a market with future potential. Nevertheless, Googling symptoms or consulting an app for a diagnosis is no substitute for a doctor's visit.

24/7-Appointments with Dr. Smart

SMART MEDICINE MAKES IT POSSIBLE TO MONITOR YOUR OWN BODY AT HOME AND MAKE DIAGNOSES AROUND THE CLOCK – BUT NOT WITHOUT RISKS OR SIDE EFFECTS. WHAT ARE IOT MEDICAL DEVICES REALLY CAPABLE OF AND WHERE IS THIS DEVELOPMENT LEADING US?

Smart medical software and technology are nothing new. IoT devices are already commonly used in hospitals. But now that such devices can be easily operated with a smartphone, they are becoming more popular than ever as demand continues to increase. Wearables that measure heart rate and other physical data around the clock are just as trendy as blood pressure meters and medical apps that support patients with conditions such as diabetes. Users can choose the medical device that suits their needs from an app store at a reasonable price or follow the recommendations of their medical specialist.

DIAGNOSIS THROUGH ARTIFICIAL INTELLIGENCE

Using an app to maintain good health can increase an individual's life span and reduce the risk of secondary damage from diseases. Continual monitoring motivates users to change unhealthy behaviors, exercise more, and make other improvements. Digital assistants can enhance patients' quality of life by reminding them which medications they need to take and at what dosage. Smart home equipment can use a light switch to collect information about sleep behaviors, for example. A doctor can analyze this data and recognize patterns that allow him to make a remote diagnosis and determine the patient's health status. Furthermore, researchers are using previously anonymized data from sick and healthy people to detect health risks and develop new diagnostic procedures. Companies in countries like the United Kingdom use artificial intelligence to detect rare diseases. AI software designed for this purpose asks specific questions and advises the patient to consult a doctor, if necessary.

HIGH-LEVEL DATA SECURITY

It is not always easy to tell a medical device apart from a lifestyle/wellness device. In most cases it is the manufacturer who decides on the definition. They are sorted and divided into a range of risk categories depending on what they do. Smart medical devices are subject to stricter requirements than fitness trackers in terms of patient protection. As a result, some manufacturers of apps and wearables will run into significant costs due to their obligation to comply with the requirements of the medical devices directive and the requirements of the medical device regulation as of May 2020. "The legal requirements can be particularly challenging for small-scale manufacturers and start-ups, and this might slow the pace of innovation," explains Dr. Michael Berensmann, an expert in medical devices at TÜV Rheinland. Regardless of whether the device is medical or not, the General Data Protection Regulation (GDPR) regulates the protection of personal data against misuse, often in application together with the protection of the individual's right to privacy. The GDPR provides for data minimization as follows: Personal data shall be limited to what is necessary in relation to the purposes for which they are processed. "Technically speaking, the device should only be able to deliver the data required for the agreed purpose. It should not be collecting any other data at all. We know from experience that manufacturers have some catching up to do," says Günter Martin, an IoT privacy specialist at TÜV Rheinland. So not only do smart IoT medical devices and services need to consider the strict data privacy and data security requirements; they must also meet user expectations with regard to privacy, regardless of the novelty of the technology or the financial situation of the manufacturer. The devices are tested and evaluated by specialists, who grant the relevant certificates if they pass inspection. "The market for IoT devices is growing rapidly," says Martin in conclusion. "We can help make digital services and smart devices safer and more reliable while also building trust between end users and manufacturers through our efforts."

REGULAR SECURITY UPDATES ARE ESSENTIAL

Smart medical devices are often connected wirelessly to a smartphone, which is used to operate them. Some of them are also voice controlled, and the interfaces are constantly improving. In any case, users should give each app a unique password and install any required security updates. "Despite all the precautions, the devices unfortunately still have vulnerabilities. While we are continually developing better procedures for protecting data, hackers are getting smarter at the same time," says Martin. He claims that the safest option at the moment is to use a separate smartphone containing no other data or applications to operate intelligent medical devices. Given the potential for misdiagnosis, Martin advises people to take the feedback from digital data with a grain of salt and keep taking care of their bodies as they did before.

More Pixels for more Security

NOWADAYS, INTELLIGENT HEADLIGHT SYSTEMS ARE EQUIPPED WITH LEDS, SENSORS, AND CAMERAS THAT ENABLE THEM TO DO FAR MORE THAN JUST LIGHT UP THE ROAD. FOR CAR MANUFACTURERS, HEADLIGHTS AND LIGHTS HAVE BECOME AN IMPORTANT DESIGN ELEMENT WHOSE PURPOSE IS TO MAKE BRANDS AND MODELS HIGHLY DISTINCTIVE.

The latest generation of intelligent lighting systems is already being tested at the new light technology lab in Berlin.

Eyes are for people what headlight systems are for cars. Adaptive LED car headlights now make it possible for drivers to identify obstacles and dangers sooner than with the old halogen lights. Modern lighting systems react to speed, weather, visibility, and road conditions. Where is the road going? How fast is the car driving? Is there any oncoming traffic? Variable, adaptive headlights provide the optimal lighting in these and other situations. "Intelligent lighting systems use sensors and cameras to record external influences and the current driving conditions and adjust the light accordingly," explains Fabian Stahl, head of the new lab at TÜV Rheinland in Berlin. For example, the beam of light automatically moves forward at higher speeds so that obstacles can be identified sooner. On the other hand, while driving through the city, a wide light distribution gives the driver a better view of the sidewalk and peripheral areas, ensuring greater safety. "With the intelligent headlight system, the high beam can also be switched on without dazzling other drivers," says Stahl. The systems detect the light from tail lights and headlights and dim the areas in the high beam that would otherwise perturb oncoming traffic or preceding vehicles.

LIGHTING AS A DESIGN ELEMENT

In an era where the streamlined silhouettes of vehicles are looking more and more alike, vehicle lighting is not just a safety factor. The stylistic elements of headlights and tail lights are important design and differentiating features – the ornaments of the car. As more emphasis is placed on individual lighting design, vehicle designers are putting more creative effort into the development of headlight concepts. Car manufacturers employ teams of specialists who work on nothing other than the design of lighting systems. Nearly every model now comes with special design features – a watchful eagle eye, a piercing look, a lipstick kiss – a striking light accent is a must. Modern headlight systems also aim to make the car seem more human. And it is well worth the effort. Studies show that, now more than ever, lighting design is high on the list of purchasing criteria.

HIGH-TECH LIGHTING CONTROL

To remain on par with the technical developments of manufacturers, TÜV Rheinland has updated its light technology lab in Berlin and expanded to include a second test facility. With the increasing number of car models and variants, the demand for testing as well as type testing for different headlights also rose significantly and it became urgently necessary to expand the lab's capacity. The next generation matrix and LED headlights are already being inspected now in the state-of-the-art test facility. Not only do these systems light the roadway, but the matrix technology and the brightness of the LEDs also allow warnings, such as excessive speed, to be projected onto the asphalt. The latest headlights can also warn drivers if they are too close to the car in front or alert them to nearby construction sites, slippery road conditions or other dangers. While the reliability of these warnings is still under discussion, traffic safety experts are supporting this development. "Having to look at the dashboard takes the driver's focus away from the traffic situation," says Stahl. The light technology laboratory is one of the test centers recognized by the Federal Motor Transport Authority (KBA) and similar authorities in other countries. These include Société Nationale de Certification et d'Homologation (SNCH) in Luxembourg, the National Standards Authority of Ireland (NSAI), the Vehicle Certification Agency (VCA) in the UK, and the Vehicle Safety Certification Center (VSCC) in Taiwan.

Heaven and Earth

THE FIFTH GENERATION OF THE GLOBAL MOBILE COMMUNICATIONS STANDARD IS BRINGING ABOUT FAR-REACHING CHANGES. TO BANDWIDTHS, FREQUENCIES AND INDUSTRY 4.0.

A big cloud is giving rise to innovations, but the origin of 5G, the fifth generation of the mobile communications network, lies in the earth. Before cloud technology, enormous bandwidths and a dense network of antennas can make applications such as autonomous driving, connected production facilities and smart cities possible, many areas in Germany and around the world must first be connected with fiber optic coverage ...

Allocation of Frequency bands

USA:	3,100 – 3,550 MHz + 3,700 – 4,200 MHz
EUROPE:	3,400 – 3,800 MHz
JAPAN:	3,600 – 4,200 MHz + 4,400 – 4,900 MHz
CHINA:	3,300 – 3,600 MHz + 4,400 – 4,500 MHz + 4,800 – 4,990 MHz

Sources: www.golem.de, www.heise.de, www.faz.net

300 bn

EUROS
is the estimated cost of 5G expansion in Europe alone.

ADDITIONAL ANTENNAS
... must be installed in Germany alone. Specifications for the new antennas: high performance, low range ...

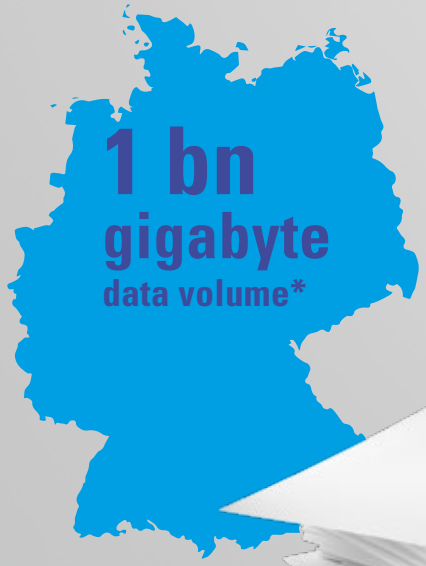
500,000

10:1

SPEED
10 milliseconds currently lie between requesting and receiving a data package in the fast fixed line network. 5G is to be ten times faster.

PRIVATE HOUSEHOLDS
of people's mobile phone contracts in 2020 will be 5G contracts. The industry benefits the greatest from 5G.

6.5 %



= 40 trillion pages A4
(40,000,000,000,000)

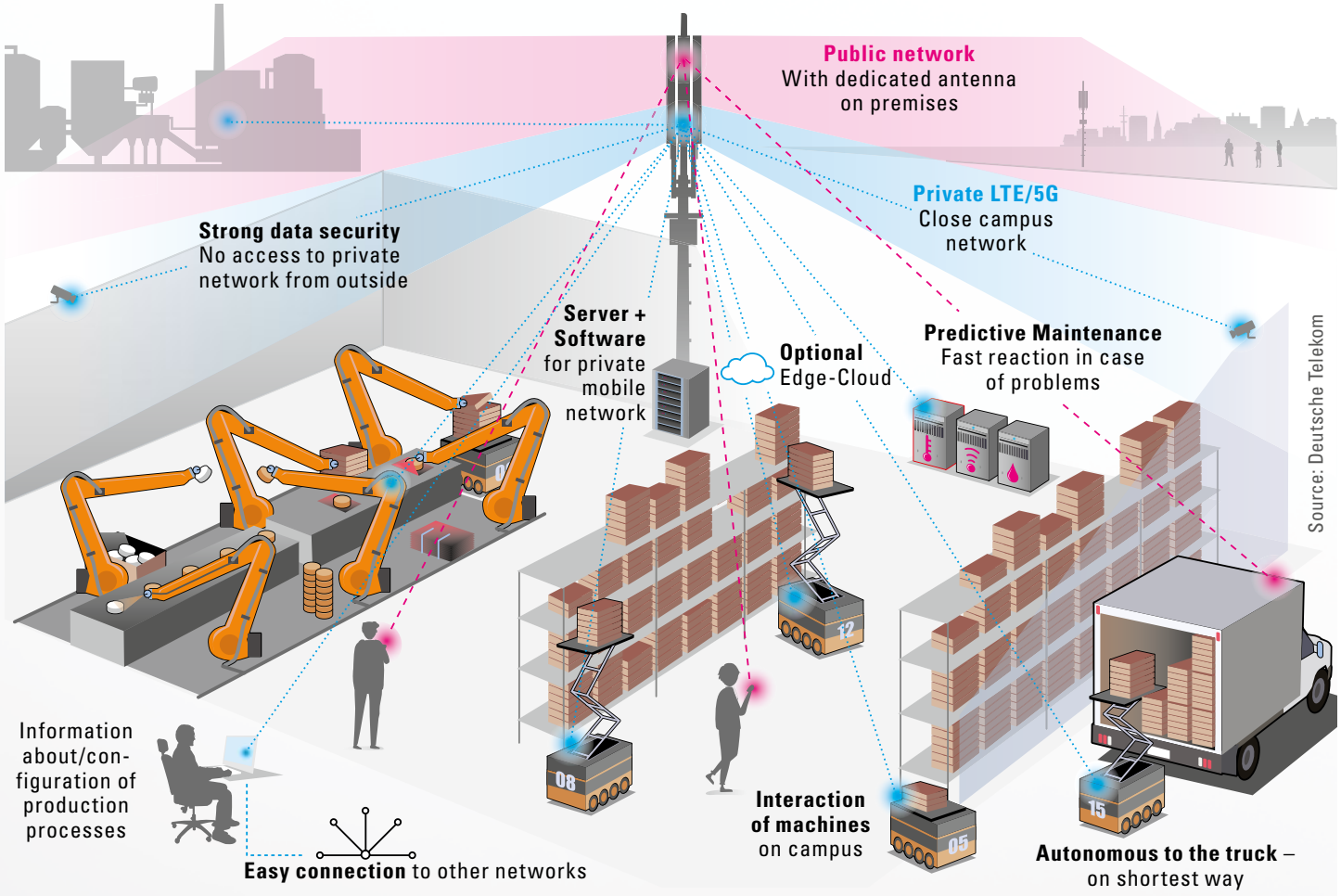
*Total mobile data consumed in Germany 2017
Source: TÜV Rheinland

Frequency bands

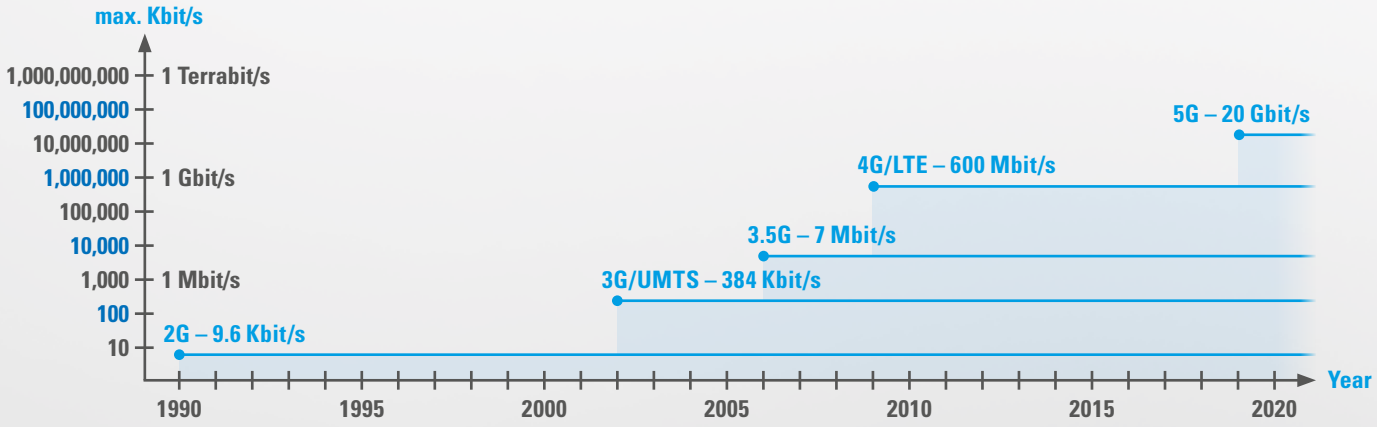
LOW

All frequencies in the MHz band are currently occupied by older mobile standards and other services, but will also be used for 5G in the future.

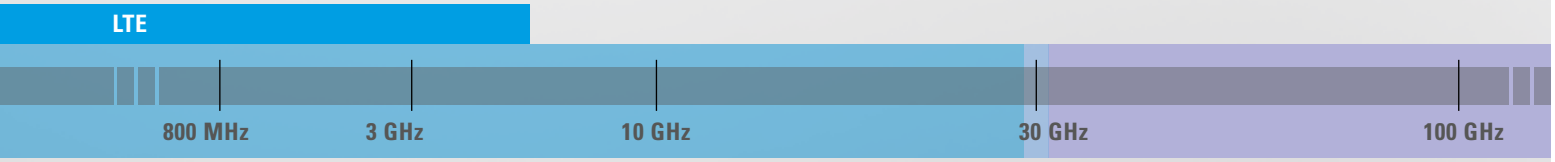
5G Campus Solutions: Welcome to Industry 4.0



Bandwidth over time: from kilo to gigabits



New frequency bands



◄ LOW

High

Frequency bands with a low transmission rate and a high range play a decisive role in the coverage of IoT devices over a larger region, such as an urban area.

VERY HIGH

Very high bandwidth with relatively low range. These frequencies are relevant for large-scale events and the household network.

Close Encounters of the Fifth Kind

5G, THE FIFTH-GENERATION GLOBAL WIRELESS STANDARD, PROMISES ULTRA-FAST INTERNET AND MANY SMART APPLICATIONS, FROM AUTOMATED DRIVING TO NETWORKED SHOP FLOORS. BUT THE KEY CHANGE EFFECTED BY THE ROLLOUT OF THE NEW WIRELESS STANDARD WILL BE SOMETHING ELSE ENTIRELY, SAYS GÜRKAN ÜNLÜ, HEAD OF CORPORATE CENTER OF EXCELLENCE DATA ANALYTICS AT TÜV RHEINLAND.

Mr. Ünlü, how is 5G different from earlier transmission technologies such as LTE, Wi-Fi or Bluetooth?

5G achieves a significantly faster, more stable connection that can transmit data volumes in the gigabit range within such short transmission times that we can actually call this real-time transmission. In other words, 5G can reliably transmit massive volumes of data from one device to another almost immediately and without any interruptions. This new standard is much more efficient than any other kind of wireless connection we have experienced so far. This is why there are very high and very diverse expectations of this technology, even though they're not always justified.

Are you saying that the current hype around 5G is overblown?

In technological terms, 5G is an update of the current network standard Long Term Evolution, or LTE. 5G is the next phase in this development. In Germany and other countries where mobile networks have so far been underdeveloped, the introduction of the new standard will not make the "white areas" disappear from the map. This is because extensive fiber optic coverage is needed in order to effectively roll out 5G. At the same time, the public has underestimated the importance of this aspect. The last mile to the end user can be bridged wirelessly but the transmission towers must be connected to fiber optic cables.

Gürkan Ünlü

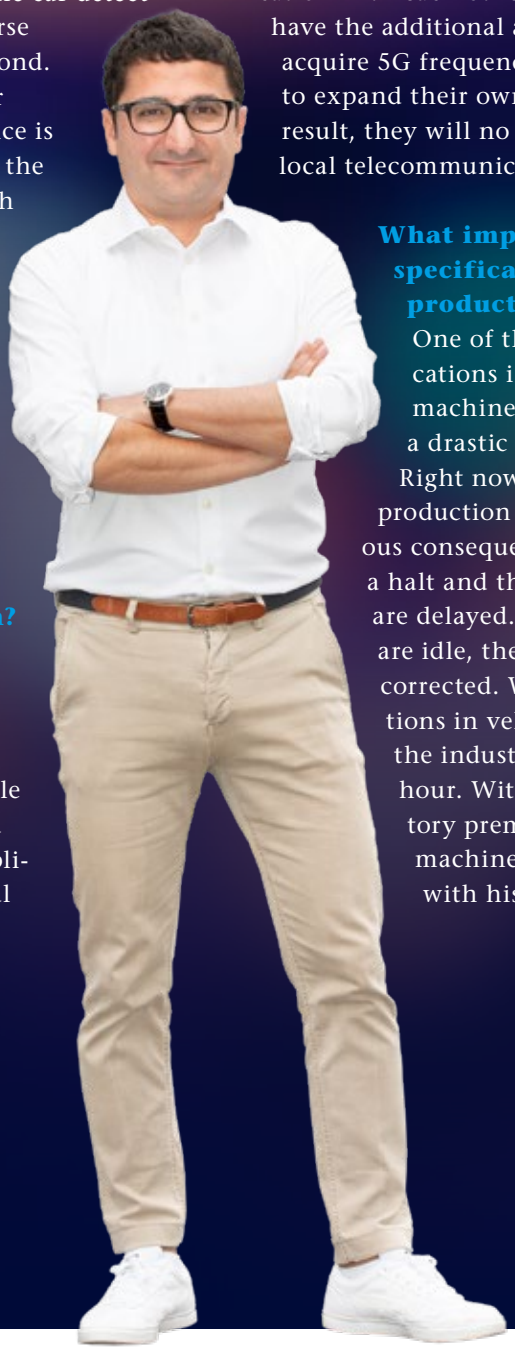
Gürkan Ünlü (46) is an expert in industrial digitalization and the head of business development in the Digital Transformation Business Field. Ünlü has also been managing the Corporate Center of Excellence Data Analytics for TÜV Rheinland globally since December 2018.

5G is often associated with autonomous driving. What exactly does 5G do in this context?

This is also an area that needs more careful consideration. We have already made it to partially automated driving at this point – traffic jam assist is one example. This means that the system in the vehicle is already able to make its own decisions in certain situations. It doesn't involve 5G at all. For example, if a child suddenly runs across the street in front of the car, the sensors in the car detect the movement and correct the course of the vehicle in a fraction of a second. The data is processed inside the car itself. Data processing inside a device is referred to as edge computing. It is the opposite of cloud computing, which plays a major role in many 5G applications. 5G lets the system completely take over the driving, but this technology is not yet ready for series production, not to mention that many important standards are missing, as are the legal conditions.

In which areas will the technology bring about a tangible improvement in the near term?

The advantages to society, such as self-driving cars and stable video streaming, are often highly touted by the media. Of course these are positive developments, but they pale in comparison to the potential and the benefits of 5G in industrial applications. This technology brings real added value to the industrial sector. The industry will be able to apply for the required frequencies in the coming months. This infrastructure will completely change the design of production facilities in the future. The factory floor of the future is dark and will perhaps operate entirely without people. Driverless transport robots will move parts at high speed to the next process step. 5G will revolutionize on-site logistics at companies because machines and transport systems will be in constant communication with each other. Companies in Germany have the additional advantage of being able to acquire 5G frequencies from the state in order to expand their own campus network. As a result, they will no longer have to depend on local telecommunications providers.



Gürkan Ünlü and his team from TÜV Rheinland advise companies on the expansion of 5G campus networks.

What impact does 5G have specifically on industrial production?

One of the main practical applications in industry is real-time machine monitoring. It allows for a drastic reduction in downtime. Right now, if a single machine in a production line fails, there can be serious consequences. Production comes to a halt and the subsequent process steps are delayed. And while the machines are idle, the error has to be found and corrected. Whenever a robot malfunctions in vehicle production, it costs the industry around 80,000 euros per hour. With a 5G network on the factory premises and sensors on every machine that are contextualized with historical data, companies can

drastically minimize these costly failures. The way it works is that sensors continually send production data to the plant's cloud. A software program analyzes the data. The program is also capable of shutting down the machine within a fraction of a second before it fails or sustains any damage, such as in the case of a sudden voltage spike or increase in vibration. Since the machine is shut down quickly enough to prevent any damage to it or the parts inside it, processing can continue when the machine starts up again. The analyzed data in the local cloud indicates which machine was affected and which errors led to the shutdown. The 5G network therefore helps improve maintenance, reduce downtime, minimize failures, and increase production efficiency. LTE and Wi-Fi are only able to ensure this kind of continual and rapid data transmission to some degree. What's more, the new network will have significant ramifications.

"5G WILL FUNDAMENTALLY CHANGE INDUSTRIAL MANUFACTURING AND HELP THE INTERNET OF THINGS ACHIEVE A BREAKTHROUGH."

Gürkan Ünlü, TÜV Rheinland

What do you mean?

5G is basically the key technology required for artificial intelligence. In a networked world and in the Internet of Things, automated AI can compile data with much less effort than with today's technology and, unlike analysis software, it can derive rules through self-learning. This can be very helpful for medical purposes and other applications. For example, sensors can automatically compare the data of a patient in the intensive care unit with 100,000 other cases. A Wi-Fi infrastructure can't do that sort of thing. Until now, around 20 percent of companies worldwide have been using more or less complex AI applications. 5G will facilitate the use of AI considerably.

Is anything else needed for the expansion of a 5G infrastructure for companies?

This is certainly the crux of the matter. Even though this move has been called for within many industrial bodies and forums for a long time, the practical implementation poses significant challenges for many companies. Not only do companies have to apply for the necessary license for the frequency band, but they also face the challenge of expanding the network on their premises and setting up the machine sensors or the analysis software in the cloud. These company networks are also vulnerable to attack. The plant cloud and devices in the company's internal Internet of Things must be secured against hacker attacks. If AI is also implemented on a larger scale, companies will need to learn how to manage this, since AI can also be used for cyberattacks.

It sounds as if there are a lot of obstacles.

We have observed an increased demand for consulting services. Companies, businesses, and authorities are grappling with the subject. They have many unanswered questions and would like a clear explanation of the benefits from the providers. But ultimately, the benefit of this technology will be the thing that establishes it in the industry.

"Measure everything that can be measured and make everything that can't be measured measurable."

Archimedes, Greek physicist, mathematician and engineer

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